

TERRITORIAL RISKS ASSESSMENT OF NATURAL HAZARDS

Ulyana Postnikova^{1,2}, Olga Taseiko^{1,3}, Maksim Anikin³

¹Federal Research Center for Information and Computational Technologies, Russia

²Siberian Federal University, Russia

³Reshetnev Siberian State University of Science and Technology, Russia

ulyana-ivanova@inbox.ru

Abstract

The socio-economic development of the territories is determined by the solution of state policy tasks, the effectiveness of the application of organizational and managerial practices, the prediction of possible dangerous events and the adoption of measures to reduce the risk of accidents and natural disasters. Modern trends in territorial administration are associated with the use of a risk-based approach. Information on the frequency of occurrence of adverse events can serve as a basis for identifying sources of various risks levels. The presence of an unstructured data array predetermines the need to create an interconnected system of risk factors. The purpose of the study is to analyze the vulnerability of the Krasnoyarsk region territories to hazardous natural phenomena. This paper analyzes floods and forest fires, which are the most typical natural hazards for the areas under consideration. To identify areas most prone to natural hazards, a ranking was carried out according to the level of risk using GIS technologies.

Keywords: risk-based approach, natural hazards, territorial management

I. Introduction

Improving the security of the territory (country, region, municipality) in the face of the possible implementation of natural and man-made disasters is one of the key tasks in the framework of sustainable development. Technogenic and natural emergencies are significant sources of danger and risk to the life of the population. Recently, the risk-based approach has been widely used in various fields of research. A significant number of works [1-8] are devoted to the issues of risk analysis. However, the currently existing regulatory and methodological base for the quantitative assessment of hazards requires significant additions, which is complicated by the difficulty of analyzing natural disasters. Effective territorial management should be based on determining the level of threats to life, the range of risk factors and their significance.

Floods are one of the most dangerous natural phenomena that occur as a result of changing weather conditions. Heavy rains, a large amount of snowfall are prerequisites for floods. The main cause of destruction is the impact on buildings and structures of hydraulic shocks of water masses, ice floes floating at high speed, various debris, watercraft, etc. [9]. In the region, floods are mainly caused by spring floods, high summer-autumn rain floods, high water levels during jam events, as well as flooding of the area due to the destruction of reservoir dams, rupture of dams [10]. According to the data of the Yenisei Basin Water Administration and the materials of state reports, more than 1,000 floods occurred on the territory of the Krasnoyarsk Territory from 1967 to 2021, in which more than 50 thousand people suffered.

In the Krasnoyarsk region, the problem associated with an intensive decrease in the area of the forest fund is especially acute. The reduction of the forest fund is one of the global environmental problems, which leads to additional threats associated with a decrease in biodiversity, weakening of water regulation and protective functions. The Krasnoyarsk region as one of the largest reserves of forest resources among the regions of Russia. The areas of weakened and dead stands increase annually under the influence of unfavorable factors. The main reason for the decrease in the stability of forest plantations of the region are fires and insect pests. According to official data, more than 280 thousand hectares of forest plantations have died in the Krasnoyarsk region over the past ten years [11].

In the work, an assessment was made of the risks of natural hazards, the most typical for all territorial entities of the Krasnoyarsk region - floods and the reduction of the forest fund (forest fires, insect pests and forest diseases).

II. Methods

Based on statistical data on the implementation of natural hazards (reduction of the forest fund or floods), a risk calculation was performed. The level of risk $R_i^{fo/fl}$ for the i -th ($i = \overline{1, \dots, 41}$) region depends on the value of damage $U_i^{fo/fl}$ [mln. rub] and the probability of occurrence of a hazardous event $P_i^{fo/fl}$ (1):

$$R_i^{fo/fl} = P_i^{fo/fl} \times U_i^{fo/fl} \quad (1)$$

The probability of reducing the forest P_{ij}^{fo} and was estimated as the ratio of the area damaged due to cause j on the i -th site to the total area of the forest fund on the territory of the region, taking into account the forest cover indicator::

$$P_{ij}^{fo} = \frac{S_{ij}}{S} \times L_i \quad (2)$$

where S_{ij} – the damaged area of the forest fund due to cause j in region i , S – the total area of the forest fund, L_i – the forest cover in the i -th region, $j=1$ – forest fires, $j=2$ – insect pests, $j=3$ – forest diseases.

To assess the likelihood of hydrological hazards P_{ik}^{fl} y cause of each event was taken into account:

$$P_{ik}^{fl} = \frac{n_{ik}}{N} \quad (3)$$

where n_{ik} – is the number of events of type k in region i , N – is the total number of events in the entire territory for the entire period under consideration, $k=1$ are snow floods, $k=2$ are rain floods, $k=3$ are jam floods.

Determination of damages from the consequences of natural hazards is one of the tasks that have not yet had an unambiguous solution. Thus, when assessing damage from floods, only the cost of destruction of buildings and structures is taken into account [12]:

$$U_{ik}^{fl} = C_{r,n} \times H_{ik} \times K_m \quad (4)$$

where $C_{r,ii}$ - is the average cost of the housing stock per 1 rural resident, H_{ij} - is the number of residents affected by destruction in the i -th district from the occurrence of a hazardous hydrological phenomenon due to k , K_m - is the degree of destruction / loss of the residual book value by zones: ($K_1= 0,8$ - destruction; $K_2=0,4$ - zone of medium destruction; $K_3=0,1$ - zone of weak destruction).

Forest fire damage assessment should take into account many factors, such as the value of burned objects and finished products in the forest, the cost of extinguishing fires, damage from air pollution. Due to limited initial data, when assessing damage U_{ij}^{fo} the costs of reforestation were taken into account in accordance with [13]:

$$U_{ij}^{fo} = C \times k_i / 100 \times F \quad (5)$$

where C - is the standard cost of growing plantings up to the age of crown closing, equal to 800 rubles/ha; k_{ij} - the percentage damage to the forest in the i -th plot due to j , F - the area of the forest fund in the entire territory under consideration that died or was damaged due to j .

To assess the complex natural risk, the following ratio is used:

$$R_c^{nr} = \sum_{j=1}^J R_j^{fo} + \sum_{k=1}^K R_k^{fl} \quad (6)$$

where R_j^{fo} - is the risk of reducing the forest fund from the causes of damage j , R_k^{fl} - the risk of dangerous hydrological phenomena by the factors of origin k .

III. Results

Despite the variety of reasons for the occurrence of hydrological hazards in the Krasnoyarsk region, the largest number of them are due to snow, jam and rain events (Table 1).

Table 1: Probability of floods by cause

Cause of occurrence:	Probability of an event:
Rain floods	0,076
Jamming floods	0,27
Snow floods	0,44
Mixed floods	0,05
Slope drain	0,017
Freezing of the stream	0,007
Dam break	0,003

Fig.1 presents risk maps of hazardous hydrological phenomena for the territories of the Krasnoyarsk region for the most common causes of their occurrence.

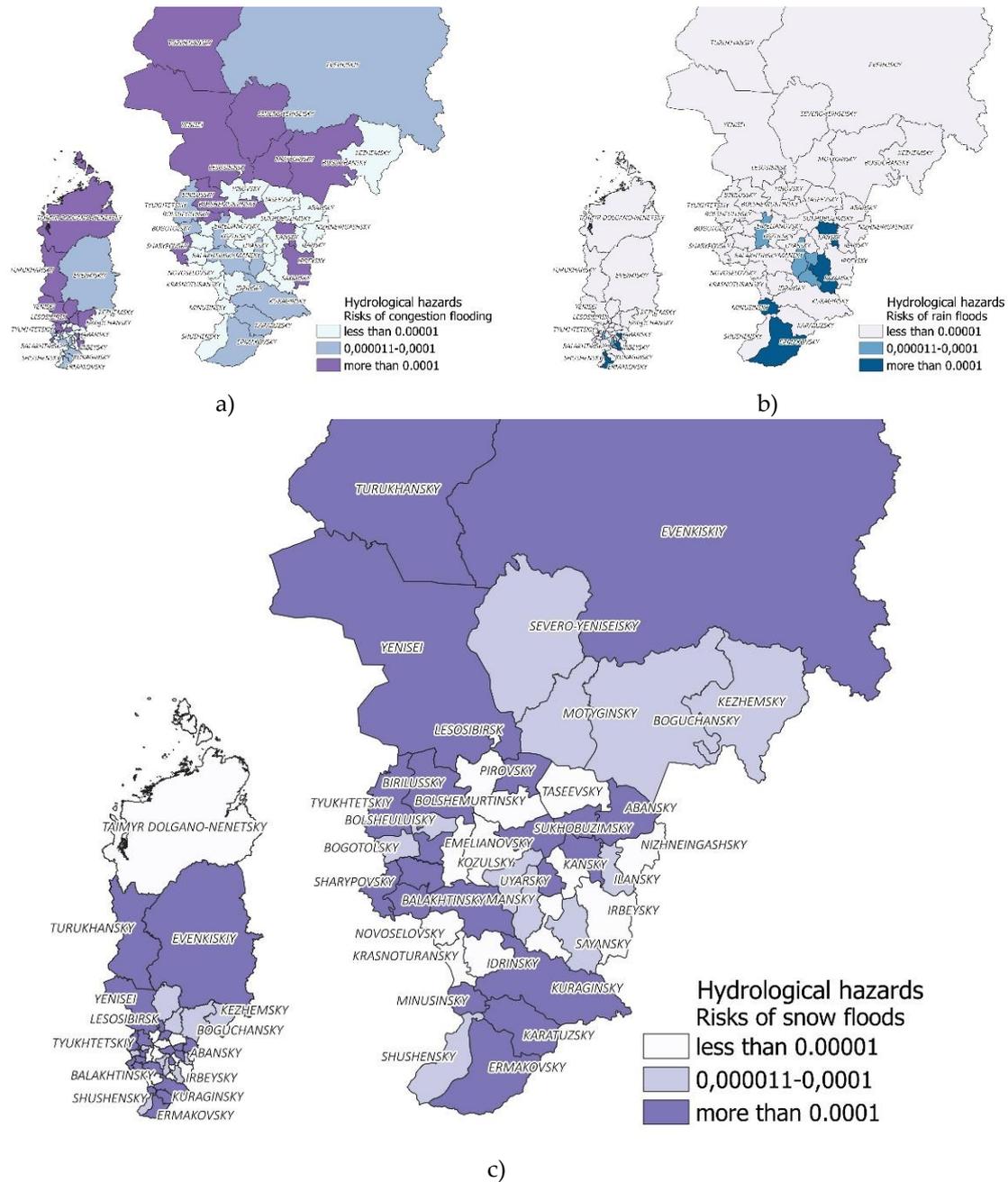


Fig. 1: Hydrological hazard risk maps (a - jamming floods, b - rain floods, c - snow floods)

Drawing up risk maps makes it possible to quantify the possible loss of life and material damage caused by the development of one or more hazardous processes. The greatest risk from hazardous hydrological phenomena, formed by jamming floods, was identified in Turukhansky, Taimyrsky Dolgano-Nenetsky and Yenisei regions, the greatest danger associated with rain floods is concentrated in Yermakovskiy, Minusinsk, Sayansky and Kansk regions, and the greatest risk of snow floods is in Nazarovskiy, Kuraginsk and Karatuz municipal districts (Fig. 1).

The paper presents an analysis of the reduction of the forest fund on the territory of the Krasnoyarsk Territory according to various factors (Table 2). Forest fires, insect pests, forest diseases have the greatest impact on the state of plantations and are one of the leading factors in the annual weakening and drying of forests.

Table 2: Probability of forest fund reduction by factors

Factors of reduction of the forest fund	Probability of an event
Forest fires	0,002
Damage by insect pests	0,003
Adverse weather conditions and soil-climatic factors	$9,8 \cdot 10^{-5}$
Diseases of the forest	0,0003
Anthropogenic factors	$8,7 \cdot 10^{-5}$
Non-pathogenic factors	0,00025

The territories of the Evenk, Yenisei, and Turukhansk regions are at the highest risk of forest fires (Fig. 2). The highest forest fire risk values were obtained for the territories of the Kezhemsky, Motyginsky, Severo-Yeniseisky and Boguchansky regions. The forests of the Balakhtinsky, Motyginsky, Ermakovsky and Kezhemsky districts are most prone to diseases forest The greatest danger associated with pests is concentrated in the Bolshemurtinsky, Balakhtinsky, Pirovsky and Irbeysky districts..

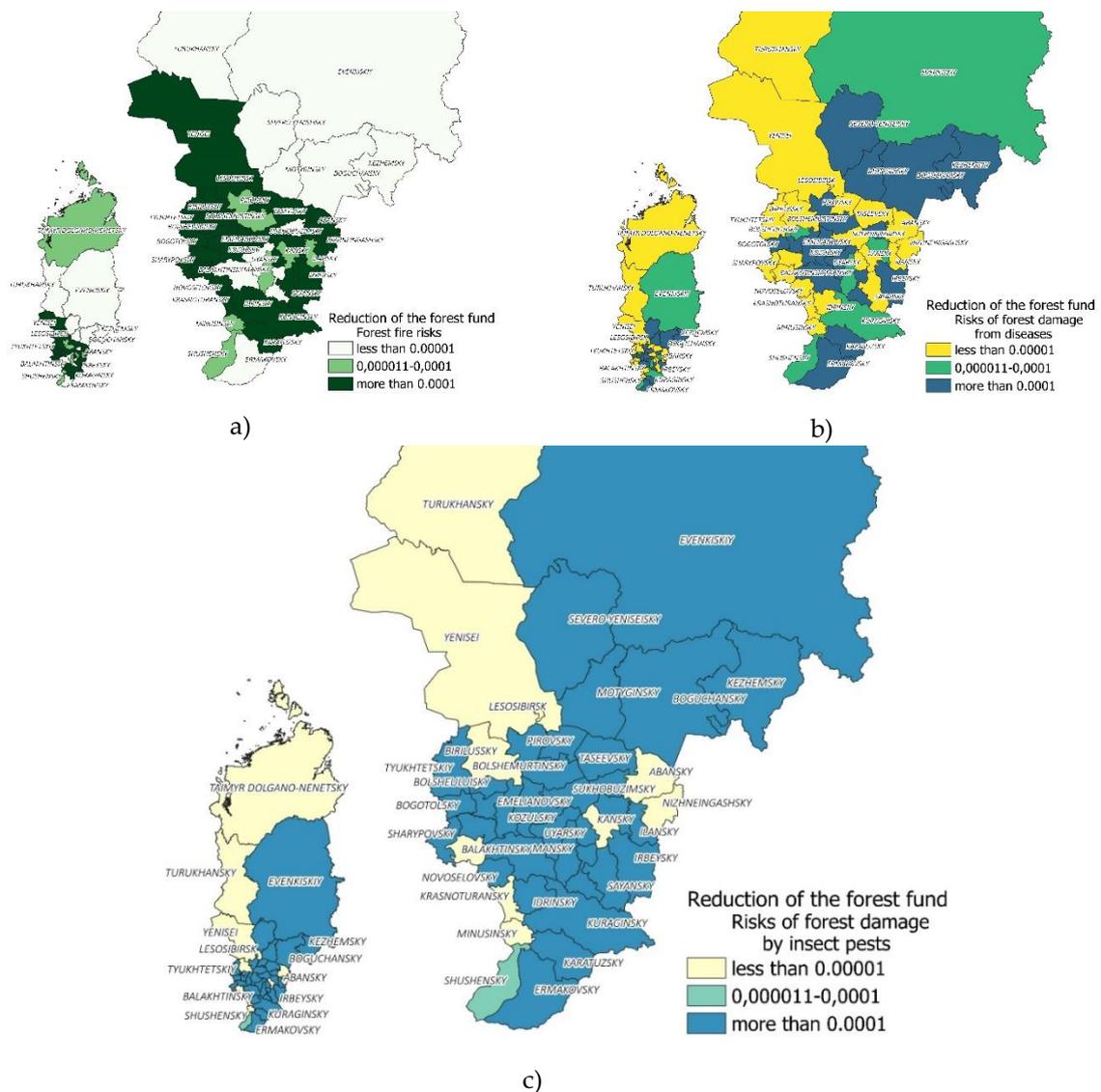


Fig. 2: Risk maps of forest fund reduction (a - forest fires, b - forest diseases, c - insect pests)

Based on the proposed model for assessing the complex natural risk (formula 6), territorial formations with a high level of danger were identified (Fig. 3).

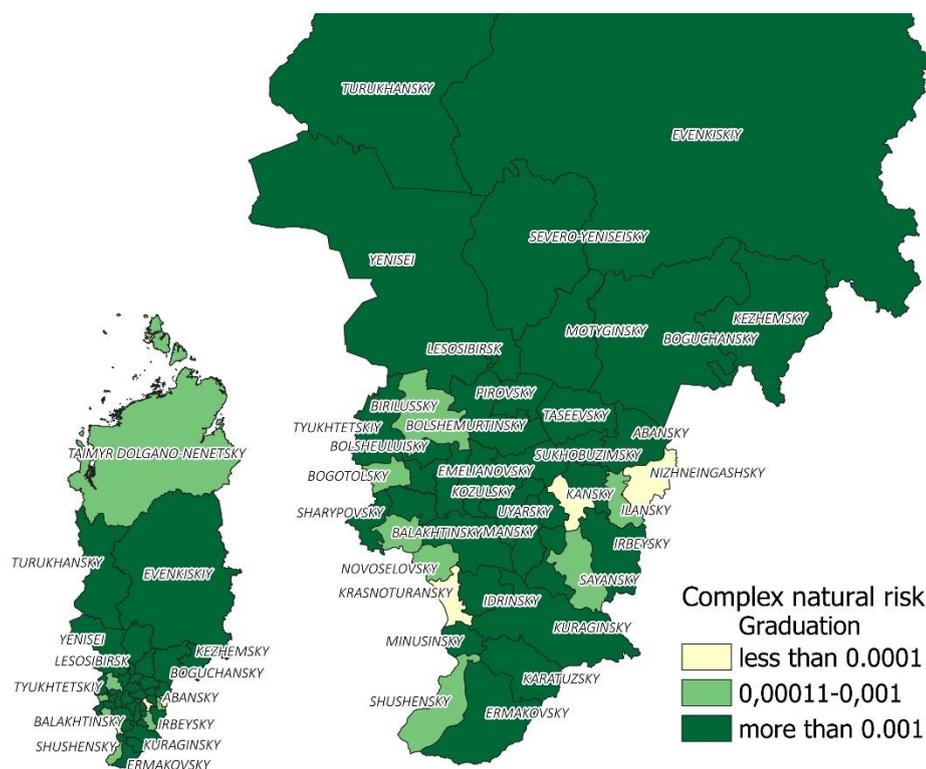


Fig. 3: Complex natural risk map

Probabilistic assessments of the risks of hazardous natural phenomena make it possible to predict the occurrence of such phenomena in the future, which can be the basis for an economically feasible increase in the protection of territories. Although a reduction, if not in the number, then at least in the extent of flooding, can be achieved to some extent by reforestation efforts.

IV. Discussion

The analysis of natural hazards is an important component in the prevention and reduction of possible negative consequences for the population, economy and infrastructure. The assessment of natural risks is important for the protection of the population, the conservation of natural resources, the development of infrastructure and the economy. The social and economic security of the Krasnoyarsk region as a whole directly depends on effective management based on risk assessment.

References

- [1] Assessment and management of natural risks // Materials of the All-Russian conference "Risk-2000". – M.: Ankil, 2000. – 478 p.
- [2] Makhutov N.A., Petrov V.P., Akhmetkhanov R.S. Natural-technogenic-social systems and risks // Problems of safety and emergency situations. 2004. No. 3. pp. 3-28.
- [3] Akimov V.A., Oltyan I.Yu., Ivanova E.O. Methodology for ranking emergency situations of natural, man-made and biological-social nature according to the degree of their catastrophism // Technologies of civil security. 2021. Vol. 18. No. 1 (67). pp. 4-7.

[4] Faleev M.I., Oltyan I.Yu., Arefyeva E.V., Bolgov M.V. Methodology and technology of remote risk assessment // Problems of risk analysis. 2018. Vol. 15. No. 4. pp. 6-19.

[5] Oltyan I.Yu., Arefyeva E.V., Krapukhin V.V., Vereskun A.V., Kotosonova M.N., Baler M.A. Re-implementation of the Sendai Framework Program for Disaster Risk Reduction in the Russian Federation // Publishing House: All-Russian Research Institute on Civil Defense and Emergency Situations of the Ministry of Emergency Situations of Russia. Results of the fifth year (Moscow). Moscow, 2021. 344 p.

[6] Artyukhin V.V., Arefyeva E.V., Vereskun A.V., Morozova O.A., Posokhov N.N., Sosunov I.V., Oltyan I.Yu., Chyasnavičius Yu.K., Gutarev S.V., Leonova E.M., Leonova A.N., Bryk D.I., Zhukova L.A. Risk management of man-made disasters and natural disasters (manual for heads of organizations) // Under the general editorship of M.I. Faleev. Moscow, 2016. 270 p.

[7] Anisimova T.B. Plotnikova T.V. Atlas of natural and man-made hazards and risks of emergency situations in the Russian Federation (ed. Shoigu S.K.), M. 2004. – 272 p.

[8] Postnikova U., Taseiko O., Efremova I. Assessment of territorial man-caused risks in the Arctic territories using probabilistic-graphic models. Reliability: Theory and Applications. Special Issue № 4 (70). 2022. Vol. 17. P 207–211.

[9] The scale and danger of floods in the Siberian regions // Cyberleninka URL: <https://cyberleninka.ru/article/n/masshtaby-i-opasnost-navodneniy-v-sibirskom-regione-rossii/viewer> (accessed: 04/01/2023).

[10] Floods in the history of the Krasnoyarsk Territory // Website of the Yenisei district URL: [https://enadm.ru/uploads/prevention/public_safety / FloodshistoryKrasnoyarsk.pdf](https://enadm.ru/uploads/prevention/public_safety/FloodshistoryKrasnoyarsk.pdf) (date of issue: 15.06.2023).

[11] Overview of the sanitary and forest pathology state of the forests of the Krasnoyarsk Territory for 2019 and forecast for 2020: Branch of the Federal State Institution "Roslesozashchita" "Forest Protection Center of the Krasnoyarsk Territory" : 355 p.

[12] RD 153-34.2-002-01, TEMPORARY METHODOLOGY FOR ASSESSING DAMAGE POSSIBLE AS A RESULT OF AN ACCIDENT OF A HYDRAULIC ENGINEERING STRUCTURE // Federal Service for Environmental, Technical and Nuclear Supervision URL: <http://enis.gosnadzor.ru/activity/control/hydro/Временная%20методика%20оценки%20ущерба,%20возможного%20вследствие%20аварии%20гидротехнического%20сооружения.pdf> (accessed: 15.06.2023).

[13] Rosleskhoz Order No. 53 dated 03.04.1998 "On approval of Instructions for determining damage caused by forest fires". URL: http://www.consultant.ru/document/cons_doc_LAW_31959/5f4bed452dc0105baf6db594cad944092e1e0587/ (accessed: 15.06.2023).