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K. Zhaksybayev, Z. Yeskerova

Ye.A. Buketov Karaganda State University, Kazakhstan
(E-mail: Kuat2009@mail.ru)

Short-term forecasting of agricultural raw materials resources as a basis for planning the production of processing industries of the agro-industrial complex

The agricultural industry is among difficult economic systems. Expanded reproduction in agricultural industry represents interrelation of biological, engineering, organizational and economic procedures. Branches of agricultural industry are closely connected among themselves and with other branches of agro-industrial complex. The main task of forecasting and planning the development of the agroindustrial complex is to maximize the volume of the end product of the agroindustrial complex and to approximate the volume and structure of production to the volume and structure of the needs in it. The final output of the agroindustrial complex includes products used for personal consumption of the population, industrial consumption in non-agricultural sectors, increase in reserves, stocks and exports. Products are supplied to the consumer mainly through the sphere of circulation: state and cooperative trade, public catering, collective-farm market. A part of production, passing the sphere of circulation, is consumed directly by the families conducting personal subsidiary farm. Forecasting and planning of the development of agroindustrial complex is carried out on subcomplexes which are defined proceeding from technological interrelation of production of final products. An ultimate goal of agricultural industry - achievement of a steady rise of agricultural production, reliable provision of food and agricultural raw materials to the country, the unification of the efforts of all sectors to obtain high end results in accordance with the food program.

Keywords: agriculture, forecast, dynamics, growth indicators, raw materials, regional economies, asymmetry, excess, priori distribution of the system.

Short-term forecasting resources of agricultural raw materials is the basis of current and operational planning of production of processing branches of agro-industrial complex. At the same time, it is necessary to estimate not only the total amount of resources for the planned year, but also the characteristics of changes in quantitative and qualitative indicators of resources throughout the vegetative period.

Usually the expected volume, quality of raw materials and their dynamics are determined from observations of growing crops in trial plots. The indicators of the growth of agricultural crops are measured at certain points in the growing season. For example, in the sugar industry, from July 1 to September 20, annual measurements of the mass and sugar content of the beet root are carried out. The expected rate of growth beet in August and September is the basis for the adoption of the most important management decisions to optimize the timing of the harvest and the start of sugar factories.

The President of the Republic of Kazakhstan N. Nazarbayev in his address to the people of Kazakhstan, «The Third Modernization of Kazakhstan: Global Competitiveness», noted that «the agro-industrial complex of Kazakhstan has a promising future. In many respects, we can be one of the world's largest producers of agricultural exports. Especially, for the production of organic food. The brand made in Kazakhstan should become the standard of such products» [1].

Usually the expected volume, quality of raw materials and their dynamics are determined from observations of growing crops in trial plots. The indicators of crop growth (ICG) are measured at some points during the vegetation period. For example, in the sugar industry are carried out annual measurements of the mass and sugar content of the beet root from July 1 to September 20. Information on the expected rate of growth beet in August and September is the basis for the adoption of the most important management decisions to optimize the timing of the harvest and the start of sugar factories.

We will call the crop growth characteristic curve showing the change ICG during the season, and the characteristics of the sections - ICG values at discrete points corresponding to the date of the measurement.

Analysis of long-term statistical data on ICG in different sections of the growth characteristic gives grounds to believe that ICG are random variables, and the growth characteristics themselves are random functions of time.

We denote by X_i the value of ICG in section i of the characteristic, $i = 1, ..., m$. The uncertainty of X_i is a consequence of a multitude of independent random influences (seed quality, weather conditions, agrotechnical factors, ICG measurement errors, etc.).

$$\hat{E} = \begin{Vmatrix} \hat{E}_{11} & \dots & \hat{E}_{1m} \\ \dots & \dots & \dots \\ K_{m1} & \dots & K_{mm} \end{Vmatrix}. \tag{1}$$

Until the first measurements of ICG are received this year, these parameters serve as the only source of information on the characterization of growth. However, they have very little predictive value, since in most cases the values of Xi are strongly scattered around their averages.

With short-term forecasting, the use of a posteriori data - the measurement results at the initial segment of the growth characteristic in the current season $X_l = x_l, \dots, X_l = x_l$ allows to significantly refine the predicted values of the crop growth indices for the remainder of the vegetation period: $X^*_{l+1}, \dots, X^*_m$ [2].

The best of the predicted growth rates of crops can be found using the apparatus of the statistical decision theory (SDT) [3].

According to SDT, the best estimates $X^{*(0)}_{l+1}, \dots, X^{*(0)}_m$ are determined from the condition for minimizing a posteriori risk

$$R(X^*_{l+1}, \dots, X^*_m) = \int_{-\infty}^{\infty} \int L(x_{l+1}, \dots, x_m; X_{l+1}, \dots, X^*_m) W(x_{l+1}, \dots, x_m \big| X_1 = x_1, \dots, X_l = x_i) dx_{l+1}, \dots, dx_m, \tag{2}$$

where $L(x_{l+1}, \dots, x_m; X^*_{l+1}, \dots, X_m^*)$ - loss function, which expresses the damage caused by the fact that as the predicted values of crop growth indicators taken as X_i, while in reality they are equal x_i, $i=l+1, \dots, m$; $W(x_{l+1}, \dots, x_m \left[X_1 = x_1, \dots, X_l = x_l\right)$ — conditional density of subsystem probability of random variables $X_{l+1}, \dots, X_m$, calculated on the assumption that $X_l, \dots, X_l$ took values of $x_l, \dots, x_l$ respectively.

Since X_i, $i=1, \dots, m$ a priori distribution system is known, and

$$R(X^{*(0)}_{l+1}, \dots, X^{*(0)}_m) = \inf_{X^*_{l+1}, \dots, X^*_m} M\left\{L\left(X_{l+1}, \dots, X_m, X^*_{l+1}, \dots, X^*_m\right) \Big| X_1 = x_1, \dots, X_l = x_l\right\}, \tag{3}$$

sought $X^{*(0)}_{l+1}, \dots, X^{*(0)}_m$ are bayesian estimation of the quantities $X_{l+1}, \dots, X_m$.

Negative economic consequences from the adoption of unreasonable planned decisions (wrong determination of the outputs, resource providing, etc.) are more weightful if the greater the error in forecasting the expected harvesting of agricultural crops is [4]. Therefore, in the role of loss function L, it is advisable to consider the sum of absolute values of prediction errors

$$L(x_{l+1}, \dots, x_m; X^*_{l+1}, \dots, X^*_m) = \sum_{i=l+1}^{m} \left|x_i - X^*_i\right|. \tag{4}$$

With regard to (4) economic sense of posteriori risk minimization procedure R is that the fact that any admissible set of numbers $X^{*(0)}_{l+1}, \dots, X^{*(0)}_m$ are minimizing (2) and represents a set of predicted values of crops growth parameters that meet the minimum economic losses as long as the observed values $X_l, \dots, X_l$ are $x_l, \dots, x_l$.

Further, we introduce the notation

$$U = \left\|X_1, \dots, X_m\right\|^T, \quad U_1 = \left\|X_1, \dots, X_l\right\|^T, \quad U_2 = \left\|X_{l+1}, \dots, X_m\right\|^T,$$

$$A_1 = \left\|a_1, \dots, a_l\right\|^T, \quad A_2 = \left\|a_{l+1}, \dots, a_m\right\|^T, \quad \chi_1 = \left\|x_1, \dots, x_l\right\|^T,$$

$$\hat{E} = \left\| \begin{array}{ccc:ccc} \hat{E}_{11} & \dots & \hat{E}_{1l} & K_{1,l+1} & \dots & K_{1m} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ K_{l1} & \dots & K_{ll} & K_{l,l+1} & \dots & K_{lm} \\ \hdashline K_{l+1,1} & \dots & K_{l+1,l} & K_{l+1,l+1} & \dots & K_{l+1,m} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ K_{m1} & \dots & K_{ml} & K_{m,l+1} & \dots & K_{mm} \end{array} \right\| = \begin{Vmatrix} \sum_{11} & \sum_{12} \\ \sum_{21} & \sum_{22} \end{Vmatrix}.$$

From the properties of the multidimensional normal distribution, it is known that if we fix the values of some set of random variables, then the subsystem of the remaining indicators will also be distributed according to the normal law. According to the conditional distribution of the vector U_2 at fixed U_i (described as W density) - is a normal distribution with a mathematical expectation vector

$$\mu = \left\| M\{X_{l+1}|U_1 = \chi_1\},...,M\{X_m|U_1 = \chi_1\}\right\|^T = A_2 + \sum\nolimits_{21}\sum\nolimits_{11}^{-1}(\chi_1 - A_1) \tag{5}$$

and covariance matrix

$$v = \sum\nolimits_{22} - \sum\nolimits_{21}\sum\nolimits_{11}^{-1}\sum\nolimits_{12}. \tag{6}$$

The values of the components of the vector μ and the elements of the matrix v completely determine the conditional probability density W in the integrand (2).

Since the absolute error (3) is used as L, the point $X^{*(0)} = \left\| X_{l+1}^{*(0)},...,X_m^{*(0)} \right\|$ at which the minimum (1) is reached is the median of the conditional distribution of the vector U_2 for a fixed U_1. Since for a normal distribution of the median coincides with the scattering center, the choice of

$$X_i = M\{X_i|U_1 = \chi_1\}, \qquad i = l+1,...,m, \tag{7}$$

minimizes a posteriori risk R and thus solves the problem of synthesis of optimal predicted values of the indicators of crop growth $X_i^{*(0)}$, $i = l+1,...,m,$.

It can be shown that the cumulative mean absolute error of ICG prediction by the proposed method

$$S = R(X_{l+1}^{*(0)},...,X_m^{*(0)}) = \sqrt{\frac{2}{\pi}}\sum_{i=l+1}^{m}\sqrt{D\{X_i|U_1\}}, \tag{8}$$

where $D\{X_i|U_1\}$ are the diagonal elements of the covariance matrix (6).

The algorithm for finding the optimal predicted values of the crops growth rates is based on the relationship (5) (Table 1).

Table 1

An example of calculating the predicted values of the beet root weight

№ algorithm steps	Indicators	Section number								
		1	2	3	4	5	6	7	8	9
1	Calendar date	1.VII	10.VII	20.VII	1.VIII	10.VIII	20.VIII	1.IX	10.IX	20.IX
	Asymmetry	0,992	0,643	0,158	-0,165	-0,148	-0,216	-0,211	-0,131	0,008
	Kurtosis	0,412	-0,615	-0,734	-1,046	-0,768	-1,004	-0,995	-0,932	-0,845
2	a_1, e	12,6	36,7	72,8	121,3	172,9	216,2	259,3	292,8	317,8
	$\sigma_i = \sqrt{K_{ii}}, e$	8,3	18,7	26,0	33,6	37,4	43,5	46,0	46,5	48,4
3	A priori covariance matrix	68	143	178	205	192	198	185	157	135
		143	350	462	547	546	563	542	487	439
	$K = \begin{Vmatrix} \sum_{11} \sum_{12} \\ \sum_{21} \sum_{22} \end{Vmatrix}$	178	462	678	834	855	923	925	864	816
		205	547	834	1127	1208	1351	1368	1298	1252
		192	546	855	1208	1398	1582	1612	1556	1520
	$i, j = 1,...,9, e^2$	198	563	923	1351	1582	1888	1956	1909	1885
		185	542	925	1368	1612	1956	2117	2110	2129
		157	487	864	1298	1556	1909	2110	2165	2225
		135	439	816	1252	1520	1885	2129	2225	2343

Note. Source — compiled by the author on the basis of the application of the mathematical apparatus of the statistical decision theory (SDT).

As an example, we give the results of using the algorithm in relation to statistical data on the dynamics of beet growth in the southern regions of the republic. The initial statistical mass represents ten-day changes in the mass of the beet root during the vegetative period (from July 1 to September 20). In this case, m= 9. Define the forecasted values for the state of the raw materials base on August 10 (i=5) (Table 2).

Table 2

An example of calculating the predicted values of the beet root weight

№ algorithm steps	Indicators	Section number								
		1	2	3	4	5	6	7	8	9
4	$\sum_{11}^{-1}$, e^{-2}	0,128 -0,076 0,025 -0,020 0,014	-0,076 0,078 -0,045 0,017 -0,007	0,025 -0,045 0,055 -0,034 0,010	-0,020 0,017 -0,034 0,045 -0,022	0,014 -0,007 0,010 -0,022 0,015				
5	$\begin{Vmatrix} X_6^{*(0)} \\ X_7^{*(0)} \\ X_8^{*(0)} \\ X_9^{*(0)} \end{Vmatrix} = \begin{Vmatrix} 216,2 \\ 259,3 \\ 292,8 \\ 317,8 \end{Vmatrix} + \begin{Vmatrix} 0,804 & -1,016 & 0,058 & 0,288 \\ 0,945 & -1,719 & 0,543 & 0,182 \\ 0,580 & -1,885 & 0,762 & -0,004 \\ 0,612 & -2,348 & 1,000 & -0,056 \end{Vmatrix}$ $\begin{Vmatrix} 1,133 \\ 1,205 \\ 1,308 \\ 1,357 \end{Vmatrix} \times \begin{Vmatrix} x_1 - 12,6 \\ x_2 - 36,7 \\ x_3 - 72,8 \\ x_4 - 121,3 \\ x_5 - 172,9 \end{Vmatrix}$									
6	$\tilde{o}_1,\ldots,\tilde{o}_5$, e	10,0	37,0	87,0	139,0	198,0				
	$\tilde{O}_6^{*(0)},\ldots,\tilde{O}_9^{*(0)}$, e						248,3	297,7	334,3	362,8
	$\sqrt{D\{X_i \mid U_1\}}, e$ $\tilde{o}_6,\ldots,\tilde{o}_9$, e $\delta_i = (X_i^{*(0)} - x_i)\cdot 100 / x_i$,%						8,1 246,0 0,94	13,4 298,0 -0,12	17,5 335,0 -0,20	21,9 361,0 0,50

Note. Source — compiled by the author on the basis of the application of the mathematical apparatus of the statistical decision theory (SDT).

1. Testing the hypothesis of the normality of the random variables distribution X_i, i=1,...,9, by estimates of the quantities of asymmetry and kurtosis. At n = 28, the mean square error in the asymmetry is σ_a= 0.425, the kurtosis is σ_e=0.765. Thus, the hypothesis of normality can be accepted.

2. Determination of the a priori numerical characteristics: $\{a_i,\ i=1,..,9\}$ and K. It should be noted that the strong dispersion of the initial statistical data around the averages is explained by the significant differences in the agrometeorological and economic-organizational conditions of beet cultivation in different seasons.

3. The partition of the covariance matrix K into blocks and the allocation of submatrices $\sum_{11}, \sum_{12}, \sum_{21}, \sum_{22}$.

4. The inversion of the submatrix $\sum_{11}$.

5. Calculation $\sum_{21}, \sum_{11}^{-1}$ and the formation of a decisive rule (4).

6. Determination of optimal forecast values within known $\tilde{o}_1, ..., \tilde{o}_5$.

From (4) it is clear that the optimum predictive values consist of a priori medium and additives, which are linear combinations of the values of parameters intentional deviation crop growth from their average. The value of these additives in this example is approximately 15 %, which indicates that a priori means can not be taken as predictable values. At the same time, the relative prediction error calculated with the help of (4) is 0.2 ÷ 1.0 %, and the predicted values determined in accordance with (4) have significantly smaller variances than the a priori means [5].

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К.Жаксыбаев, З.Ескерова

Агроөнеркәсіптік кешеннің өңдеуші салаларын өнеркәсіптік өндірісін жоспарлау негізі ретінде ауыл шаруашылығы шикізатын қысқамерзімдік болжау

Мақалада ауыл шаруашылығы ең күрделі экономикалық жүйелердің бірі екендігі туралы айтылған. Ауыл шаруашылығында кеңейтілген жаңғырту — биологиялық, технологиялық, ұйымдастырушылық және экономикалық процестердің өзара байланысы. Ауыл шаруашылығы салалары бір-бірімен және агроөнеркәсіптік кешеннің (АӨК) басқа салаларымен тығыз байланысты. Ауыл шаруашылығы саласының дамуын болжау және жоспарлаудың негізгі міндеті АӨК өнімдерінің көлемін және ол қажет көлемі, құрылымы өндіріс көлемі мен құрылымы соңғы көзқарас барынша қамтамасыз ету болып табылады. Соңғы ауыл шаруашылығы өнімдерінің құрамы жеке тұрмыстық тұтыну, АӨК енгізілмеген секторларында индустриялық тұтыну, қорлардың өсуі, қорлары, экспортқа пайдаланылатын өнімдер жатады. Өнім, негізінен, айналым саласы бойынша тұтынушыға кіреді: мемлекеттік және кооперативтік сауда, қоғамдық тамақтандыру жүйесі, ұжымдық шаруа қожалығы. Айналым саласын айналып өтетін өнімдердің бір бөлігі жеке қосалқы учаскелерді басқаратын отбасылармен тікелей тұтынылады. Болжау және жоспарлау АӨК арқылы жүзеге асырылады, қорытынды өнімдерін технологиялық өндіріс негізінде анықталады. Ауыл шаруашылығының түпкі мақсаты — азық-түлік бағдарламасына сәйкес жоғары өнімділікті қамтамасыз ету үшін барлық секторларының күш-жігерін біріктіріп, ауыл шаруашылығы өнімдерін орнықты өсуін, елдің азық-түлік және ауыл шаруашылығы шикізатын сенімді жабдықтауға жету.

Кілт сөздер: ауыл шаруашылығы, болжам, қарқын, өсім көрсеткіштері, шикізат, аймақтық экономика, асимметрия, жүйе артықшылығы, жүйені априориалды бөлу.

К. Жаксыбаев, З. Ескерова

Краткосрочное прогнозирование ресурсов сельскохозяйственного сырья как основа планирования производства перерабатывающих отраслей агропромышленного комплекса

В статье отмечено, что сельское хозяйство относится к числу сложных экономических систем. Расширенное воспроизводство в сельском хозяйстве представляет собой взаимосвязь биологических, технологических, организационных и экономических процессов. Отрасли сельского хозяйства тесно связаны между собой и с другими отраслями агропромышленного комплекса (АПК). Главная задача прогнозирования и планирования развития АПК — максимизация объема конечной продукции и приближение объема и структуры производства продукции к объемам и структуре потребностей в ней. Указано, что в состав конечной продукции АПК входит продукция, используемая на личное потребление населения, производственное потребление в отраслях, не входящих в АПК, прирост запасов, резервов, экспорт. Продукция поступает потребителю главным образом через сферу обращения: государственную и кооперативную торговлю, систему общественного питания, колхозный рынок. Часть продукции, минуя сферу обращения, потребляется непосредственно семьями, ведущими личное подсобное хозяйство. Авторами показано, что прогнозирование и планирование развития АПК осуществляется по подкомплексам, которые определены исходя из технологической взаимосвязи производства конечной продукции. Конечная цель сельского хозяйства — достижение устойчивого роста сельскохозяйственной продукции, надежное обеспечение страны продуктами питания и сельскохозяйственным сырьем, объединение усилий всех отраслей для получения высоких конечных результатов в соответствии с продовольственной программой.

Ключевые слова: сельское хозяйство, прогноз, динамика показателей роста, сырьё, экономика регионов, асимметрия эксцесса, априорное распределение системы.

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