Forecasting the Risk of the Resource Demand for Dairy Farms Basing on Machine Learning

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Abstract. The work supplies analysis of the conditions of use of the intellectual systems of support for managerial decision making in agrarian production. The authors argue the expediency of forecasting the risk of the resource demand for dairy farms on the base of application of machine learning tools. In the article, the authors propose the approach to forecasting the risk of the resource demand for dairy farms, which is based on machine learning and suggests fulfilment of eight stages. The approach peculiarity is that formation of the bases of data and knowledge is completed with consideration of the features of the set project environment. It is argued that computer modeling of the case branch secures system consideration of the variable factors of costs for fodder production and its market price. The proposed approach creates a basis for improvement of quality and accelerated formation of the database for forecasting the resource reserve basing on machine learning. Referring to the developed approach and computer program in the Python language, the authors substantiate a base of knowledge. The knowledge base is represented by the tendencies of a change of the forecasted figures of the risk of the resource demand for dairy farms in the set project environment. The computer modeling is conducted on the example of Zabolottsi amalgamated territorial community in Brody district of Lviv region. The obtained figures of the limits and tendencies of a change of the volume of the reserve of hay, made of perennial herbs, and field area for its growing serve as markers for conducting machine learning with a teacher. The further research should be conducted concerning the choice of a method and development of an algorithm of machine learning for forecasting the risk of the resource demand for dairy farms.

Keywords: Forecasting, risk, resources, dairy farms, machine learning, model.

1 Introduction

Every year, machine learning is getting more popular in different fields of people's life and activities. It is also true for agrarian production, which has its specificity and needs consideration of a set of factors for adequate managerial decision-making.

Nowadays, in Ukraine, there is sufficient amount of resources for production of milk as raw material of the appropriate quality [1-3]. However, the major amount of milk is produced by family dairy farms, which require implementation of the projects on establishment of cooperatives for their fodder supply. Thus, forecasting of the resource demand for dairy farms is one of the most important tasks of such project management, which involves machine learning [4].

Considering the fact that the project environment of the projects of establishment of fodder supplying cooperatives is characterized by the changeable nature, which is caused by a complex of factors, it is impossible to achieve the appropriate quality of the approved managerial decisions without the intellectual systems of the decision support [5-7]. Particularly, the use of an efficient intellectual analysis of statistical data on the market value of some kinds of fodder, costs of its production, and yield capacity secures foresting the need to create a reserve as a response to the risk of resource supply for dairy farms. Moreover, the adequate forecasting of the resource demand for dairy farms can be done on the base of application of the methods and algorithms of machine learning.

2 Analysis of Published Data and Problem Setting

The managerial problems of creation of new and development of the existing systems of support for decision making in agrarian production, which is based on the peculiarities of the domain and methods of artificial intellect, is currently widely used.

The scientific works [8-10] supply the analysis of the possible use of the data mining tools for solution of the managerial problems. Those tools involve traditional models.

In their researches, some authors [11-13] solve the scientific-applied problems of support for managerial decision making by applying the algorithms of forecasting. Their principal advantages include the adequate assessing of profit, obtained by enterprises. However, it is impossible to use them for forecasting the resource demand for dairy farms, because they do not consider peculiarities of the domain.

In some publications [14-16], their authors argue the necessity to consider peculiarities of the domain. It requires application of the personalized approach to development of a system of support for decision-making. There are some works in that direction, which are devoted to development of effective intellectual systems for agrarian production [3, 6, 17]. However, all of the above-mentioned authors do not pay significant attention to the study and analysis of different methods and algorithms of machine learning.

The scientific works [18-24] substantiate the main advantages of the methods and algorithms of machine learning. Some researches [6, 12, 17] are devoted to development of the tools of machine learning for agrarian production. Nevertheless, none of them considers the possibility to use the methods and algorithms of machine learning for forecasting the resource demand for dairy farms. Particularly, there is no a base of knowledge, which could serve as a fundamental for the models of machine learning, which secures forecasting the risk of the resource demand for dairy farms. It eliminates the possibility to conduct machine learning with a teacher because of no markers.

The aim of the work is to develop an approach and substantiate a knowledge base, which secure forecasting the risk of the resource demand for dairy farms on the base of machine learning, and are founded on modeling of a changeable project environment of the domain.

To reach the set goal, it is necessary to solve the following tasks:

– to propose an approach to forecasting the risk of the resource demand for dairy farms with the use of the domain modeling;

– to substantiate the knowledge base, which creates fundamentals for forecasting the risk of the resource demand for dairy farms on the base of machine learning.

3 The Approach to Forecasting the Risk of the Resource Demand for Dairy Farms with the Use of the Domain Modeling

The work outlines the main stages of development of the model of forecasting the risk of the resource demand for dairy farms, basing on machine learning (Fig. 1).

The research studies the peculiarities of forecasting the demand of variable volumes of fodder and field area for its growing with consideration of the risk of natural-climatic conditions (variable durations of the periods of fodder supply of dairy farms, causing variable amounts of some kinds of fodder and cropping area for its growing), as well as the risk of the organizational-scale factor of the value, which are expressed in a variable structure of a milking herd, determining the fodder demand.

Thus, it is necessary to use the known method [3], which suggests argumentation of the resource demand for the projects of milk production with consideration of changeable natural-agrometeorological conditions and milk yields during a lactation period. However, that method does not consider the variable structure of the livestock number in a milking herd (an organizational-scale constituent of the risk), which is specific for the set project environment, and calculated for the average value (mathematical expectation) of duration of the periods of a milking herd maintenance. To eliminate the mentioned drawbacks and consider the impact of natural-climatic and organizational-scale risks on the risk of their subject matter, it is proposed to make forecast of the demand of variable amounts of fodder and field area for its growing in the following sequence.

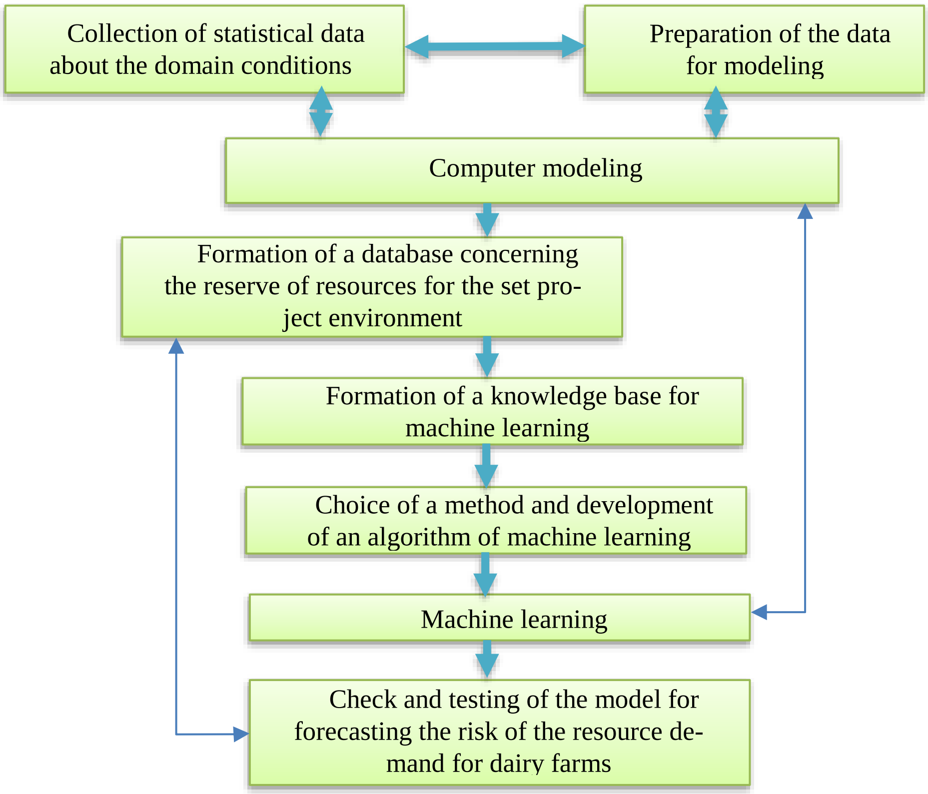

Fig. 1. The stages of development of a model of forecasting the risk of the resource demand for dairy farms, basing on machine learning

The annual demand $\left(Q_{kjp}^{i}\right)$ of k kinds of fodder for the j age group of a milking herd with the p productivity is determined by the formula:

$$Q_{kjp}^{i} = M\left[Q_{kp}^{i}\right] \cdot t_{bi} \cdot k_{kjp}\,, \tag{1}$$

where $M\left[Q_{kp}^{i}\right]$ – stands for the mathematical expectation of the forecasted daily need for k kinds of fodder with its p productivity in the i calendar year, c; t_{bi} – stands for duration of the b period of a milking herd maintenance, during which the k kinds of fodder are used, days; k_{kjp} – stands for the factor of a relative demand for the k kinds of fodder for the j age group of a milking herd with the p productivity.

The mathematical expectation $M\left[Q_{kp}^{i}\right]$ of the forecasted daily demand for the *k* kinds of fodder for a milking herd with its p productivity in the i calendar year is determined by its energy and nutritive value, basing on the dependences, which are argued in the work [3]. The duration $\left(t_{bi}\right)$ of the b period of a milking herd maintenance is determined on the base of performance of the first stage of that method. The factors $\left(k_{kjp}\right)$ of the relative demand of the k kinds of fodder for the j age groups of a milking herd with the set p productivity are equal to 1.0 – for milking cows; 0.75 – for heifers and young cows above two years old; 0.5 – for young cows from 1 to 2 years old; 0.25 – for calves under one year [6].

The total annual demand of the k kinds of fodder for a milking herd, serviced by a cooperative of fodder supply, is calculated by the formula:

$$\bar{Q}_k^i = \left(\sum_{j=1}^{m} \sum_{p=1}^{n} Q_{kjp}^i \cdot n_{jp} \right) \cdot k_{вз} \cdot k_{вт} \cdot k_{вн} , \qquad (2)$$

where n_{jp} – stands for the livestock number in the j age group of a milking herd with the set p productivity, cows; $k_{вз}, k_{вт}, k_{вн}$ – stand for the factors of losses of the k kinds of fodder during the periods of storage, transportation and distribution respectively, as well as due to not eating up by animals; m – stands for the number of age groups of a milking herd, units; n – stands for the number of productivities of a milking herds, units.

Referring to the obtained figures of the total demand $\left(\bar{Q}_{kp}^i\right)$ of the k kinds of fodder for a milking herd with the p productivity in the i calendar year, it is possible to determine the forecasted area of fields $\left(\bar{S}_{kp}^i\right)$, which should be used for the fodder growing:

$$\bar{S}_{kp}^i = \frac{\bar{Q}_{kp}^i}{M\left[У_{si}\right] \cdot K_s} , \qquad (3)$$

where $M\left[У_{si}\right]$ – stands for the mathematical expectation of the expected yield of the s kind of fodder crop on the territory of a community in the i calendar year, c/ha; $K_з$ – stands for multiplicity of harvesting of the yield of the s kind of fodder crop, units.

The expected yield $У_{si}$ of the s kind of fodder crops on the territory of a community is variable, and to determine its quantitative characteristics, it is necessary to use statistical data of the community. Using the methods of mathematical statistics and statistical data on the yield $У_{si}$ of the s kind of fodder crop in the i calendar year, the researchers obtain their multiplicity $\{У_{si}\}$, which make a basis for argumentation of the density $f\left(У_s\right)$ of its law of distribution, and determination of its main characteristics: mathematical expectation – $M\left(У_s\right) = \sum_{i=1}^{j} У_{si} \cdot P_i$, $D\left(У_s\right) = \sum_{i=1}^{j} (У_{si} - У_{sc})^2 \cdot P_i$, $\sigma\left(У_s\right) = \sqrt{D\left(У_s\right)}$, $\nu\left(У_s\right) = \frac{\sigma\left(У_s\right)}{M\left(У_s\right)}$. Where $У_{si}$ – stands for yield $У_{si}$ of the s kind of fodder crop in the previous i calendar year, c/ha.

Referring to the forecast of the total annual demand $\left(\bar{Q}_{kjp}^i\right)$ of the k kinds of fodder for a milking herd with its p productivity and expected field area $\left(\bar{S}_{kp}^i\right)$, which should be used for its growing, it is possible to make a set of calculations for the i calendar years with the change of durations (t_{bi}) of the b-x periods of maintenance of a milking herd, which are determined at the first stage of that method. The obtained set of figures of the annual demands $\{\bar{Q}_{kjp}^{i}\}$ of the k kinds of fodder and forecasted field area $\{\bar{S}_{kp}^{i}\}$ for its growing makes a basis for argumentation of its distribution and determination of its main features, characterizing risks of the resource demand for dairy farms.

The main responses to the risks of the resource demand for dairy farms are manifested by creating the reserves of the k kinds of fodder for a milking herd. To argue the responses to the case risks, it is first required to settle the limits of a change of the demand for an annual reserve $R(\bar{Q}_k^i)$ of the k kinds of fodder. To calculate a maximal relative value of the annual reserve $R(\bar{Q}_k^i)$ of the k kinds of fodder, the following formula can be used:

$$R(\bar{Q}_k^i) = \frac{\bar{Q}_k^{max} - M\left[\bar{Q}_k\right]}{M\left[\bar{Q}_k\right]} \cdot 100, \qquad (4)$$

where $\bar{Q}_k^{max}$ – stands for the figure of an annual demand of the k kinds of fodder for a milking herd, c; $M\left[\bar{Q}_k\right]$ – stands for the mathematical expectation of the annual demand of the k kinds of fodder, c.

Having found the limits of a possible change of a relative value of the reserve $R(\bar{Q}_k^i)$ of the k kinds of fodder for a milking herd, it is possible to determine expenditures for creation of the reserve $B_{R(\bar{Q}_k^i)}$ within a set range of changes and expenditures $C_{R(\bar{Q}_k^i)}$, caused by purchasing its deficit at the market (Fig. 2).

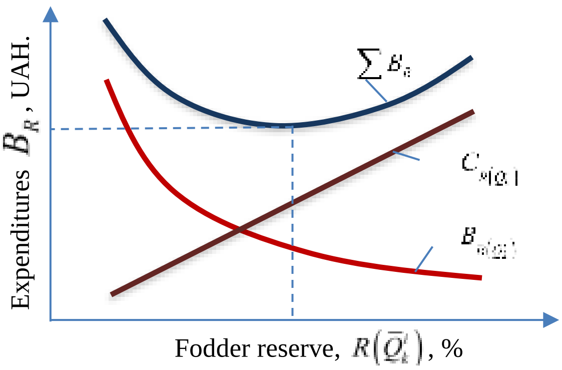

Fig. 2. Determination of rational responses to the risks of the resource demand for dairy farm: $B_{R(\bar{Q}_k^i)}$, $C_{R(\bar{Q}_k^i)}$ – stand for expenditures for the reserve creation and expenditures because of buying its deficit at the market; $\sum B_R$ – stands for total expenditures for creating the fodder reserve

The rational responses to the case risks of the resource demand for a dairy farm are those, which secure minimal total costs for creation of the fodder reserve $-\sum B_R \rightarrow min$.

Considering the fact that the expected yield Y_{si} of the s kind of fodder crops, which are planned for growing, is variable both on separate fields and in the i calendar years, the reserve area should be calculated with consideration of its mean square deviation $\sigma(Y_s)$. However, the average expenditures (mathematical expectation of the total costs) $M(B_R)$ for determining the reserve of field area $R(S_k)$ for growing of fodder crops under the set figure of that reserve can be calculated by the following formula:

$$M(B_R) = 0,5 \cdot B_{R(S_k)} \cdot R(S_k) + B_{R(S_k)} \int_0^{R(S_k)} \left(R(S_k) - R(S_k)_n\right) \cdot f\left(R(S_k)_n\right) \cdot dR(S_k)_n + \\ + C_{R(S_k)} \int_{R(S_k)}^{\infty} \left(R(S_k)_n - R(S_k)\right) \cdot f\left(R(S_k)_n\right) \cdot dR(S_k)_n \quad (5)$$

where $M(B_R)$ – stands for the mathematical expectation of the total costs for determination of the reserve area for fodder crops growing, UAH; $B_{R(S_k)}, C_{R(S_k)}$ – stand for expenditures for creation of the reserve of field area and expenditures of dairy farms because of their deficit, UAH; $R(S_k), R(S_k)_n$ – stand for the set value of the reserve of the area for fodder crops growing and the required reserve of it, %; $f\left(R(S_k)_n\right)$ - stands for the density of distribution of the probability of need for the reserve of area for fodder crops growing.

The first summand of the formula (5) demonstrates that under no need of the area reserve for fodder crops growing (probability is equal to 0.5), dairy farms will not experience the expenditures equal to $B_{R(S_k)}$, multiplied by the value of that reserve. If the current value of the reserve $R(S_k)_n$ does not exceed the value $R(S_k)$, the expenditures will be determined by the second summand of the formula (5). If the need of the field area reserve $R(S_k)_n$ for fodder crops growing exceeds the value $R(S_k)$, the expenditures of dairy farms will be determined by the third summand of the formula (5).

4 The Results of Argumentation of the Knowledge Base for Forecasting the Risk of the Resource Demand for Dairy Farms, Basing on Machine Learning

The statistical data on the domain conditions are gathered under conditions of Lviv region, basing on the official statistical data. The project environment, which conforms to the conditions of the agricultural servicing cooperative “Pokrova” in Brody district of Lviv region while growing perennial herbs for hay, was taken as an example.

To complete the appropriate and fast creation of the database concerning the resource reserve for the set project environment, there is a developed computer program in Python language, which supplies computer modeling for determination of the resource demand for dairy farms. It is based on the above-presented approach to forecasting the risk of the resource demand and supplies the figures of the components of the case risks.

The response to the case risks of the resource demand for dairy farms is manifested by creation of the reserve of the k kinds of fodder. It is approved that the reserve can be formed by purchasing some kinds of fodder at the market and their production at the cooperative. The results of the analysis of statistical data on market prices (as of January 1, 2019) of some kinds of fodder on the territory of Lviv region determines their statistical characteristics, which are presented in the Table 1.

Using the formula (4) and the obtained data on the mathematical expectation of the annual demand for hay, made of perennial herbs, the authors calculate the maximal relative value of their annual reserve $R\left(\bar{Q}_k^i\right)$.

Table 1. The initial data for substantiation of the reserve of hay, made of perennial herbs

Characteristic	Market price of hay, UAH/c	Costs of hay production, UAH/c
Mathematical expectation	220	165
Mean square deviation	73	58

It supplies the opportunity to determine the limits of a possible change of the relative value of the reserve $R\left(\bar{Q}_k^i\right)$ of the k kinds of fodder for the set livestock number in a milking herd (Fig. 3).

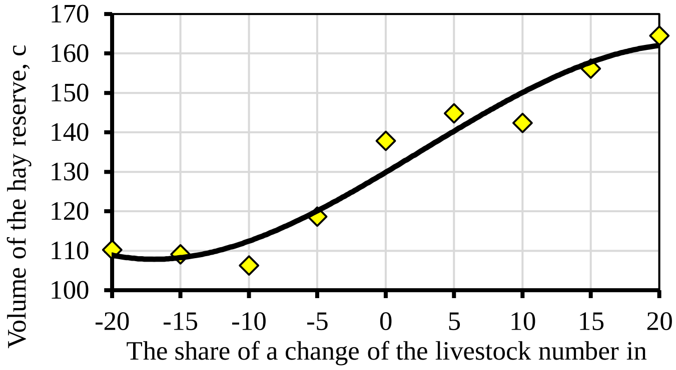

Fig. 3. The dependence of the amount of the reserve of hay, made of perennial herbs, on the livestock number in a milking herd, serviced by the cooperative

The obtained dependences (Fig. 3) confirm that the amount of the reserve $R\left(\bar{Q}_k^i\right)$ of hay, made of perennial herbs, with a proportional change of the livestock number in a milking herd Z_n is changed by the polynomial dependences of the third order. They are described by the corresponding equations:

$$R\left(\bar{Q}_{ci}^{i}\right) = -0.0018 \cdot Z_n^{\ 3} + 0.0139 \cdot Z_n^{\ 2} + 2.0678 \cdot Z_n \ + 129.87,\ r\ =\ 0.94\ , \qquad (6)$$

The irregularity of a change of the amount of the reserve $R\left(\bar{Q}_k^i\right)$ of hay, made of perennial herbs, with the change of the structure of the livestock number in a milking herd Zn is explained by a transformation of the structure and demand for that fodder under a different productivity of the milking herd.

Having obtained the results of the forecast of the demand for hay of perennial herbs (Fig. 3), as well as their specific market price and specific costs of production in a cooperative (Table 1), the researchers calculate the costs for creation of the reserve $B_{R\left(\bar{Q}_k^i\right)}$ and expenditures of dairy farms $C_{R\left(\bar{Q}_k^i\right)}$, because of purchasing their required volume at the market. It supplies the opportunity to compose a dependence of the mentioned costs on the share of their reserve (Fig. 5).

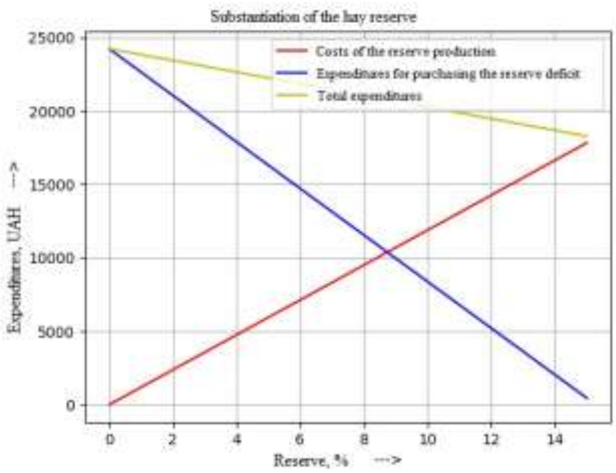

Fig. 5. The dependences of the costs for creation of the reserve of hay, made of perennial herbs, at the cooperative on its share

The obtained dependences (Fig. 5) confirm that the costs for creation of a hay reserve depend both on the source of its reserve (purchasing at the market or production at the cooperative), and on the reserve share. It is determined that the maximal volume of the reserve should by equal to 15.2%.

The least expenditures for creation of a hay reserve are observed in the variant, where the whole reserve is produced at the cooperative. It will supply the opportunity to reduce the impact of case risks, caused by hay deficit.

The rational responses to the risk of the hay demand for dairy farms suggest production of an argued amount of their reserve at the cooperative, securing minimal total expenditures for its creation.

As it is mentioned above, the expected yield Y_{si} of the s kind of fodder crops, which is planned at the cooperative, is variable both on different fields and in different i calendar years. Referring to the statistical data on the conditions of Lviv region, the authors define the characteristics of distribution of the yields Y_{si} of hay, made of perennial herbs (Table 2).

Table 2. The characteristics of distribution of the yield Y_{si} of hay, made of perennial herbs, in the conditions of Lviv region

Kind of fodder crops	Statistical characteristics of distribution, c/ha			
	$M(Y_{si})$	$\sigma(Y_{si})$	$Y_{si\,min}$	$Y_{si\,max}$
Perennial herbs for hay	45	6	39	51

Using the computer program of formation of the database on the resource reserve for the set project environment and obtained statistical data concerning characteristics of distribution of the yield Y_{si} of hay, made of perennial herbs (Table 2), the research determines limits of a possible change of the expected volume of the reserve of field area $R(\bar{S}_k^i)$ for hay growing under a change of the livestock number in a milking herd, serviced by the cooperative, for the conditions of the agricultural servicing cooperative "Pokrova" in Brody district of Lviv region (Fig. 6).

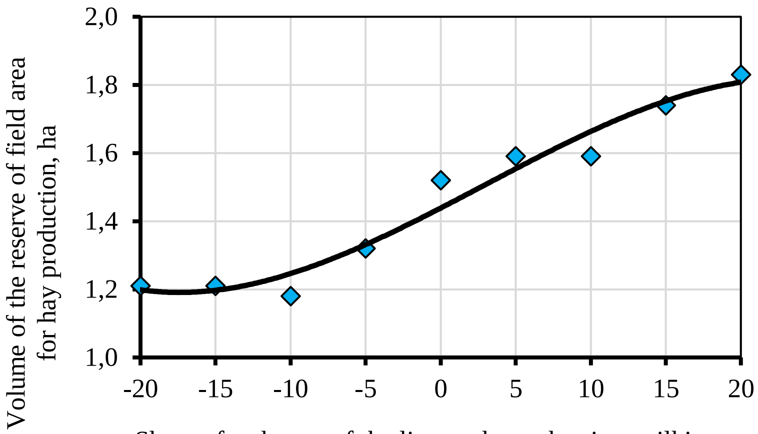

Fig. 6. The dependences of the volume of the reserve of field area $R(\bar{S}_k^i)$ for hay growing on a change of the livestock number in a milking herd, serviced by the cooperative

The obtained dependences (Fig. 6) confirm that the forecasted volume of the reserve of field area $R(\bar{S}_k^i)$ for growing of hay with a proportional change of the livestock number in a milking herd Zn is changed by the polynomial dependences of the third order:

$$R\left(\bar{S}_{ci}^{i}\right) = -2\times 10-5\cdot Z_{n}^{3} + 0.0002\cdot Z_{n}^{2} + 0.0227\cdot Z_{n} + 1.43,\ r = 0.96\ . \qquad (7)$$

Having obtained results of the forecast of the volume of the reserve of field area $R\left(\bar{S}_{k}^{i}\right)$ for hay growing (Fig. 6), characteristics of distribution of its yield y_{si} (Table 2) and the specific costs of production at the cooperative (Table 1), as well as using the formula (5), the authors calculate the average expenditures (mathematical expectation of the total costs) $M\left(B_{R}\right)$ for determination of the reserve of field area under perennial herbs for hay.

To perform the mentioned calculations, the researchers used the developed computer program, which secured the opportunity to develop the dependences of the degree of the reserve risk on the volume of the set field area $R\left(\bar{S}_{k}^{i}\right)$ for hay growing (Fig. 7).

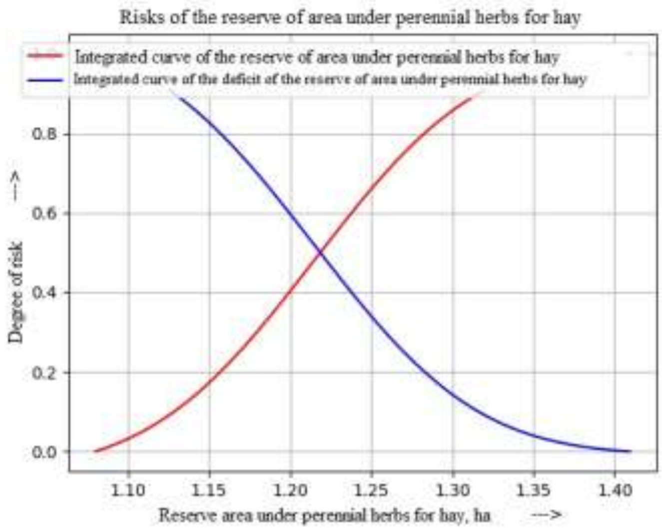

Fig. 7. The dependences of the degree of risk of the demand of hay, made of perennial herbs, for dairy farms on the reserve of field area for its growing

The obtained dependences (Fig. 7) supply the opportunity to make quantitative assessment of the degree of risk of the demand for hay, made of perennial herbs, for dairy farms, depending on the volume of the reserve of field area $R\left(\bar{S}_{k}^{i}\right)$ for its growing. The results of assessment of the degree of the mentioned risk are presented in the Table 3.

Table 3. The results of assessment of the degree of risk of the demand of hay, made of perennial herbs, for dairy farms

Kind of fodder crops	Limits of the volume of the reserve of field area for growing of hay of perennial herbs, ha				
	Critical risk 0.81…1.0	High risk 0.61…0.8	Average risk 0.41…0.6	Admissible risk 0.21…0.4	Minimal risk 0…0.2
Perennial herbs for hay	1.33…1.45	1.46…1.5	1.51…1.55	1.56…1.62	1.63…1.77

The data of the Table 3 argue that for the set scale of the cooperative, the level of their case risk influences the volume of the reserve of field area for growing of hay, made of perennial herbs, for dairy farms within the set limits.

The obtained figures of the limits and tendencies of changes of the volume of the reserve of hay, made of perennial herbs, and field area for its growing are the markers for the machine learning with a teacher. The further research should be conducted concerning the choice of a method and development of an algorithm of machine learning for forecasting the risk of the resource demand for dairy farms.

5 Conclusions

The proposed approach to foresting the risk of the resource demand for dairy farms is based on machine learning and suggests fulfilment of eight stages. The peculiarity of that approach is that formation of the bases of data and knowledge is fulfilled on the fundamentals of consideration of the peculiarities of the set project environment due to computer modeling, which secures a system involvement of variable factors of the costs of fodder production and their market value. It creates a basis for improvement of the quality and acceleration of formation of the databases for forecasting the resource reserve.

Basing on the developed approach and computer program in the Python language, the authors of the work argue a knowledge base, which is represented by the tendencies of changes of the forecasted figures of the risk of the resource demand for dairy farms on the example of Zabolottsi amalgamated territorial community in Brody district of Lviv region. The obtained figures of the limits and tendencies of changes of the volume of the reserve of hay, made of perennial herbs, and field area for its growing are used as the markers for machine learning with a teacher. The further research should be conducted concerning the choice of a method and development of an algorithm of machine learning for forecasting the risk of the resource demand for dairy farms.

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