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Ability to use available electronic resources for modeling the development of forest fires

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Abstract. The article discusses various types of monitoring of forest fires, studied and analyzed satellites that are used by the space monitoring system of the Ministry of Emergency Situations of Russia for remote sensing of the Earth. The statistical data of the Forestry Department on forest fires over the past 15 years in the territory of the Voronezh region are given. The dependence of the number of forest fires on meteorological conditions, in particular on the amount of precipitation, wind gusts and air temperature, was studied using the example of 2010 and 2020. The municipalities that are most prone to forest fires are identified. The monitoring systems of the forest fire situation on the territory of the Voronezh region, which are used in the crisis management center of the Main Directorate of the Ministry of Emergency Situations of Russia for the Voronezh region, are analyzed. The program "Forest Fires" has also been developed to predict the spread of forest fires based on the Methodology for assessing the consequences of forest fires, developed by the All-Russian Research Institute of Civil Defense and Emergency Situations in 1994 and put into effect by the order of the Ministry of Emergency Situations of Russia dated 14.04.1995. No. 194. A comparative analysis of the solution of the same problem with the same initial data in the developed program "Forest Fires" and in the risk analysis and management system (SAUR) of the automated information control system of the unified state system for the prevention and elimination of emergencies (AIUS RSChS) is presented.

1 Introduction

Mankind is puzzled by the question of not only the timely detection of fires, but also the prediction of a fire hazardous situation. Therefore, the question of the relevance of this research topic does not make you think about yourself. The protection of forests and territories from fires is closely related to the most important task of the state policy of Russia in the field of national security. To be more precise, it is the speed of detection and the prompt organization of measures to prevent and eliminate emergencies and incidents that will contribute to the timely protection of the population and territories from natural and man-made emergencies [1]. All this becomes possible thanks to the constantly developing means of remote monitoring systems. At present, this issue is becoming more relevant than ever,

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since the number of natural disasters has recently increased, as a result of which a large number of people and animals suffer and die, huge environmental and economic damage is inflicted, buildings and structures that can bear historical damage are damaged value [2].

The frequency and destructive effect of forest fires are exacerbated by human activity, which is trying to subjugate nature. The anthropogenic contribution not only increases the probability of occurrence, but also the rate of spread of fire.

The object of the study is the monitoring of the forest fire situation in the territory of the Voronezh region.

According to the Decree of the Government of the Voronezh Region No. 116 dated 05.03.2022 “On Approval of the List of Settlements of the Voronezh Region Subject to the Threat of Forest and Other Landscape (Natural) Fires in 2022 and the List of Territories of Organizations for Recreation and Recreation of Children, Territories of Gardening or Horticulture of the Voronezh Region, exposed to the threat of forest fires in 2022” on the territory of the Voronezh region included 847 settlements, 35 children's recreation and recreation organizations, 93 gardening or horticulture, which are subject to the threat of forest and other landscape (natural) fires [3].

In terms of forest area on the territory of the Voronezh region, they occupy:

on the lands of the forest fund - 476.173 thousand hectares;

on the lands of the Ministry of Defense of the Russian Federation - 2.1 thousand hectares;

on the lands of specially protected natural areas of federal significance - 33.9 thousand hectares;

on the lands of settlements - 0.1 thousand hectares;

on lands of other categories - 0.7 thousand hectares.

The primary cause of forest fires has been and remains the human factor. More than 90% of fires occur in places of residence and human activity.

Most forest fires will occur near large settlements and in recreational areas. The largest forest fires most often occur between July and September [4-5].

2 Model and method

Statistical data on forest and landscape (natural) fires over the past 15 years (2007-2022) on the territory of the region allow us to trace the following pattern: on average, about 45 fires are recorded during the forest fire period, on a total area of 572.8 ha, the maximum number of forest fires fall in August (an average long-term number is 9 forest fires) and September (an average number is 14 forest fires) [6-7].

According to the statistics of the Forestry Department of the Voronezh Region, the maximum number of forest fires in the region over the past 15 years was recorded in 2008 and amounted to 1408 fires (Figure 1), the minimum - in 2016 - 7 fires.

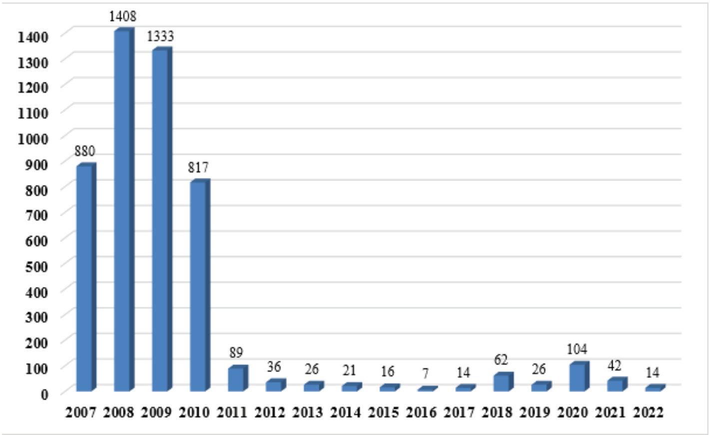

Fig. 1. Statistics of forest fires over the past 15 years in the Voronezh region.

However, regardless of the fact that the largest number of forest fires was in 2008, their total area was not so large and amounted to 1530 hectares. However, in 2010, due to meteorological conditions favorable for the emergence and rapid spread of forest fires, their area was significantly higher and amounted to 18174.85 ha (Figure 2).

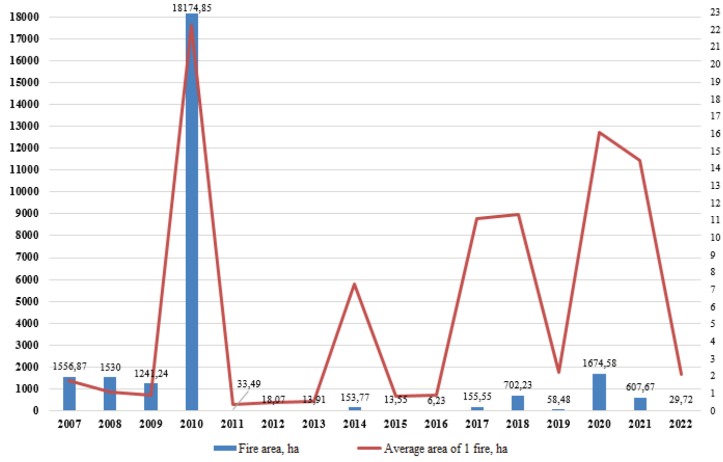

Fig. 2. Distribution of the area of forest fires over the past 15 years in the territory of the Voronezh region.

One of the conditions for the occurrence of a forest fire and its rapid spread are meteorological conditions that contribute to the dry period. Under conditions of rainfall deficiency and high temperature conditions in forests with increased fire danger (mainly pine), large forest fires (over 25 ha) are likely to occur [8-9].

The reason for the increase in the area of forest fires in 2010 and 2020 was a dry summer combined with strong gusty winds and high air temperatures.

3 Research and results

Based on the analysis of daily meteorological observations, the following pattern was revealed: dry weather was established in 2010 and 2020, with a minimum amount of precipitation and strong gusts of wind. And these are just favorable conditions for the rapid spread of forest fire.

The greatest risk of fires occurs near large settlements, highways and in recreational areas. According to the average statistical data, the highest probability of forest fires occurrence exists in the city district of Voronezh, Borisoglebsk urban district, Bobrovsky, Liskinsky, Novousmansky and Novokhopersky municipal districts (Figure 3).

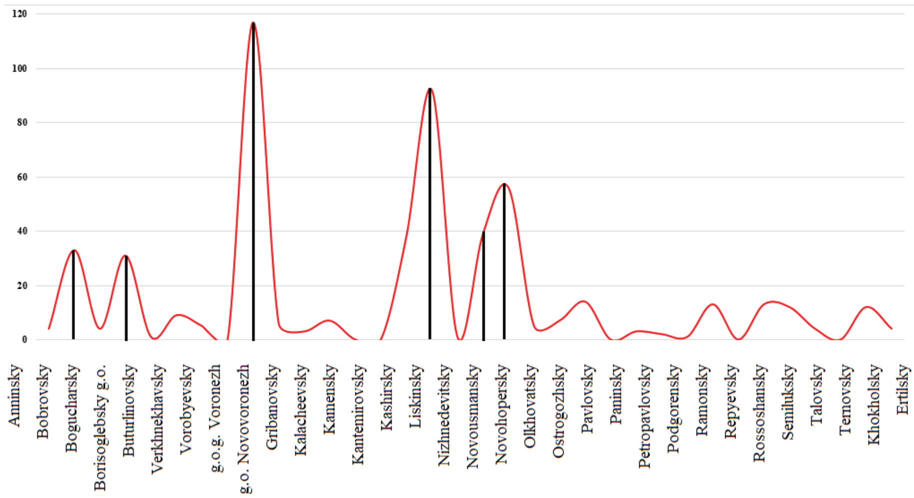

Fig. 3. The municipalities of the Voronezh region most prone to forest fires.

The probability of occurrence of large forest fires with high and extreme fire danger is predicted to be within 0.6-0.7.

To monitor the forest fire situation on the territory of the Voronezh region, the following information resources are used, access to which is available at the Central Control Center of the Main Directorate of the Ministry of Emergency Situations of Russia for the Voronezh Region:

- Hardware-software complex (hereinafter referred to as HSS) "Forester

"Lesozhranitel" is a video surveillance system that transmits information to the server using special software. PAK is considered a geographic information system, since there is a direct link to the coordinates. All received data is stored on servers that analyze, process and store it [10-12].

- SCM EMERCOM of Russia

According to the data received from artificial satellites of the Earth, not only monitoring of emergencies is carried out, but modeling of the development of the situation. The prepared models are brought to the territorial authorities of the EMERCOM of Russia. These activities contribute to the timely adoption of urgent decisions.

- ISDM "Rosleskhoz"

The remote monitoring information system of the Federal Forestry Agency is designed for timely and immediate monitoring of wildfires. The information displayed in the ISDM "Rosleskhoz" was obtained not only with the help of remote sensing, but also from aviation and ground services.

It contains information on the number and area of natural fires, maps of forest fires, maps of forest fires by subject for the season, meteorological information: air temperature, humidity, KPO according to weather conditions.

Access is available in the ODS TsUKS, EDDS of municipal districts and urban districts of the Voronezh region [13-15].

- AIMS RSChS - calculation of forest fire parameters

To calculate the parameters of a fire and simulate its development, the risk analysis and management system (RAMS) of the automated information management system of the unified state system for the prevention and elimination of emergencies (AIUS RSChS) is used.

The system allows you to calculate the possible area and perimeter of a fire, depending on the input data (KPO according to weather conditions, natural fire hazard class of forests, meteorological conditions) for a specified time, smoke area; determines the settlements that fall into the zone of influence of fire hazards; models the area of fire and smoke spread on the map [16].

Based on the situation monitoring data, analysis of long-term data and calculations made by a specialist in monitoring and forecasting the development of emergencies, a model of a possible development of the situation is developed, which is timely communicated to the operational duty officers of the municipal districts, the operational group of the Central Control Center and the operational headquarters of the Main Directorate [17].

The above information systems and resources give a complete picture of the forest fire situation in a given area. The information obtained makes it possible to calculate, predict and model the possible development of the situation.

Assessment of the consequences of a forest fire obtained by solving computational problems using software [18].

Let us calculate the consequences of a forest fire using the SAUR programs.

Consider the occurrence of a forest fire near the territory of the Anninsky meat processing plant, located at the address: town. Anna, st. Novy Trud, 2

Initial data:

Time of occurrence of the fire 10:00.

Forest fire characteristics:

- type of fire - grassroots;
- forest fire class - coniferous forest;
- the duration of the fire - 1 hour.
- KPO - IV High PO.

Meteorological conditions: no precipitation, air temperature +25°C, western wind 5 m/s, atmospheric pressure 746 mm Hg. Art., humidity 80%, the state of the atmosphere is inversion, visibility is good.

Calculation results:

As a result of the forest fire that occurred, 0.8 hectares of forest could burn out in an hour. The perimeter of the fire will be approximately 0.3 km. The area of the smoke zone can be 1276.2 hectares. The number of people affected by the fire may be 10 people. Of these, up to 1 person died. The length of roads in the fire zone is 0.3 km.

Settlements in the forest fire impact zone are presented in Table 1.

Table 1. Settlements in the forest fire impact zone.

Name	Population, persons	Total area, ha	Forest fire impact area, ha	Population in the forest fire impact zone, people	Time to reach the fire front, hour	Smoke area, ha*	Population in the smoke zone, persons*
ANNA	19600	1574.0	0.0	0	0	199.0	2478
Brodovoe	1400	199.0	0.0	0	0	55.0	386

The area of smoke and the population in the smoke zone is taken without taking into account the area and population in the zone of forest fire impact.

The need for forces and means of emergency response

According to operational forecasts, to eliminate emergencies, it will be necessary to involve:

a) personnel:

- forest fire formations, numbering - 44 people;
- fire units, numbering - 18 people;
- medical formations of a general profile, numbering - 6 people, including doctors - 2 people;

b) techniques:

- heavy engineering equipment, total - 1 unit, of which: bulldozers - 1 unit;
- manual forest fire devices - 9 units;
- ambulance cars - 2 units.

Conclusions from the assessment of the situation:

Dry hot weather creates favorable conditions for the emergence and spread of fire, under the influence of the wind, the spread rate of existing fires increases and new foci may arise by transferring burning particles.

During the day, the air humidity is lower, which contributes to the burning of trees, dry grass and shrubs, so at night, make every effort to extinguish (limit the spread) and localize fires that get out of control during the day [19].

The influence of the season on the spread of forest fires: early spring fires mainly develop on dry grass, spring-summer ground fires are more stable, summer and autumn-summer fires are very stable, autumn fires are stable, develop mainly in the daytime.

Calculation using the developed program "Forest fires".

Now consider the program "Forest Fires". It was developed in Microsoft Excel on the basis of the Methodology for assessing the consequences of forest fires and we compare the results of the calculations. This technique was developed by the VNII GOChS in 1994 and put into effect by the order of the Ministry of Emergency Situations of Russia dated 14.04.1995. No. 194 .

The calculation methodology for deciduous forests is presented in Figures 4-6 and Tables 2-3.

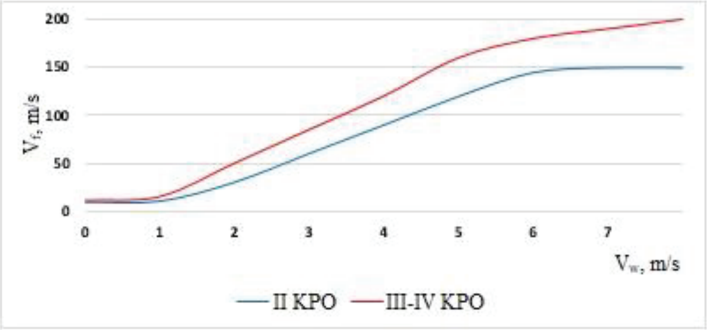

Fig. 4. The propogation velocity Vf of the fire from the wind speed Vw.

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Table 2. Calculation methodology for deciduous forests.

Grassroots II KPO				III-IV KPO			
V_w	Front	Flank	Rear	V_w	Front	Flank	Rear
0	9	9	4	0	11	19	4
1	10	10	5	1	15	19	5
2	30	12	8	2	50	20	9
3	60	17	9	3	85	23	12.5
4	90	21	10	4	120	26	16
5	120	24	11	5	160	28	20
6	145	25	11.5	6	180	29	21.5
7	150	25	12	7	190	29.5	22
8	150	18	12	8	200	30	22

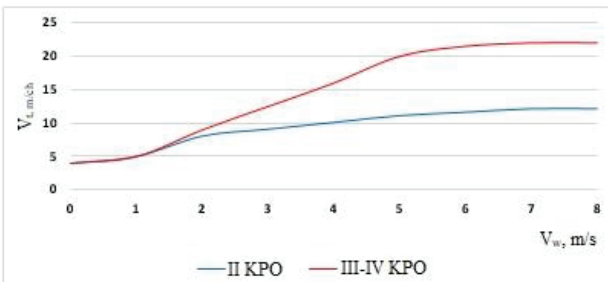

Fig. 5. The propogation velocity Vr of the rear of the fire from the wind speed Vw.

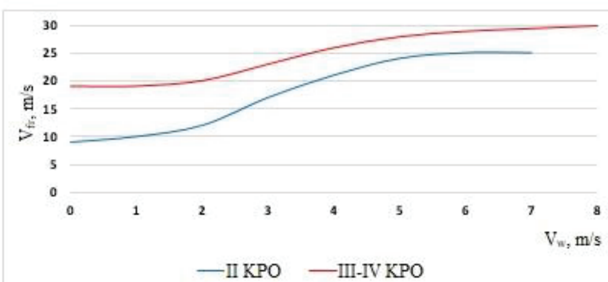

Fig. 6. The propogation velocity Vff of the fire flank from the wind speed Vw.

Table 3. Calculation methodology for deciduous forests.

Riding II KPO					Riding III-IV KPO				
	V_w	Front	Flank II	Rear II		V_w	Front	Flank III	Rear III
Stable	0	120	9	4	Stable	0	120	19	4
	1	120	10	5		1	120	19	5
	2	120	12	8		2	120	20	9
	3	120	17	9		3	120	23	12,5
	4	120	21	10		4	120	26	16
Runaway	5	4500	24	11	Runaway	5	4500	28	20
	6	4500	25	11,5		6	4500	29	21,5
	7	4500	25	12		7	4500	29,5	22
	8	4500		12		8	4500	30	22

The calculation methodology for coniferous forests is presented in Figures 7-9 and Tables 4-5.

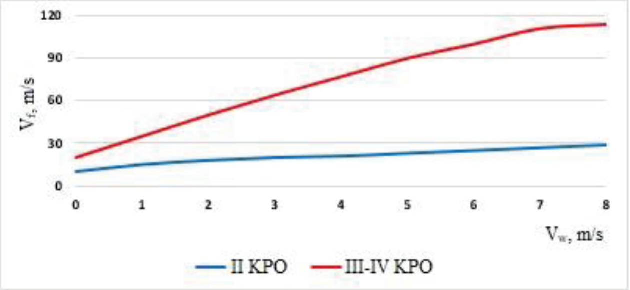

Fig. 7. The propogation velocity Vf of the fire from the wind speed Vw.

Table 4. Calculation methodology for coniferous forests.

Grassroots							
II KPO				III-IV KPO			
V_w	Front	Flank	Rear	V_w	Front	Flank	Rear
0	10	9	3	0	20	19	9
1	15	12	6	1	35	23	12
2	18	15	9	2	50	27	15
3	20	16	11	3	64	29	16,5
4	21	17	11,5	4	77	30	17
5	23	17,5	12	5	90	31	17,5
6	25	18	12,5	6	100	32	18
7	27	18	13	7	111	33	18,5
8	29	18	13,5	8	114	34	19

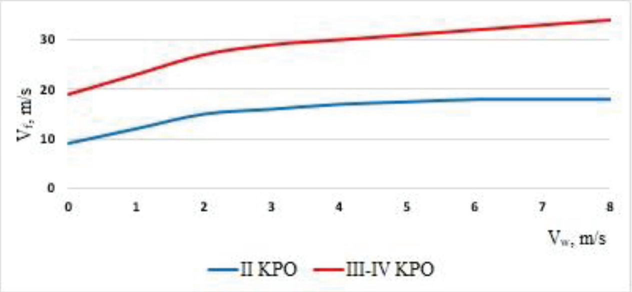

Fig. 8. The propogation velocity Vff of the fire flank from the wind speed Vw.

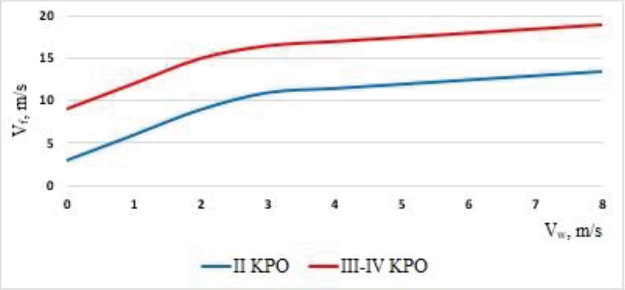

Fig. 9. The propogation velocity Vr of the rear of the fire from the wind speed Vw.

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Table 5. Calculation methodology for coniferous forests.

Riding II KPO					Riding III-IV KPO				
	V_w	Front	Flank II	Rear II		V_w	Front	Flank III	Rear III
Stable	0	120	9	3	Stable	0	120	19	9
	1	120	12	6		1	120	23	12
	2	120	15	9		2	120	27	15
	3	120	16	11		3	120	29	16.5
	4	120	17	11.5		4	120	30	17
Runaway	5	4500	17.5	12	Runaway	5	4500	31	17.8
	6	4500	18	12.5		6	4500	32	18
	7	4500	18	13		7	4500	33	18.5
	8	4500	18	13.5		8	4500	34	19

The program takes into account such indicators as:
- type of fire;
- type of forest;
- KPO;
- wind speed;
- initial value of the area (or perimeter) of the fire;
- fire propagation time [20].

"Forest Fires" contains 3 tabs. On the first tab "Initial data" in section 1 (Figure 10), the data necessary for the calculation are entered or selected from the drop-down list.

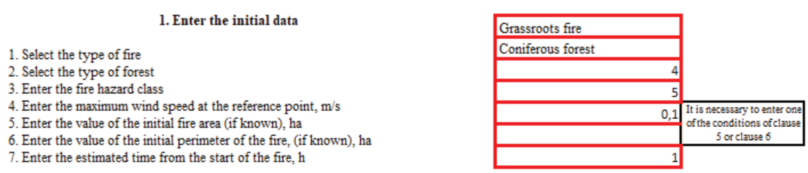

Fig. 10. Section 1.

Section 2 displays the calculation results (Figure 11).

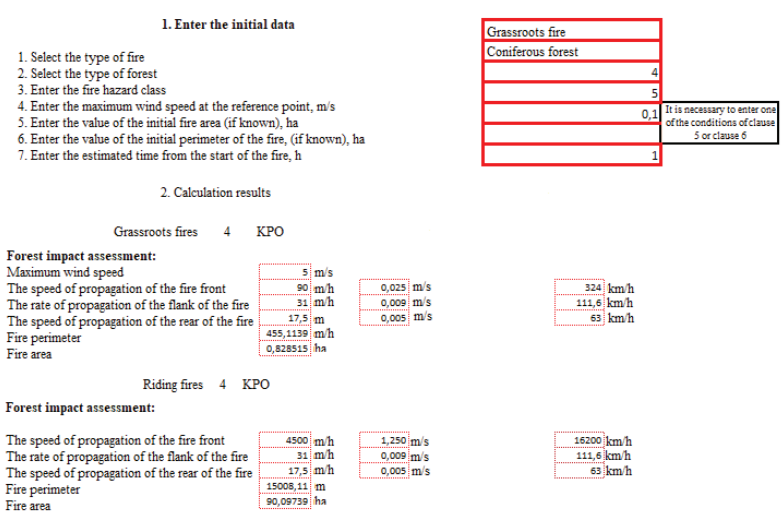

Fig. 11. Section 2 - calculation results.

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On the second and third tabs, there are "Methodology for deciduous forests" and "Methodology for coniferous forests", which reflect the dependence of the speed of propagation of the front, flank and rear of the fire on the wind speed.

4 Conclusion

As a result of calculations, we obtained that the fire area after 1 hour will be 0.8 ha. The perimeter of the fire, after the same amount of time, will be 455 m.

Under the worst scenario of the development of the situation, a crown fire may develop, the area and perimeter of which can be 90 hectares and 15,008 m, respectively.

The calculation results obtained using the "Forest Fires" program coincide with the results obtained in the calculation in the SAUR program with the same initial data. And this development has a number of advantages:

- ease of use;
- the program is autonomous, i.e. does not require any additional and special software for correct operation;
- the calculation results are similar to the results obtained using the SAUR program, which operates exclusively in the internal network of the EMERCOM of Russia intranet;
- when updating the calculation formulas in the methodological recommendations, on the basis of which the "Forest Fires" program was written, there is the possibility of their adjustment;
- if necessary, it is possible to introduce new parameters for calculations (for example, calculation of C&S, smoke zones, etc.), i.e. the program is flexible and can be changed taking into account the requirements of the operator;
- when calculating a ground fire, the program also considers a crown fire as the worst scenario for the development of the situation;
- The program does not require financial investments.

In addition to the listed positive aspects of the developed Forest Fires program, there are also disadvantages:

- the calculation problem does not give such a detailed conclusion in the solution;
- there is no possibility of applying the calculated zones of forest fire impact and smoke zones on the cartographic basis.

As for the calculation problem of SAUR, there are also a number of shortcomings here:

- the program displays the zone of influence of a forest fire, regardless of the terrain or obstacles in the path of the spread of the outbreak, taking into account that in the initial data a “tick” is set in front of the item “Take into account relief”;
- the cartographic basis needs to be updated;
- forest fire can only be counted on the green area of the map, i.e. if the litter does not light up in a wooded area, then it will not be possible to make a calculation;
- information on the number of people, SZOs and ROOs that fall into the zone of influence of a forest fire and a smoke zone requires updating;
- the program, as mentioned earlier, operates exclusively in the departmental intranet, i.e. if the internal network fails, the calculation will also fail;
- there is no possibility of prompt adjustment of this task, with changing methods.

However, the SAUR program has positive aspects:

- the program clearly gives an idea of the predicted situation of the development of a fire over time;
- gives a complete list of documents that will facilitate the work of the ODS TsUKS.

In general, both programs have a number of advantages and have the right to be used both in combination and separately.

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