Uncertainty and Crop Production Planning in the Context of Supply Chain Management Optimization

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Abstract- In the supply chain management system (SCM) in agribusiness, it is critical to ensure the economic sustainability of farms - suppliers of raw materials for processing. The purpose of the study was to develop methods and procedures for calculating the projected values of income per hectare from the crops cultivated, taking into account the conditions of crop production in the Northern Kazakhstan. The main features of crop production in the region are (1) it is highly exposed to the risks of natural and market properties; (2) farms are, as a rule, diversified with the cultivation of many different crops.

Keywords- *agriculture, crop production, farm planning, forecast, economic uncertainty, productivity, statistical model, supply chain management.*

1. Introduction

In the economy of alternatives, each market player has to make a choice [1, 2]. Three components – choice, risk and responsibility-lead each participant of the economic system to the need to revise traditional approaches to business planning and selection of economic activities in the enterprise, which, in turn, requires not only special knowledge, but also specific thinking [3,4]. Within the framework of the supply chain management concept, business approaches and models are now being spread, in which the supplier assumes full responsibility for maintaining the level of stocks of these goods in the distributor's warehouses [5, 6]. In agribusiness, the optimization of the combination of crops and agricultural production structure in the face of uncertainty of economic conditions is the first link in harmonizing the level of service and the size of stocks between suppliers and buyers. This harmonization allows minimizing economic losses associated with an overabundance of reserves or, conversely, their lack in certain periods of the economic cycle. The high expected profitability of a product at risk does not in itself guarantee its entry into the optimal production plan; the low variability of income from the production of a particular crop is also not a sufficient condition for its entry into an effective production plan [7]. In conditions of uncertainty, the economic value of a product can be considered only by the ratio "profitability - variability", and in conjunction with other products [8]. In the Northern Kazakhstan, in most cases, there is a stochastic relationship between income levels across crops and industries [9]. Therefore, when planning and making business decisions under uncertainty, it makes no sense to make point forecasts on the income from individual crops. Projections of the income probability distribution are required. Moreover, optimization of crops combination requires taking into account the interdependency of distributions of the income probability from different crops [10]. The interrelationship of income probability distributions across crops and industries in multi-profile enterprises is a key factor in developing a strategy for their sustainable development. No less important in optimizing the production structure and crops combination in conditions of uncertainty is the attitude of the entrepreneur to risk solutions [11, 4]. Therefore, due to differences in economic conditions and unequal treatment of risk by entrepreneurs, recommendations for choosing the most preferred economic solution are individual for each enterprise. The use of mathematical risk models allows determining the most appropriate solutions for the conditions of a particular economic system. Obviously, such limiting factors as market size, contractual obligations, crop rotation conditions, financial and other circumstances are to be taken into account. The validity of direct use of data from past observations for forecasting and decision-making on the future state of object of management is questionable. Mainly, due to the presence of such a fundamental feature in the development of economic systems, as the inability to accurately repeat in the future events that took place in the past (primarily due to

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the presence of trends in the economic environment, in the dynamics of prices of both products and the resources used, as well as the changes in production technologies). It is also necessary to bear in mind measurement errors, insufficient reliability of information sources. In crop production, there are often attempts to use directly the results of experiments, conducted at experimental stations, for economic calculations in the conditions of commercial farms [4, 12]. Meanwhile, yields of agricultural crops obtained at experimental stations, as a rule, higher than on commercial farms. This is not difficult to verify by comparing the data from research stations and economic entities. The difference in the yield of the same crops is very significant: for example, in the experimental fields of the Barayev Grain Farming Research Institute average wheat yield in 2006-2017 ranged from 9.7 to 23.6 centners per hectare depending on the technology used, while in the nearby commercial farms of Short and yrayon of Akmola oblast the average crop yield for the same period did not exceed 9.5 c/ha [13]. There are many reasons for this discrepancy; important among them are differences in production conditions and management. It is also important to take into account that yield volatility manifests itself much more at the level of individual enterprises than at the regional and, especially, national levels [12]. Regarding cost indicators (revenue, production cost, income) data for a number of years, as a rule, are not comparable due to inflation. Inflation adjustments are usually made using the consumer price index [4]. Further, after clearing the data from inflation, it is necessary to analyze the presence of a trend in the dynamics of economic indicators. Thus, a database is formed, which, firstly, is cleared of inflation, and secondly, is adjusted for the trend. In addition, the adjustment of the trend eliminates - at least partly - the impact of changes in production technologies (especially in cases where data are available for long intervals) on the dynamics of economic indicators in the industry. In addition, the trend correction allows for changes in individual prices – both for resources and for products – to be taken into account in analysis and decision-making. Thus, the existence of even a complete database on the conditions and results of economic activities in the past in itself is not a panacea for errors in forecasting, analysis and decision-making. It is necessary to adjust the observation data taking into accountthe changes in economic conditions, the presence of trends in the dynamics of production and economic indicators. Moreover, the direct use of historical data (after preliminary adjustments for inflation and trend) to estimate the income probability distribution over the planning period is justified when no significant changes in the business environment are expected in the future. In other cases, for example, when agricultural production subsidies change or even subsidies are completely eliminated, the income probability distribution calculated from the historical period can no longer be used directly for analysis and decision-making for the future period [14]. For Kazakhstan's realities, this fact is well illustrated by [12]. The non-critical use of past observations leads to erroneous conclusions about the future state of the economic system. With a noticeable change in the economic conditions for agricultural entrepreneurs or in the presence of too short a database, it is possible to fit the collected data for the past period to some well-known multivariate distribution. In principle, estimation of the statistical distribution of the crop yield in planning agricultural crops can be performed in two ways. One of them is to construct such a model separately for each crop, without regard to links with other crops. This approach is justified only if the statistical distribution of the yield of one crop is not related to the same distribution for the other crop. Or, it is assumed that the company is engaged in the cultivation of a single crop [11, 4]. Recall that two variables are considered stochastic mutually independent if the probability distribution of one of them does not depend on the probability distribution of the other. In practice, however, most farms cultivate multiple crops, with stochastic variable independence being the exception rather than the rule. On the other hand, taking into account the stochastic interrelationship of the yields of different crops is a rather difficult task in making a decision [4]. Therefore, in those rare cases when the covariance of the variables is not relevant, it is permissible to ignore the problem. For example, there is a clear stochastic relationship in grain yield fluctuations. For example, in the North-Kazakhstan oblast the correlation between income from the production of spring wheat and barley is 0.85; between incomes from wheat and oats correlation is also very high (0.87), between barley and oats, the correlation of incomes is almost functional and reaches 0.95 (calculated with use of data from [15], inflation taken into account). However, as a rule there is no such a link between wheat and potato yields.

In most cases, there is a stochastic interdependency across crops income. And if the task is to find the cost-effective production structure and combination of crops, the optimization risk-model should take into account the joint probability distribution of incomes between crops [16]. The task is not easy, and it requires the development and application of methodological techniques and procedures to take into account the relationship in the dynamics of the levels of indicators involved in the analysis. In relation to Kazakhstan's realities, studies on agricultural forecasting and decision-making under uncertainty have been carried out relatively recently [9, 12]. [4] Provide an analysis of the advantages and disadvantages of currently known methods and procedures for assessing the joint probability distribution of economic variables. The paper [14] presents a scheme for predictive estimation of marginal income probability distribution, which allows preserving covariance properties of variables. In the context of the problem under consideration, this scheme is of the greatest interest to us; it consists of the following steps implemented one by one:

1) Marginal income data from past observations for each crop are adjusted for inflation and trend. Thus, the original matrix of marginal income data is formed;

2) Probabilities are assigned (in the sum equal to one) to the last years conditions reflecting chance of occurrence of similar conditions in the future;

3) Based on the adjusted data, average and standard deviations of marginal income for each crop are calculated taking into account the assigned probabilities;

4) With the help of an expert, the expert marginal income probability distribution is derived separately for each crop (regardless of the other stochastic variables);

5) The average and standard deviation of marginal income for each crop are calculated using the obtained expert marginal income probability distribution;

6) A new matrix of marginal income is generated for crops with the same averages and standard deviations as in step 5, but with the joint distribution inherent in the data from the original matrix. The estimated marginal income for crop j in year i, that is, is given by

$$GM_{ij} = E[GMs_j] + \{(GMh_{ij} - E[GMh_j]) / \sigma[GMh_j]\} \times \sigma[GMs_j] , \quad (1)$$

Where $E[GMs_j]$ is a subjective average marginal income on crop j; GMh_{ij} is an adjusted marginal income on crop j in year i; $E[GMh_j]$ is the average marginal income (from the adjusted data of previous years) on crop j; $\sigma[GMh_j]$ is the standard deviation of marginal income on crop j (from the adjusted data of previous years); $\sigma[GMs_j]$ is the subjective standard deviation of marginal income on product j.

The matrix calculated this way contains the predicted values of marginal income by products and states of nature maintains the correlation and other stochastic relationships inherent in the initial data matrix.

It should be noted that the method of presenting uncertainty in economic problems is based on the use of the principles of the subjective approach to the decision analysis. At the same time, the use of a subjective approach does not reject at all, but, on the contrary, involves the widespread use of actual observation data. This approach reflects current trends in the development of methods of data analysis and decision-making. It is important to emphasize that the assessment of the probability of the economic system future state is always subjective: all probabilities are subjective, even if they are based on so-called objective data [17, 18, 19].

It is not difficult to calculate the marginal income that occurred in previous periods using the corresponding economic data for previous years. In the above scheme, the most difficult is the calculation of the income probability distribution by products for the planned year. Its evaluation requires the involvement of the experience and knowledge of an entrepreneur or an expert. The difficulty of estimating is that income is a complex indicator: it is the product of a combination of other, simple indicators such as yield, cost and price. If, before sowing works, to ask the farmer to estimate the expected production value per hectare in the planning year, he will be uncomfortable with finding the answer. However, if the discussion focuses on the assessment of future yield, the experienced farmer, as a rule, will find question and, based on the level of soil moisture accumulated by the time of sowing works and possible conditions of the upcoming vegetation period, will give his forecast of a crop yield; moreover, the majority of experienced farmers will be able to assess the minimum, maximum and most likely yield levels under the prevailing conditions. Using the available knowledge about the peculiarities of the dynamics of prices for products and taking into account the market and regulatory conditions, the entrepreneur is able to give similar estimates about the prices of his products. The explanation for this phenomenon should be sought in the fact that simple indicators (yield, price) are constantly present in entrepreneur's everyday economic life. While complex indicators (production value, income) are the product of a complex combination of simple indicators and are usually present only in financial statements [20, 21]. It is important to note that our reasoning is not about the degree of accuracy of the entrepreneur's forecasts: the conversation is about the ability of the individual to effectively usehis knowledge and experience for forecasting; in other words, the question is about the degree of rationality or irrationality of decision-making. The above considerations make us to believe that attempts to obtain directly from the farmer the forecast of complex indicators give us unreliable results.

These circumstances allow us to formulate the following hypothesis: rationality of the assessment of the marginal income probability distribution for a product can be provided if only the assessment is made on the basis of the forecasts of the income components (yield, costs, price).

The adoption of such a hypothesis leads us to the need of developing methodological techniques for estimating the marginal income probability distribution using simple indicators – yields, product prices, variable costs. In other words, the above scheme for the estimation of marginal income probability distribution with taking into account the covariance properties of variables requires its rethinking. It is obvious that the calculation of the matrix of marginal income should be based on the use of its simple elements, such as yield, product price, variable costs.

It is very important to note that the calculation method depends on the presence or absence of correlation between the crop yield and sale price. Therefore, there are two ways of the scheme for marginal income calculation. One for the case when such correlation is either completely absent or insignificant. The other for the case, if such a relationship is essential and can not be ignored.

The purpose of this study was to develop methods and procedures for calculating the projected values of income per hectare from crops, taking into account the conditions of crop production in the Northern Kazakhstan and principles of supply chain management. It must be pointed out that the most critical conditions of crop production in the region are as follows: (1) high explosion of the production to the risks of natural and market properties, and (2) fairly high degree of diversification with the cultivation of many different crops on farms both small and large.

2. Methods

Methods and procedures for calculating and presenting uncertainty in agricultural decision analysis were tested on the basis of data on crop yields and sale prices over the period 2010 to 2017in Kyzylzhar rayon of the North-Kazakhstan oblast [15]. Table 1 provides information on the crop yields.

Table1. Crop yields in Kyzylzhar rayon of the North-Kazakhstan oblast for the period 2010 to 2017

Year of observation	Crops						
	Wheat	Barley	Oats	Buckwheat	Peas	Canola	Flax
2017	17,4	20,8	19,8	4,3	22,7	14,9	14,0
2016	16,6	19,6	16,9	6,0	15,8	17,3	10,7
2015	18,7	19,9	21,6	12,2	24,1	16,0	10,3
2014	16,0	18,5	20,2	6,6	11,2	9,5	13,8
2013	13,7	16,1	19,5	6,6	14,6	8,7	10,0
2012	16,5	18,7	16,9	9,6	12,9	10,2	8,3
2011	22,8	26,5	27,5	8,0	18,3	12,3	13,9
2010	12,6	14,3	15,4	4,8	12,0	8,0	6,9

Table 2 shows the sale prices for the crops.

Table2. Sale prices for crops in Kyzylzhar rayon of the North-Kazakhstan oblast for the period 2010 to 2017

Year of observation	Crops						
	Wheat	Barley	Oats	Buckwheat	Peas	Canola	Flax
2017	3 306	3 041	2 762	8 140	4 337	21 469	15 950
2016	3 237	2 755	2 056	3 836	5 420	13 478	9 862
2015	2 556	2 155	1 676	2 554	2 513	9 219	6 727
2014	2 986	1 839	1 422	2 548	1 754	8 720	8 609
2013	2 670	1 526	1 107	2 419	2 807	7 078	8 061
2012	2 522	1 696	1 730	1 168	1 495	7 043	6 881
2011	1 915	1 228	810	1 975	1 824	8 123	9 205
2010	2 521	1 318	618	2 624	3 024	5 562	6 343

Estimated variable costs (seeds, fertilizers, fuel, plant protection),tenge/ha, by crops for the planning yearare as follows: wheat – 36000, barley – 32000, oats – 29500, buckwheat – 14000, peas – 32000, canola – 45000, flax – 33000. Per hectare direct subsidies are not expected.

Table 3 presents inflation rates and expert estimates of the probability of states of naturefor the planning year.

Table3. Inflation rate by year of observation and estimation of probability of states of nature

Yearofobservation	Inflation, %	Probability	Yearofobservation	Inflation, %	Probability
2017	7,1	0,15	2013	4,8	0,15
2016	8,5	0,20	2012	6,0	0,20
2015	13,6	0,10	2011	7,4	0,05
2014	7,4	0,10	2010	7,8	0,05

The use of triangular distribution is very convenient for the expert estimation of probability distribution. The peculiarity of the triangular distribution is that it can be fully determined using only three data units: the smallest, the largest and the most likely value of the variable. The simplicity of this type of distribution has special advantages in the absence of sample data and, therefore, the probability distribution can be estimated only subjectively (by entrepreneurs or experts in agriculture). Another important advantage of the triangular distribution is that the mechanism of its evaluation is quite clear to the agricultural entrepreneur and therefore is likely to be credible on his part. The extreme usefulness of triangular distribution for use in uncertainty modeling allows us to remind that:

1) the probability density of the distribution is estimated by formulas

$$f(x) = \frac{2(x-a)}{(b-a)(m-a)}, \qquad x \le m \qquad \text{и}$$

$$f(x) = \frac{2(b-x)}{(b-a)(b-m)}, \ x \succ m;$$

(2)

2) The cumulative distribution is estimated by formulas

$$F(x) = \frac{(x-a)^2}{(b-a)(m-a)}, \qquad x \le m \qquad \text{и}$$

$$F(x) = 1 - \frac{(b-x)^2}{(b-a)(b-m)}, \ x > m;$$

(3)

3) the first two distribution moments (expectation and variation) are calculated using formulas

$$E[x] = \frac{a+b+m}{3} \qquad \text{и}$$

$$V[x] = \frac{\{(b-a)^2 + (m-a)(m-b)\}}{18}.$$

(4)

The Monte Carlo method [22] was used for computer simulation in assessing the probability distribution of crop yields and sale prices for the planning period.

3. Results

First, a calculation scheme is presented under the assumption that the correlation between the crop yield and sale price is insignificant.

On the basis of data from tables 1 to 3, the matrix of marginal income by states of nature was formed (table 4). Prior to that, the prices had been adjusted for inflation.

Table 4. The matrix of marginal income by crops and by states of nature, tenge per hectare

State of nature	Crops						
	Wheat	Barley	Oats	Buckwheat	Peas	Canola	Flax
1	21 524	31 253	25 188	21 002	66 450	274 888	190 300
2	21 549	25 832	7 713	10 650	59 716	204 724	80 016
3	19 542	17 833	12 568	22 208	38 377	126 405	47 515
4	27 068	12 911	8 418	8 199	-6 067	64 355	123 830
5	15 860	2 832	1 104	8 635	26 103	42 303	81 285
6	25 829	15 123	13 941	2 660	-3 345	61 738	51 858
7	32 766	19 252	5 582	10 884	20 571	112 359	168 515
8	17 730	-120	-13 402	7 305	29 381	30 265	41 032
Expected marginal income	22 269	17 335	9 982	11 058	30 886	127 078	94 724
Standard deviation	4 297	9 666	8 938	6 619	27 228	85 368	50 320
Note: expected marginal income and its standard deviation are calculated based on the probability of statesof nature							

Table 5 presents expert estimates of the minimum, maximum and most likely yields by crops for the planning year.

Table5. Expert estimates of crop yields for the planning year, center per hectare

Yield	Crops						
	Wheat	Barley	Oats	Buckwheat	Peas	Canola	Flax
Minimum	15,5	21,0	21,0	4,5	12,0	12,0	7,0
Maximum	19,0	24,0	24,0	6,0	18,0	17,0	12,5
Mostlikely	17,0	23,0	22,5	5,0	16,0	15,5	10,0

Table 6 presents expert estimates of the minimum, maximum and most likely prices for crops for the planning year, tenge per centner.

Table 6.Expert estimates of the prices for cropsfor the planning year, tenge per center

Price	Crops						
	Wheat	Barley	Oats	Buckwheat	Peas	Canola	Flax
Minimum	3 200	3 000	2 500	7 500	4 000	16 000	10 500
Maximum	3 800	3 400	3 000	9 000	4 700	18 000	13 000
Mostlikely	3 500	3 200	2 800	8 500	4 500	17 000	12 000

Then, with use of the properties of the triangular distribution there wascarried out computer simulation of the yield levels and crop prices for the planningyear. Pairwise multiplication of yield and price estimates gives us the value of a crop per hectare. Formally, this process is as follows: $R_{kl} = Y_k \times P_l,\ k = 1,2,\ldots,n,\ l = 1,2,\ldots,n$,where R_{kl} is crop value, Y_k is yield, P_l is price, n is the number of tests. Then, variable costs (per

hectare)are deducted from the value of a crop, and thus the marginal income is calculated. Note that the size of variable costs per hectare, as a rule, becomes known by the beginning of the sowing season. That is, in the context of the problem under consideration, variable costs are manageable factors. After calculating the possible levels of marginal income, we determine its expected level $E[GMs_j]$ and the standard deviation $\sigma[GMs_j]$.
Obviously, the number of possible values of a crop increases exponentially as the number of tests increases. If $n = 100$, then R_{kl} equals 10,000; if $n = 500$, then R_{kl} becomes equal to 250000. The number of options for calculating can be reduced in the same proportion, if the calculations carried out according to the following scheme: 1) arrange a set of yields and a set of prices in ascending (or descending) order; 2) divide each of the arranged sets into intervals with the same amount of data; 3) calculate the average for each interval; 4) calculate the values of a crop based on the interval average values.
Surely, to a certain extent the accuracy of the forecast decreases. However, the simulation of stochastic economic processes, in principle, gives only an approximate idea of the probability distribution of an economic variable. In any case, in practice, where, according to the Nobel laureate in Economics P. Samuelson, rough approximation can be better than none at all [23], the given method of calculation of probability distribution has a pragmatic usefulness.
Table 7 shows the results of the calculation of the expected marginal income and its standard deviation by crops done in accordance with the scheme.

Table 7.Projected expected marginal income and its standard deviation by crops for the planning year, tenge per hectare

Indicator	Crops						
	Wheat	Barley	Oats	Buckwheat	Peas	Canola	Flax
Expected marginal income	24 674	40 099	32 293	29 825	34 617	204 522	81 273
Standarddeviation	3 445	2 611	2 743	4 914	5 720	18 154	13 580

Finally, using formula (1) and the data from table 4 and table 7, the projected matrix of marginal income for the planning year is calculated (table 8).

Table 8.Projected matrix of marginal incomes, tengeper hectare (option 1)

State of nature	Crops						
	Wheat	Barley	Oats	Buckwheat	Peas	Canola	Flax
1	24 077	43 858	36 960	37 208	42 089	235 953	107 066
2	24 097	42 394	31 597	29 523	40 674	221 033	77 303
3	22 488	40 233	33 087	38 103	36 191	204 379	68 532
4	28 521	38 904	31 813	27 703	26 854	191 184	89 128
5	19 536	36 181	29 569	28 027	33 613	186 494	77 646
6	27 528	39 501	33 508	23 591	27 426	190 627	69 704
7	33 089	40 617	30 943	29 697	32 450	201 392	101 187
8	21 035	35 384	25 117	27 039	34 301	183 935	66 783

Thus, the procedure for calculating the projected matrix of marginal income according to the first proposed scheme is as follows:
1) On the basis of historical data on yields and sale prices, the values of each crop per hectare is calculated for the years of observation. Prices should be pre-adjusted for inflation;
2) By deducting the estimated amount of variable costs from the calculated values of a crop in step 1, the initial matrix of marginal income by crops and states of nature is formed. Recall that the size of variable costs for the current year (seeds, fertilizers, fuels, plant protection) becomes quite certain by the beginning of sowing season;

3) Probabilities are assigned (equal to one in the sum) to states of nature. Assigned probabilities reflect the chance of occurrence in the planning year of conditions similar to those in years of observation;
4) Average level and standard deviations of marginal income for each crop are calculated taking account of the assigned probabilities;
5) With the help of experts (or by entrepreneur himself), the minimum, maximum and most likely yield and price for each crop for the planning year are estimated;
6) Using the properties of the triangular distribution, computer simulation of estimates of crop yield and sale price for the planning period is carried out. By pairwise multiplication of estimates of the yield and price, we calculate the values of a crop per hectare, from which the corresponding amount of variable costs is then deducted. Further, from the obtained series of projected estimates of marginal income, its expected level and standard deviation for each crop are calculated;
7) Using the formula (1), a new matrix of marginal income is generated for crops with average levels and standard deviations as in step 6, but with the joint distribution inherent in the data from the original matrix.

Now let's begin the presentation of the second version of the scheme for calculations of projected marginal income, which implies the existence of a significant relationship between crop yields and sale prices.

Its essence consists in forming separately projectedyieldsmatrix and projected sale prices matrix on the basis of data from tables 1 to 3. To calculate the matrixes, the same formula (1) is used, with the only difference that it replaces the marginal income with the yield in the first case and with the price in the second case. Then,pairwise multiplication of the yields and prices of the obtained matrixesis run. And after deducting the variable costs,the desired matrix of marginal incomesis generated. The resulting new matrix of the projected marginal incomes preserves the stochastic relationship between yields and prices on each crop, as well as the correlation between marginal incomes across crops.

Table 9 shows the projected matrix of marginal incomes with taking account of the correlation between crop yields and sale prices.

Table 9.Projected matrix of marginal incomes, tenge per hectare (option 2)

State of nature	Crops						
	Wheat	Barley	Oats	Buckwheat	Peas	Canola	Flax
1	23 768	45 771	35 763	29 037	43 261	233 979	106 787
2	23 892	44 467	32 140	27 450	37 545	234 890	77 771
3	23 115	42 352	33 334	32 652	42 091	221 628	70 334
4	25 829	41 020	32 397	27 413	26 198	189 212	95 147
5	22 830	38 093	30 840	27 470	32 919	182 883	75 955
6	25 281	41 629	33 587	28 905	27 976	191 259	65 138
7	26 995	43 637	33 233	28 592	35 296	205 805	102 885
8	24 165	37 240	26 941	26 500	31 679	178 371	59 011

4. Discussions

It should be noted that certain aspects of the concept of supply chain management in relation to agribusiness are reflected in the publications of modern researchers [24, 25, 26], including those related to the improvement of information support and automation of commodity management processes [27]. At the same time, there is a shortage of studies that would study the processes of ensuring the sustainability of the supply of agricultural products (raw materials) within the framework of the SCM concept. In the conditions of crop production in the Northern Kazakhstan, the account of stochastic interdependency is critical for the proper planning of the structure and combination of the crops. Adequate representation of the stochastic relationship requires specification of the joint distribution of all analyzed variables. The Monte Carlo method, with rare exceptions, is practically inapplicable. However, there are other ways to account for stochastic interdependence. [4] Distinguish three such ways: (1) hierarchy of variables approach, (2) use of historical data and lookup table, (3) definition of correlation matrix.

Hierarchy of variables approach requires the selection of a variable that is the cause of the variation of the variables under study. In the Northern Kazakhstan, the key factor determining the yield of crops grown in the region is precipitation [28]. However, its use is limited by a very low density of weather stations, despite the fact that the production is carried out on large areas. Suffice it to say that the area of arable land in local agricultural enterprises ranges up to 40 thousand hectares or even more [15]. Use of historical data and lookup table approach, as the name implies, finds its application in cases where data from past observations are taken representative for the planning period and, therefore, can be used in the analysis directly. Even if the historical data do not sufficiently reflect the possible state of the system in the future, they can nevertheless be used in the analysis to capture the stochastic relationship between the yields of the crops. However, the average levels and standard deviations of crop yields need to be adjusted on the basis of subjective estimates. The limiting factor for the effective use of the specifying a correlation matrix approach is that the correlation matrix formed to quantify the relationship does not reflect the full picture of the interdependence between the variables, and gives only an idea of their covariance. To extract more information about the relationships between variables, researchers in recent years have increasingly turned to an approach called copula – a function that joins two or more distributions [29]. Using copulas, a complete picture of the stochastic relationship between any forms of distributions can be found – at least theoretically. There are not many examples of the use of copulas for the analysis of agricultural problems [30, 31]. Note that the difficulties in measuring and accounting for all aspects of relationships between variables are the reason why researchers are often limited to using correlation to represent stochastic interdependency [4].These approaches for assessing the relationship can be used in the analysis of yields, prices, income. In principle, farmers are not interested in the yield and even the price. They are interested in income. In other words, income per hectare of different crops is a key indicator for use in calculating the effective combination of crops and crop structure. However, income per hectare is a composite indicator, that is, a combination of other indicators, such as yield and price. The attempts to obtain directly from a farmer the forecast of complex indicators give, as a rule, unreliable results. This idea is supported by the outcomes of an experiment conducted by the authors amongst farmers in the North-Kazakhstan oblast. The point of the experiment was as follows. Farmers were given questionnaires asking to specify several possible levels of productivity and wheat prices in the current year, as well as assign each level a particular probability. Farmers generally coped with this task, although there were some difficulties with the indication of the probability. These peasants fell into stupor, when they were asked to give the same assessment about the production value per hectare of crops. Meanwhile, any proposals of researchers to improve the organization and conduct of business find a response among farmers only if they are based on understandable and easily measurable indicators, assumptions, methods. Otherwise, the results of scientific research, as a rule, cause farmers at best only curiosity, but no more. It is considerations of practicality and acceptability for farmers that underlie the proposed schemes of calculation and presentation of uncertainty in the development and adoption of planning decisions in crop production in the Northern Kazakhstan. These methodological techniques and procedures for presenting uncertainty in agricultural planning, of course, have their limitations for use. The main limitations are dictated by the degree of adequacy of expert assessments regarding the future state of the system and the degree of preservation in the future of the interdependency between crops (on yield and on product price), which took place in the past. In the conditions of Northern Kazakhstan there is a reason to believe that in the years of high grain yield the quality of products tends to decrease [32]. Changes in the quality inevitably lead to a change in price. Therefore, it seems useful and promising to carry out an in-depth and comprehensive study of the relationship between the yield and quality, as well as a study of the impact on the price of each of the two factors: (1) the actual change in the volume of supply of products on the market (due to high or low yields) and (2) changes in product quality [33].

5. Conclusion

A well-chosen supply chain management strategy, among other things, reduces the risk of goods shortages for the buyer, maintains an optimal level of stocks for both the seller and the buyer; and (which is critically important for each of the participants of the process) allows to maintain the sustainability of the entire economic system in conditions of uncertainty.

In conditions of uncertainty, only probabilistic models of economic processes can be an effective tool of economic planning. When choosing strategic decisions on the farm development, agricultural entrepreneurs have to take account of many factors. Amongst them, the correct use of economic data from the past periods is of great importance, since economic conditions tend to change over time. In addition to adjusting the baseline data for inflation, trend and the expected changes in the conditions of economic activity, it is also necessary to take account of covariance between incomes. The task becomes more complicated if there is a link between changes in crop yield and sale price. This link is most common in cases where access to international agricultural markets is difficult for one reason or another. In more open markets, the link between the crop yields and sale prices is much less apparent. For example, the correlation between the domestic and international market prices for kazakh food wheat is 0,70-0,80. However, the yield of wheat in Kazakhstan affects the prices through changes in the quality of the product: in the rainy years, the yield is much higher than average, but gluten falls to unacceptably low levels. These circumstances determine the need to be armed with different methods of calculating the income probability distribution. It should be noted that the second way of calculation of the projected matrix of incomes for crops claims the status of universal and can be used both in the presence and in the absence of a link between crop yield and sale price. The resulting projected matrix is then usedin farm planning with use of a risk-model.

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