Risk management of forest fire occurrence

V N Petrov¹, T E Katkova¹*, E V Vinogradova²

¹ Department of Forest Policy, Economics and Management, Institute on Management and Economics of Forest Sector, St. Petersburg State Forest-Technical University, 5 Institutskiy Lane, St. Petersburg 194021, Russian Federation
² Department of Foreign Languages, Faculty of Fundamentals and Humanities, Federal State Budgetary Educational Institution of Higher Education “Saint-Petersburg Mining University”, 83 Maliy V.O. Avenue, St. Petersburg 197136, Russian Federation

*Corresponding email: tatianakat@mail.ru

Abstract. This academic paper is devoted to the issue of how to reduce forest fire damage through affecting the fire causes. Forest fire causes are a subject of random probability. Adequate forest management is not possible when there is lack of precise information about when and where a forest fire may occur. When there are no ways and methods to influence the reasons of forest fires occurrence, the likelihood of a wrong decision is directly proportional to the negative consequences of forest fires. The research purpose was to develop mechanisms of risk management taking into account the cause and effect relation between human activities, natural phenomena and occurrence of forest fire. The risk as economic category is the target of the research. The scope of the research encompasses the process of decision-taking in forest management with regards to forest preservation from fires under the conditions of unpredictability. The research was based on a comprehensive approach to the problem and used contemporary regulations of sustainable forest management and global experience in forestry relationship. It was suggested to classify the causes of forest fires in groups. Probability of forest fires occurrence was estimated in accordance with various causes. There was introduced an approach of forest fire risk management based on strategic risk management. The results of the research can be used by scientific institutions, as well as by forestry companies while planning environmental protection measures. The research can proceed towards assessment and forecasting of fire risks in forestry at the national and international levels.

1. Introduction

Forest fire is a natural phenomenon completely or partially destroying forest ecosystem at an unrestricted area, which leads to inevitable negative economic, ecological and social consequences.

Thinking pattern and attitude have shifted from treating a forest as economic resource to considering it as forest ecosystem.

Due to this reason this tendency makes many high forest cover countries take a fresh look at the problem of conservation of forests focusing on the environmentalization of the forest legislation and ecological education of the young generation.

Precise comprehensive information about possible reasons of the forest fires and their consequences plays an important role in the forest management.
The approaches to the practical arrangement of the forest protection from fires existing in different countries were repeatedly reconsidered [1-4].

Vast experience is accumulated with regards to the methods and technologies of preventive and repressive fire-fighting measures [5-7].

Some scientists admit that forest fires are indispensable in the evolution process of the forest ecosystems [4, 8].

The concept of controlled forest fire is developing [4, 9, 10].

In this paper, it is attempted to substantiate the methodological approaches aimed at the prevention of the forest fires causes basing on the social and economic strategic risk management.

2. Research Methods

Theoretical basis of the research includes works of Russian and foreign scientists concerning the issues of forest protection from fires, risk management, legislation acts controlling forestry relations with regards to the forest protection from fires.

The informational basis for the analysis and eduction of forest fire tendency comprises data of the Federal State Statistics Service, national reports on the environment condition, scientists’ reports, scientific publications, reference books, records of the Federal Forestry Agency and further sources.

The research is based on the application of the comprehensive approach to the problem being considered. During the research, such methods as abstract-logical, statistical, economic and mathematical methods were used as well as the technique of research material visualization in the form of tables.

In order to process information, the Microsoft Excel software was used.

3. Results and Discussion

3.1. Data analysis on the forest fire occurrence in Russia

Geographical area of the research is restricted to the forests growing on the territory of Russia. Forest lands amount to 67% of the total area of Russia.

In the Russian Federation there are three following options of forest protection from fires:

- the first one is ground-based protection zone which covers 4.4% of the forest lands area (48261.4 thousand hectares),
- the second one is aerial protection zone – 45.2% of the forest lands area (501176 thousand hectares),
- finally, there is space monitoring and extinguishing zone of level 1 – 19.4% of the forest lands area (215465 thousand hectares),
- and space monitoring zone of level 2 – 31% of the forest lands area (343222.5 thousand hectares).

The dynamics of the forest fires amount, their area and the losses of standing timber in Russia over a long-term period are represented in table 1.

According to table 1, one can see that after the Forest Code of the Russian Federation was accepted in 2006 there was registered a negative tendency in the forest protection from fires: area of the forested lands subjected to fires increased by a factor of 1.7 and the average annual area of one fire has increased threefold.

According to the data of the Federal Forest Agency over a long-term period, only 14% of the forest fires are triggered by the natural causes, the rest of the cases are caused by human activity.

Increase of the economic damage caused by the forest fires in Russia indicates that it is necessary to improve forest management in terms of protection from fires.

Relying on the concept when the forest fires are considered to be a naturally occurring phenomenon as part of the evolution process of the ecosystem, the maximum admissible area of one forest fire in a specified region might be deduced.

However, it would be very difficult to make such a deduction as the main cause of the forest fires is human activity.
Table 1. The dynamics of the forest fires amount, forest fires area, losses of standing volume in Russia over a period of 1992 – 2017.

| Year   | Amount of forest fires, thousand cases | Forest lands subjected to fires, thousand ha | Average forest fire area, ha | Losses of standing timber, million m³ |
|--------|---------------------------------------|-----------------------------------------------|------------------------------|-------------------------------------|
| 1992   | 25.8                                  | 691.5                                         | 26.8                         | 11.1                                |
| 1993   | 18.4                                  | 748.6                                         | 40.7                         | 22.3                                |
| 1994   | 20.3                                  | 536.8                                         | 26.4                         | 10.2                                |
| 1995   | 26.0                                  | 360.1                                         | 13.9                         | 8.5                                 |
| 1996   | 32.8                                  | 1853.5                                        | 56.5                         | 55.9                                |
| 1997   | 31.3                                  | 726.7                                         | 23.2                         | n/a*                                |
| 1998   | 28.0                                  | 4268.8                                        | 152.5                        | n/a*                                |
| 1999   | 36.6                                  | 751.7                                         | 20.5                         | n/a*                                |
| 2000   | 22.4                                  | 1328.6                                        | 59.3                         | 39.6                                |
| 2001   | 23.7                                  | 896.8                                         | 37.8                         | n/a*                                |
| 2002   | 43.4                                  | 1369.5                                        | 31.6                         | n/a*                                |
| 2003   | 33.0                                  | 2352.8                                        | 71.3                         | n/a*                                |
| 2004   | 27.2                                  | 543.3                                         | 20.0                         | n/a*                                |
| 2005   | 19.2                                  | 845.3                                         | 44.0                         | 12.3                                |
| 2006   | 32.5                                  | 1493.5                                        | 46.0                         | 34.5                                |
| Average value over 1992-2006 | 28.0                                  | 1251.2                                        | 44.7                         | 24.3                                |

| Year   | Amount of forest fires, thousand cases | Forest lands subjected to fires, thousand ha | Average forest fire area, ha | Losses of standing timber, million m³ |
|--------|---------------------------------------|-----------------------------------------------|------------------------------|-------------------------------------|
| 2007   | 17.8                                  | 1036.1                                        | 58.2                         | 16.5                                |
| 2008   | 26.3                                  | 2069.8                                        | 78.7                         | 30.1                                |
| 2009   | 23.2                                  | 2111.6                                        | 91.0                         | 25.4                                |
| 2010   | 34.8                                  | 2027.8                                        | 58.3                         | 93.4                                |
| 2011   | 21.1                                  | 1408.4                                        | 66.8                         | 28.6                                |
| 2012   | 20.2                                  | 2101.2                                        | 104.0                        | 63.1                                |
| 2013   | 10.0                                  | 1158.0                                        | 115.8                        | 15.6                                |
| 2014   | 16.9                                  | 3190.7                                        | 188.8                        | 39.7                                |
| 2015   | 12.3                                  | 2748.9                                        | 223.5                        | 37.5                                |
| 2016   | 11.0                                  | 2508.3                                        | 228.0                        | 28.9                                |
| 2017   | 10.9                                  | 3282.1                                        | 301.1                        | 51.9                                |
| Average value over 2007-2017 | 18.6                                  | 2149.4                                        | 137.7                        | 39.2                                |
| Average value over 1992-2017 | 24.0                                  | 1631.2                                        | 84.0                         | 32.9                                |

* no data

b- compiled by the authors according to the data [11; 12].

Thus, our research focuses on the detection and prevention of the fires caused by the anthropogenic activities with allowance for natural causes.

3.2. Improvement of forest fires risk management

It is a well-known fact that for a forest fire to start there should be some combustible material and a fire source as well as some conditions for the combustible material and the fire source to interact. Our research considers conditions under which the combustible material and the source of fire interact. The interaction depends on many reasons. Among the main reasons are the administrative (forest management in terms of protection from fires) and cultural (behaviour of society and its attitude towards nature).
Basing on a long-term analysis of the amount of forest fires in Russia, causes of the forest fires were grouped, the occurrence probability of the forest fires was estimated with regards to different causes. Table 2 represents the results.

Average probability of the forest fire occurrence was calculated on the ground of the data of the Federal Forest Agency over the period of 37 years (1981-2017).

Table 2. Input information that was used to form the risk management system of forest fires occurrence

| No. | Groups of forest fires causes          | Average probability of forest fires, % | Risk management method                          | Risk management strategy                          |
|-----|----------------------------------------|----------------------------------------|-------------------------------------------------|--------------------------------------------------|
| 1.  | Anthropogenic causes                   |                                        |                                                 |                                                  |
| 1.1 | Careless handling of fire by the population | 56.95                                 | Methods of propaganda of knowledge              | Strategy of preventive impact on the risks       |
| 1.2 | Harvesting and logging residue burning | 0.42                                   | About forests and promoting public awareness    |                                                  |
| 1.3 | Timber contractors                     | 1.14                                   |                                                 | Strategy of preventive impact on the risks       |
| 1.4 | Uncontrolled agricultural burning in spring and in autumn | 6.50                                   |                                                 |                                                  |
| 1.5 | Activities of expeditions              | 0.47                                   |                                                 |                                                  |
| 1.6 | Activities of other organizations      | 0.05                                   |                                                 |                                                  |
| 2.  | Technology-related causes              |                                        |                                                 |                                                  |
| 2.1 | Railway transport                       | 1.09                                   | Organizational (administrative) methods         | Strategy of preventive impact on the risks       |
| 2.2 | Infrastructure lines                   | 0.07                                   |                                                 |                                                  |
| 3.  | Natural causes                         |                                        |                                                 |                                                  |
| 3.1 | Thunderstorm                           | 14.33                                  | Uncontrollable                                 | Strategy of risk acceptance                      |
| 4.  | Undetermined reasons                   | 18.98                                  | Uncontrollable                                 | Strategy of subsequent impact on the risks       |

*a-calculated by the authors according to the data [13]

The forest fires grouping can become a useful tool in forecasting the risks of forest fires due to various causes and in reducing the fire damage.

Table 2 shows the recommended methods and strategies of risk management depending on the causes of forest fires.

The authors of this article suggest an approach to risks management of forest fires occurrence. According to this approach, it is necessary to pay attention to the cause and effect relation and to deal with the causes of fires while arranging the forest protection activities.

At the same time it is necessary to endeavor not to the total elimination of the forest fires but to the averagely admissible area of the forest fires depending on the region.

In practice, currently the forest fire protection is based on the fight with consequences of forest fires rather than with their causes.

Unfortunately, they mostly use repressive and compensatory methods in Russia nowadays. To our opinion, among the basic methods in the Russian forestry there should be a method aimed at reduction of the forest fire risk.
Sometimes it is considered that forest fires are an indispensible factor of the forest ecosystem evolution. In this case, the strategy of risk acceptance is relevant as it does not imply any special activities regarding risks of forest fires occurrence due to natural causes.

Undetermined causes of the forest fires indicate that there are drawbacks in the work of the forest fire-fighting service.

In case fires occur due to some undetermined reasons, it is recommended to use the strategy of subsequent impact on the risks. Such strategy is elaborated in order to create conditions to reduce (minimize) the impact of consequences after the risk event has occurred.

In order to reduce risks of forest fire occurrence due to the technology-related causes, it is practicable to organize preventive fire-fighting measures which imply elimination of risks caused by technology-related reasons.

As the forest fires are mostly caused by the anthropogenic factors, the most effective strategy is the preventive one. This strategy implies prevention of risks aimed at creation of conditions under which the occurrence of anthropogenic risks is eliminated through social and psychological methods of risk management.

Forestry fire-fighting propaganda can be effectively implemented as a socially psychological method. In such case the ecological culture of the population is increased as well as ecological behavior and awareness of the young generation as they are extremely important factors of the sustainable development of the society.

The department of the forest policy, economics and management of the Saint Petersburg State Forest Technical University implements initiative project “Forest pedagogics” for the secondary school students. Within this project the following is carried out:

- preparation of special classes in forest pedagogics for school students and for teachers;
- specialized issue-related presentations;
- demonstration of IT-technologies that control the system of forest protection from fires remotely;
- preparation of reference information with scientific content on forest pedagogics for students and teachers;
- arrangement of thematic school conferences.

Development of such projects is relevant as it helps to form ecological culture of young generation and to enhance their responsibility to the nature.

Risk management methods are interrelated; hence their comprehensive application makes it possible to achieve the purpose of successful risk management in terms of forest fire.

4. Conclusion
Preservation of forest resources depends on the human culture. Currently, relations between society and natural environment have got to a whole new level. The essence of these relations is that protection of natural environment and protection of forest ecosystems in particular are among the top-priority tasks of the humanity.

Forest fire risks depend on the natural, technology-related, anthropogenic and undetermined (other) reasons, so they represent a multivariable function for the region and the whole territory.

Fire risk management with regards to forestry implies that through treating all the factors and causes it is necessary to reduce the risks to the admissible level, to aim at averagely admissible area of the forest fires depending on the region.

Most of the fires are caused by humans. This fact indicates that the fire-fighting propaganda of the governmental bodies and preventive fire-fighting activities are ineffective as well as that the level of civil forest ethics is low.

The fact that the forest fires occur because of forest users shows that their corporate ethics is not at a high level. Furthermore, it indicates that the forest users have no economic incentive to carry out preventive fire-fighting works and activities at the forest territories that the government (the actual owner of the forests) has assigned to them for use.
Such issues as teaching people to behave properly in forest, to comply conscientiously with the fire safety rules in forest, to participate actively in the forest protection are paid insufficient attention to.

This gap can be filled by the forest pedagogics. Ecological education and environmental awareness of the population, who causes most of the forest fires, is becoming the foundation on the way to the balance between the society interests and the environment protection.

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