



## Stochastic Optimization Model of Medium-Term Forecasting of Reserve of Financial Resources for Natural Fires Elimination\*

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### ARTICLE INFO

Received August 29, 2019  
Revised from September 23, 2019  
Accepted October 26, 2019  
Available online December 15, 2019

#### **JEL classification:**

C61.

**DOI:** 10.14254/1800-5845/2019.15-4.1

#### **Keywords:**

Optimization model,  
natural fires,  
economic and mathematical modeling,  
stochastic uncertainty,  
weather-economic risk,  
regional reserve of financial resources.

### ABSTRACT

The most large-scale and frequent, due to the physical and geographical location, natural disasters in some regions of Europe, natural fires. It cannot be denied that natural fires cause significant damage to the economies of the regions. The authors consider possibility of using stochastic economic and mathematical model reduce the negative economic impact of forest fires on the regional economy, by optimizing the planning and distribution of financial resources for the medium-term planning period. The developed optimization criterion for planning regional reserves to prevent negative economic consequences from natural fires is given. Experimental modeling based on the official reporting statistical data the Russia region is carried out. The model is quite general in nature and can be used to solve similar problems not only for the Russian regions, but also in European and other countries where one has face the same problems.

## INTRODUCTION

To date, the main, the most large-scale and frequent, due to the physical and geographical location, natural disasters are natural fires. It cannot be denied that natural fires cause significant damage to the economies of the regions. It is also impossible to deny the fact that the risk of wildfires is stochastic in nature. It is almost impossible to predict the probability of occurrence, number and scale of natural fires, since the risk of occurrence depends on many conditions, including weather and natural conditions (Sidorenkov V. M. et al., 2017). Some studies are devoted to the risk assessment of forest fires. The estimation of the costs for the elimination of natural fires, including in the medium term, was not found in the literature. However, such a forecast is necessary because the process of elimination and elimination of forest fires is financed from the budget.

\* The article is based on the research materials supported by RFBR grant №18-010-00842

The law on the regional budget determines the size of the reserve of financial resources, from which the process of liquidation of emergency situations is then financed. It cannot be denied that this approach loses the factor of weather and economic risk, as well as the optimization of budget funds. The developed economic and mathematical model assumes the account of a factor of weather and economic risk at planning of volumes of the allocated budgetary funds in the reserve Fund of the region on elimination of natural fires. Based on the analysis of time series data on the costs of natural fires elimination, on the basis of the proposed optimization criterion and economic-mathematical model, it is proposed to give a medium-term forecast of future costs for the period of 5-10 years. This model was tested on the statistical data of Russian region. Since data for the 30-year period are not available, a 15-year observation period was taken. When building the model, the approach proposed by V. Kardash for the sphere of agriculture was used (Kardash, 1989). This approach offers to take into account the factor of weather uncertainty in the planning and creation of state reserves of agricultural products (Raszkowski and Bartniczak, 2018). Kardash and his followers propose to plan the amount of reserves, taking into account the fact that the annual weather conditions can be favorable, medium and unfavorable. Proposed by V. A. Kardash and his followers (Ilchenko and others.) models can not be applied in pure form to the planning and management of reserves for the elimination of natural disasters - forest fires (Ilchenko, 1993). However, the approach to the construction of a model taking into account the factor of uncertainty of weather, annual weather conditions may be relevant, since weather has a major impact on the risk of forest fires (Podrezov, 2000). It is proposed to reserve financial resources for the elimination of natural fires, taking into account the fact that the year (in terms of the current weather situation) can be: favorable, average, unfavorable.

## 1. LITERATURE REVIEW

Status and problems of forest fires on the territory of the Russian Federation considers in his study, Y. Vorobyov. This work reflects the issues of the state and use of the forest Fund of Russia, the organization of forest protection from fires. The statistics of forest fires in Russia is also given there, and descriptions of the most difficult fire-dangerous seasons of the last years are given. The study considers the causes of forest and peat fires and their environmental consequences (Vorobyov, 2000).

V. Kardash (1989) devoted their works to the study of the problem of weather, and as a consequence, financial risk. Ilchenko. Their work contains the fundamentals of the Economics of weather risk, used in the dissertation research. These works can not be applied in pure form for the solution, since, in large part, these studies cover the scope of agriculture, without taking into account the scope of optimization of reserves in the territorial bodies of the Ministry of emergency situations. Kardash for the first time proposed economic and mathematical tools required to obtain m-optimal solutions in the conditions of weather uncertainty of agriculture. The tools are developed on the basis of the achievements of stochastic programming, the theory of Markov process control, economic Cybernetics, the theory of duality. The approach of Kardash, for all its specificity, can be extended to another weather-dependent sphere of activity: the elimination of forest fires.

A. Ilchenko proposed methods, algorithms and software for mathematical models, coordination of management decisions in multi-level, multi-functional territorial production systems.

Kardash's approach (and then Ilchenko and other followers) is as follows: all control decisions are divided into strategic, taken with a focus on the whole set of possible outcomes of weather conditions, and tactical, taken with a focus on the specific implementation of these conditions. Optimization conditions are described in the form of decision rules, which take into account the information about the process of development of the stochastic system. At the same time, information for the past period is taken into account through various characteristics

of the system at the moment, and information about future conditions of development (including various random situations) - through the mathematical expectation of the effect for the time remaining until the end of the planning period. For stochastic conditions, this principle is implemented in the framework of the theory of controlled Markov processes. Thus, the principles and methods of making control decisions, taking into account the random nature of weather fluctuations, are very specific. Weather risk creates specific problems when creating an economic mechanism for financing the activities of the emergencies Ministry as a whole, which must be taken into account in order to achieve maximum efficiency in the management of the financing system, through forecasting the average values of the required indicators (Chen et al, 2018).

The problem of optimization of financial reserves in the field of emergency management, taking into account the influence of the weather factor, is considered for the first time and there are no literature on the issues under study. Thus, the analysis of the situation in the field of research, on the basis of literary sources and research works, allows us to conclude about the lack of study of the issue of optimization of management decisions, taking into account the influence of the weather factor, on measures to eliminate emergency situations, as well as in the field of planning and optimization of financial resources, and The study will solve the practical problem of optimization in the field of planning of reserves of financial resources on the basis of the new data.

## 2. THE MATHEMATICAL DESCRIPTION OF MODEL

In our task of the study (determining the optimal regional amount of financial resources for the elimination of weather – related emergencies for the financial year) it is necessary to find a management solution-the optimal set of weather outcomes, in which the economic effect of the allocated funds will be maximum. The maximum economic effect will be achieved when the deviation between the funds reserved for the financial period for the liquidation of this group of emergencies and the funds actually spent (for the financial period) will be minimal.

$$E \max = |C_p - C_\phi| \rightarrow \min \quad (3.1)$$

$C_p$  - funds reserved for the financial period

$C_\phi$  - funds actually spent in the financial period

In our task of planning the reserve of financial resources for weather-dependent emergencies, the reserved funds are determined by the value of X-control solution (the optimal solution of the whole set of weather outcomes), and in fact the funds spent will be determined by the estimated value.

$$F(X) = |X - Z_p| \rightarrow \min \quad (3.2)$$

$Z_p$  - estimated value of emergency response costs for the financial year;

$X$ -tactical management decision on the amount of allocated (reserved) funds.

In order to make a decision on the amount of allocated funds, it is necessary to give an estimate of the cost for the future period (fiscal year). It is proposed to give an assessment on the basis of the accumulated statistical data and to estimate, as a mathematical expectation of costs, for each type of weather outcomes.

In a specific weather situation  $v_n$ , the economic effect  $X_i$  of a particular decision can be defined as:

$$E = / X_i - M(Z_v) / \quad (3.3)$$

$M(Z_v)$  - the expected costs of weather situation  $v_n$  ;

$X_i$  - management decision on the amount of allocated funds.

We also need to find a solution  $X_i$  that will be optimal for the whole set of annual weather outcomes. Therefore, the target function for finding a solution can be written as follows:

$$F(X) = \sum_{i=1}^m \sum_{v=1}^N / X_i - (M(Z_v)) / \cdot p_v \rightarrow \min \quad (3.4)$$

In order to make a decision on the amount of reserve funds, it is necessary to estimate the expected costs. And first of all, to highlight the possible number of weather outcomes. The possible number of outcomes of weather situations  $N$  is of course, and is considered for three cases: favorable, medium and unfavorable ( $v=1,2,3$ ), for them, the set of repetition frequencies is determined:

$$p_1, p_2, p_3 \text{ где } 0 \leq p_v \leq 1, \sum_{v=1}^N p_v = 1, N=3 \quad (3.5)$$

In order to determine the frequency of repetition, it is necessary to analyze the accumulated statistical data on the cost  $Z$ . To determine the frequency of annual weather outcomes ( $N$ ) is determined by the interval estimation of the mathematical expectation of costs  $[M_1(Z); M_2(Z)]$ . If the costs of emergency response fall within the interval, the annual outcome is considered to be average, if the cost value is below the lower limit of the interval - the annual outcome is considered favorable, if above the upper limit of the interval - unfavorable. Mathematically, we write it this way:

$$Z > M_2(Z) \text{ - adverse weather situation}$$

$$M_1(Z) \leq Z \leq M_2(Z) \text{ - average weather situation}$$

$$Z < M_1(Z) \text{ - favorable weather situation}$$

Mathematically, in General, we write down our problem of determining the optimal, in view of the weather-economic risk, management decision to determine the amount of reserve for the elimination of weather-dependent emergencies as follows:

$$F(X) = \sum_{i=1}^m \sum_{v=1}^N / X_i - (M(Z_v)) / \cdot p_v \rightarrow \min \quad (3.6)$$

$$i = \overline{1, m}$$

$$X_i \geq 0$$

$$X_i \leq b$$

$$\sum_{v=1}^N p_v = 1$$

$m$  - medium-term planning period;

$X_i \leq b$  - the limit of the regional budget;

$M(Z_v)$  - the mathematical expectation of costs in the model of the weather situation;

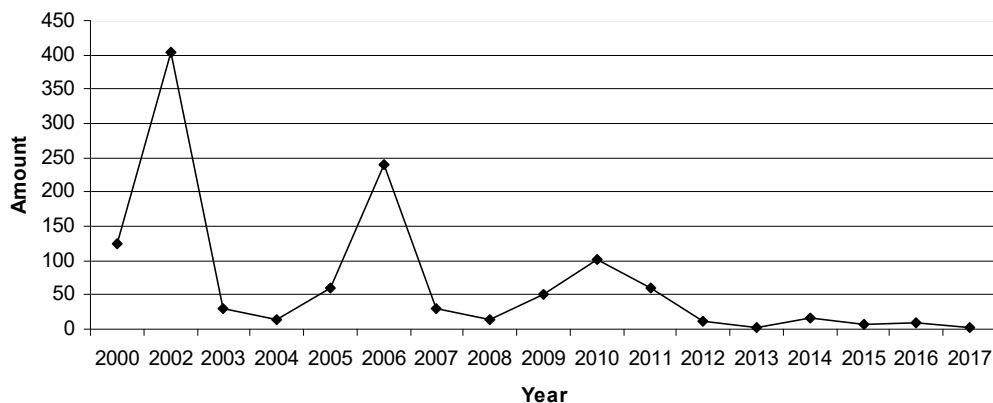
$X_i$  - the required management decision on the amount of funds allocated for the reserva-

tion for the elimination of natural disasters (for the financial year), will be the best management decision, the optimal set of annual weather conditions.

Having solved the problem 3.6 for each type of natural emergency, it is possible to find all the optimal set of weather management solutions, and to determine the total amount of financial resources for the period of medium-term planning years.

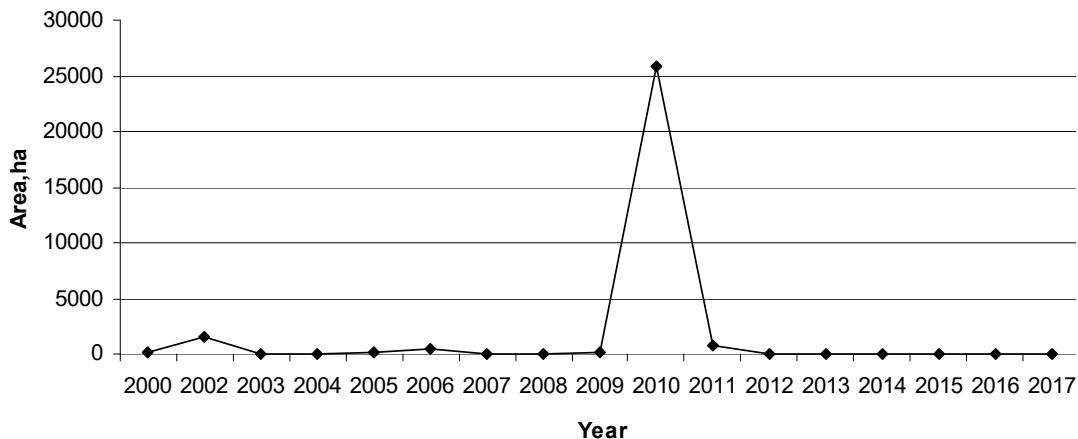
### 3. APPROBATION AND RESULTS OF THE STUDY

The developed model was tested on the statistical data of the Ivanovo region of Russia. Due to the lack of official data for the 30-year period, 15-year observations were used. Figure 1 shows the dynamics of forest fires in the Ivanovo region in the number of cases from 2000 to 2015. Figure 2 shows the dynamics of forest fires in the Ivanovo region in the area of forest fire in the period 2000-2015.



**Figure 1.** Dynamics of forest fires in the Ivanovo region in the number of cases, 2000-2015

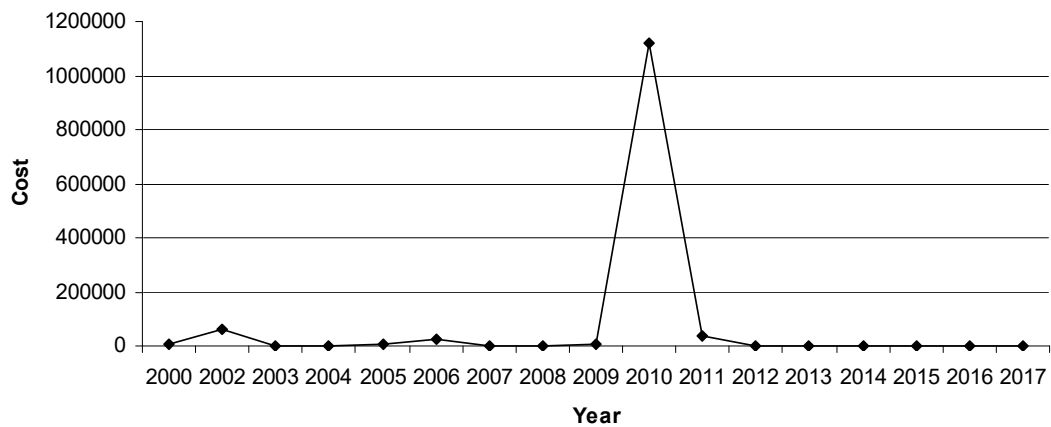
Source: Compiled by the author according to the statistical source (Rosstat. Key indicators of environmental protection [Electronic resource]. - Mode of access: [http://www.gks.ru/wps/wcm/connect/rosstat\\_main/rosstat/RU/statistics/publications/catalog/doc\\_1140094699578](http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/RU/statistics/publications/catalog/doc_1140094699578) (accessed 10.04.2017)).



**Figure 2.** Dynamics of forest fires in the Ivanovo region in the area of fire, 2000-2015

Source: Compiled by the author according to the statistical source (Rosstat. Key indicators of environmental protection [Electronic resource]. - Mode of access: [http://www.gks.ru/wps/wcm/connect/rosstat\\_main/rosstat/EN/statistics/publications/catalog/doc\\_1140094699578](http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/EN/statistics/publications/catalog/doc_1140094699578) (accessed 10.04.2017))

The dynamics of costs for the elimination of forest fires of the Ivanovo region will be presented in figure 3.



**Figure. 3.** Dynamics of costs for the elimination of forest fires of the Ivanovo region

Source: Compiled by the author according to the statistical source (Rosstat. Key indicators of environmental protection [Electronic resource]. - Mode of access: [http://www.gks.ru/wps/wcm/connect/rosstat\\_main/rosstat/EN/statistics/publications/catalog/doc\\_1140094699578](http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/EN/statistics/publications/catalog/doc_1140094699578) (accessed 10.04.2017))

Annual outcomes of weather situations of the Ivanovo region are defined in table 2. In relation to the number of years of each outcome to the total number of years of the period, determine the relative frequencies for each group of years ( ) (table 3).

**Table 2.** Annual outcomes of weather situations of the Ivanovo region for 2000-2015 g.

The year	the Annual weather situation
2001	average
2002	adverse
2003	adverse
2004	favorable
2005	favorable
2006	favorable
2007	average
2008	average
2009	average
2010	adverse
2011	average
2012	average
2013	average
2014	average
2015	average

Source: Compiled by the author based on the analysis of statistical literature (Rosstat. Key indicators of environmental protection [Electronic resource]. - Access mode: [http://www.gks.ru/wps/wcm/connect/rosstat\\_main/rosstat/ru/statistics/publications/catalog/doc\\_114004699578](http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/publications/catalog/doc_114004699578) (accessed 10.04.2017.)

**Table 3.** Relative frequencies of weather situations of Ivanovo region (2000-2015.d.)

Frequency ( $P$ )	Situation ( $V$ )
0,2	adverse ( $V_1$ )
0,6	average ( $V_2$ )
0,2	favorable ( $V_3$ )

Source: compiled by the author based on the analysis of statistical literature (Rosstat. Key indicators of environmental protection [Electronic resource]. - Access mode: [http://www.gks.ru/wps/wcm/connect/rosstat\\_main/rosstat\\_main/statistics/publications/catalog/doc\\_114004699578](http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat_main/statistics/publications/catalog/doc_114004699578) (accessed 10.04.2017.)

Having solved the problem (3.6) for the investigated type of natural emergencies, it is possible to find such an optimal set of weather conditions, management decision, and to determine the total amount of financial resources for the period of medium-term planning years.

The mathematical expectation of costs and their interval estimates for the elimination of emergencies of the Ivanovo region (wildfires) for each group of years are given in table 4.

**Table 4.** Mathematical expectation of costs for emergency response for each group of years

$M(v_1)$	$M(v_2)$	$M(v_3)$
61,34667	21,72889	8,583333
<i>Lower limit</i>		
55,67357	19,45908	6,143008
<i>Upper limit</i>		
67,01977	23,99869	11,02366

Source: compiled by the author based on the analysis of statistical literature (Rosstat. Key indicators of environmental protection [Electronic resource]. - Access mode: [http://www.gks.ru/wps/wcm/connect/rosstat\\_main/rosstat\\_main/statistics/publications/catalog/doc\\_114004699578](http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat_main/statistics/publications/catalog/doc_114004699578) (accessed 10.04.2017.)

The mathematical expectation of the effect will be determined according to the economic and mathematical model (3.6), with the calculated indicators of the relative frequencies of repetition of typical weather situations (table.3) and the mathematical expectation of costs for each typical weather situation (table. 4).

## CONCLUSION

We can find the optimum of the desired function, under given constraints and calculated parameters for the Ivanovo region. According to the simulation results, the optimal, due to the minimum weather and economic risk, the entire set of weather conditions, the management decision on the amount of funds allocated for the elimination of natural fires of the Ivanovo region will be the decision to reserve: minimum 100 720.00 thousand rubles. maximum 126 010.00 thousand rubles. (optimal value 113 036, 00 thousand rubles. RUB.) to the financial reserve of the regional budget for the elimination of forest fires for the next planning period – 5 years, the expenditure of

which in each specific year will be best if the distribution will correspond to the probabilities of weather situations from the table. 3.

The model was tested on 5 regions of the Central Federal District of Russia. The model is workable and acceptable. The model can be applied to other regions of Russia. To regions with similar weather conditions. The model may be relevant for European regions with the problem of wildfires. The analysis of the results obtained on the basis of statistically processed data and the data obtained through the application of the developed model shows that the model works for different regions. Therefore, the developed model opens up great prospects for the use of the model for managerial decision-making (about the size of the allocated and reserved funds in the budget of a constituent entity of the Russian Federation) in different regions of Europe at risk of natural disasters.

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