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Increasing Of Sustainable Production For High-Producing Dairy Cattle Based On Stochastic Modeling

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ABSTRACT

The forage reserve of cattle stability is one of the factors increasing the sustainable dairy cattle breeding. Sustainability entails minimal forage crops yield variability on an annual basis thus reducing the risk of food shortage. This is particularly important for high-producing dairy cattle feeding, which is the most sensitive to changes in feeding conditions or ingredients (Mishchenko, V.A. 2012). The optimal sown area structure for an agricultural enterprise from the sustainable production point of view can be validated on the basis of stochastic mathematical modeling. For this purpose, the authors have developed an economic-mathematical model of the forage crops sown areas structure optimization, taking into account the sustainability of their production, i.e. minimum forage crops yield deviations from the average yields of these forage crops in several years on the basis of the model developed by Yu.I. Kopyonkin (KopyeonkinYu.I.2008. , KopyeonkinYu.I. 2009., KopyeonkinYu.I. 2002). Forage crops yield data of an agricultural enterprise for eight years is used in the model; the minimum feed prime cost is taken as an optimum criterion. The science-based diet for high-producing cattle is used in the model. During solving the model, the crops with the lowest yield variability are chosen within each feed groups, i.e. concentrated, coarse and succulent, as the optimum. The model provides for a certain degree of risk to be chosen by the head of the enterprise; At this the higher the risk, the higher the forage crops yield. In the result of the model solving, the enterprise is offered the optimum, in terms of feed production sustainability maximum, as well as production prime cost minimum, forage crops sown areas structure to provide for the uninterrupted feed supply of the cattle.

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Key words: agricultural sustainability, high-producing dairy cattle breeding, feed production, feed production structure optimization, mathematical modeling, stochastic modeling.

1. INTRODUCTION

The study was aimed at recommending to an agricultural enterprise such a forage crops sown areas structure, which ensures the maximum feed production sustainability. A stochastic modeling tool has been applied for this purpose. Stochastic models are widely used in the probability-based processes modeling. In the course of the implementation of the model, with an account of an optimum criterion, the recommended ones were the forage crops with a regular yield from year to year, little dependent on the weather conditions of a given year.

The objective was to find a feed production rational structure for dairy cattle breeding for an agricultural enterprise, which determines the optimum size and structure of forage and grain-fodder crops sown area, taking into account crop rotations, as well as optimum cattle diets, balanced in the main feed groups included in the diet.

The economic-mathematical model took into account the following conditions:

a sown area shall meet crop rotation requirements for field size, predecessors, crop rotation based on agrotechnical requirements;

feed production shall completely satisfy the cattle (taking into account the cost of acquisition) in accordance with the optimum diets for species and groups of animals,

- the optimum diets, balanced by the specified nutritional elements, shall meet the requirements to animal feeding groups.

An optimum criterion for the objective solving was one of the agricultural enterprise economic efficiency indicators, i.e. the minimum feed production prime cost. Production sustainability is the basis of economic (financial) sustainability, which is an indicator that significantly determines the performance of an enterprise in a market environment over a relatively long time interval.

There is an objective pattern in the Economics – the maximum possible average income (or the minimum possible costs) is characterized by the maximum risk (quantified by the degree of the indicator variability), i.e. by less sustainability.

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The peculiarity of this objective setting and the developed model peculiarity, as opposed to the models proposed before (KopyeonkinYu.I. 2002, Liao Z and Rittscher J ,2007, Shpak, A.P. 2005, Filatov, A.I. 2016, Mikhailenko I.M.2015), is that there are several options to solve the model, depending on the degree of risk that the head of the enterprise or manager selected. (Zgajnar J.; Kavcic S. 2010, Berger PD and Zeng AZ ,2006, Bachev H. 2008, Wilson P.N.; Luginsland T.R.; Armsrong D.V. 1988).

Using this model for an agricultural enterprise, it is assumed that the decision maker will choose the most suitable production strategy: either with a low degree of sustainability (high variability) – obtaining the greatest result from the possible ones, or with a high degree of sustainability (low variability) – obtaining a result close to the average annual feed production for a few years. In order to solve the economic objective, set in such a way, it is possible to use either quadratic income deviation (reduced cost deviation) minimization models or linear income deviation (costs) from the average or, if there is sufficient time horizon to determine the appropriate trend, from the trend minimization models. In this case, an objective was set to minimize the linear deviations in the forage crops yield from the average annual yield for a number of years.

The risk is defined as the mean square deviation from the actual amount of the feed produced by an agricultural enterprise. From a logical point of view, the option of risks minimization is the most sensible, however, this option, as demonstrated by the model solution and objective laws, is characterized by the lesser output (amount of produced feed). The lower the risks, the higher the production sustainability (Markovic T.; Jovanovic M. 2011, Ndubisi NO, Jantan M, Hing LC and Ayub MS ,2005). Therefore, the option of medium-risk choice and additional measures to ensure the provision of feed safety stocks (for example, the creation of feed safety stocks) is the most sensible.

2. METHODS

A stochastic modeling method is used to solve the task. A mathematical record of the stochastic economic-mathematical model for the forage crops sown area optimization is given below.

Model constraint groups:

1. Limitation on animal numbers:

$$x_j = b_j, \qquad (1)$$

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where j is a type of cattle.

2. Limitation on nutrient balance:

$$\sum_{j\epsilon N} v_{ij}x_j + \sum_{s\in S} v_{is}x_s \geq \sum_{j\in D} a_{ij}x_j, \quad (2)$$

where v_{ij} is the nutrient output of i-type per unit of i-activity; v_{is} is an i-type nutrient content in s-feed unit; a_{ij} is the annual standard 1 average annual j-type of cattle demand for the i-type nutrient;

N is the number of the activity types, S is the number of feed types, D is the number of the cattle types.

3. Limitations on separate feed groups:

$$\sum_{j\epsilon N} v_{hj}x_j + \sum_{s\in S} v_{hs}x_s \geq \sum_{j\in D}(a_{hj}x_j + x_{aj}) \quad (3)$$

wherev$_{hj}$ is the nutrient output of h-group per unit of j-activity; v_{hs} is a nutrient content in s-feed unit of an h-group; a_{hj} is a minimum rate of feed of h-group average annual j-type of cattle; x_{aj} is a-group feed adding to the minimum demand for j-type of cattle.

4. Limitations on additional feed (above the minimum demand) for different groups of cattle:

$$x_{hj} \geq \Delta a_{hj}x_j \ , \quad (4)$$

Where x_{hj} is an additional feed of h-group for j-group of cattle; a_{hj} – is a permitted amount of additional feed for h-group of cattle.

In this model, the amount of additional feed produced above the minimum demand added to the minimum demand make up the optimum quantity for each feed group (concentrated, coarse, ensilage, haylage).

5. Limitations on the specific weight of separate feed in the corresponding group

$$\sum v_{hs}x_s \leq g_s\left(a'_{hj}x_j + x_{hj}\right) \quad (5)$$

where v_{hs} is a nutrient content in s-feed unit of an h-group; s – a subset of by-product types used for feed; x_s is a nutritional content; g_s is a specific weight in concentrated feed; a'_{hj} is a minimum rate of feed per one species of cattle.

6. Limitations on the feed resources replenishment:

$$x_s \leq b_s \quad (6)$$

wherex$_s$ is an amount of s-type purchased feed; b_s is a limit for the purchase of s-type purchased feed.

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7. Limitation on the ratio of individual variables (condition of rotation validity:) Perennial grasses (3 years) – winter wheat, maize (4 years) – spring wheat, annual grasses – spring wheat – barley):

$$\sum_{j\epsilon N} a_{rj}x_j \leq b_r \quad (r \in R)\ , \qquad (7)$$

where$R$ – is a set of production resource types*;* j – is an activity type index; b_r is an amount of r-type resource; a_{rj} – an amount of r-type resource spend for a unit of i-resource.

7. Limitations on the determination of total deviations from the average forage crops yield (years):

$$\sum \varepsilon_{ij}\, x_j + y_j^+ - y_j^- = 0, \qquad (8)$$

whereε_{ij}– j-crop deviation from the mean;

y_j^+andy_j^-deviations are forage crops yield deviations from the average for the period under review (positive and negative) at j–results (years).

9. Limitations on the maximum possible, subjectively defined results (years) deviation from the average estimate of any indicator (gross forage crops yield)

$$y_j^+ - y_j^- = b_t \qquad (9)$$

whereb_t – is the expert-imposed amount of deviation from the average rating

Target function

$$\sum_{j\epsilon J} c_j x_j \to min \qquad (10)$$

Where c_j is the j-type feed unit prime cost.

3. RESULTS

This model was tested in the agricultural enterprise AO AGROFIRMA DMITROVA GORA located in the southeast part of the Tver region.

Several variations of the model solutions were made with varying deviations from the average feed production level, from 12.5% to 19.0%, which corresponded to the range of deviations from the average annual feed production level, from 50 thousand quintal of feed units up to 76 thousand quintals of feed units (the higher the deviation, the higher the risk). Each solution to the model, depending on the degree of chosen risk (i.e. the amount of potential variation in feed production from the average), corresponded to

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a certain optimum set of forage crops areas and a certain value of production costs (Table 1).

Table 1 shows, that there are differences between the actual forage crops sown areas. Model solution options offer crops sown areas on the basis of crops yield variability minimum shaken yields, taking into account the minimum production prime cost. The largest of the given deviation values corresponds to the highest degree of risk, the lowest value corresponds to the lowest level of risk, where the minimum amount of output variances is a

from the middle level is achieved.

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Table 1 –Forage crops yield areas in practice and in the result of the model solution with varying values of deviations from the average feed production in the AO AGROFIRMA DMITROVA GORA, hectares

Deviation from average feed production, %	Deviation from the average, feed unit q	Forage crops sown areas, ha								Production cost, thous. RUB	The standard deviation	Nutrient output, feed unit q
		Barley area	Winter wheat	Triticale	Pea-barley mix	Maize for silage	Perennial grasses (hay)	Perennial grasses (haylage)	Spring wheat			
Actual area, 2016												
×	×	339	2790	66	136	1532	105	2825	2461	522520	×	380978.5
Forage yield sown areas as per model solution, ha												
12.0	*the solution is not consistent*											
12.5	50000	0	122	1929	776	776	697	2565	776	484310	38338.4	398928.4
13.0	52000	0	24	2019	776	776	705	2565	776	434320	39806.7	399200.1
14.0	56000	0	0	2041	776	776	707	2565	776	422139	37724.2	399266.3
15.0	60000	0	0	2041	776	776	707	2565	776	422139	38334.3	399266.3
16.0	64000	0	0	2041	776	776	707	2565	776	422139	38975.8	399266.3

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The decrease in the gross feed output variability is characterized by increased costs. The choice of a specific solution depends on the management of the enterprise. The standard deviation calculated for the various conditions (Table 2).

Table 2 – The standard deviation from the average feed production level under various uncertainties and risks,
quintals of feed units*

Variability indicators	Percentage deviation from the average							
	12,5 %	13 %	14 %	15 %	16 %	17 %	18 %	19 %
Deviation from the av-erage feed production, feed unit q	50000	52000	56000	60000	64000	68000	72000	76000
Standard deviation	38338.4	39806.7	37724.2	38334.2	38975.8	39647.4	40347.4	41074.5

*1 feed unit = 5.95 mJ

4. SUMMARY

It follows from the calculations, that if the enterprise is guided by sustainable produc-tion criteria for dairy cattle breeding, which ensures the financial sustainability of the enterprise, the feed production structure shall be reorganized in accordance with the proposed recommendations. The analysis showed that the higher the risk, the higher the forage crops yield. The strategy of choosing the middle level of risk strategies is practi-cable and protection from a possible food shortage shall be carried out in another way.

5. CONCLUSIONS

Stochastic modeling is the instrument by which a less risk-based agricultural develop-ment strategy can be validated, which will contribute to the growth of productive and financial sustainability of the enterprise.

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