KOŠICKÁ BEZPEČNOSTNÁ REVUE
KOSICE SECURITY REVUE
Vol. 11, No. 1 (2021), p. 21 – 35
ISSN 1338-4880 (print ver.), ISSN 1338-6956 (online ver.)

The Preventive Methods of Fighting Forest Fires

Preventívne metódy boja proti lesným požiarom

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The manuscript was received on 10. 04. 2021 and was accepted after revision for publication on 27. 05. 2021

Abstract:

In the presented scientific article, we focus on the issue of prevention and protection of forests against forest fires using the analytical-design method. We try to find out through professional publications which preventive measures serve to effectively prevent the occurrence of forest fires. The first part summarizes and describes the detection methods that are actively used for the detection and early detection of forest fires. We compared stationary fire protection camera systems in Europe and the world with camera systems in Slovakia. Subsequently, the advantages and disadvantages of individual detection methods are analyzed. The second part presents the benefits of pilot operation of a stationary detection system and proposed recommendations for a new location of their installation, model schemes and methods of effective operation.

Keywords: *forest fire prevention, detection, monitoring, camera system, forest fire.*

Abstrakt:

V predloženom vedeckom článku sa analyticko-návrhovou metódou zameriavame na problematiku prevencie a ochrany lesov pred lesnými požiarmi. Snažíme sa prostredníctvom odborných publikácií zistiť, ktoré preventívne opatrenia slúžia k efektívnemu predchádzaniu vzniku lesných požiarov. V prvej časti sú zrhnuté a popísane detekčné metódy, ktoré sa aktívne využívaju na zisťovanie a včasnú detekciu lesného požiaru.Porovnali sme stacionárne protipožiarne kamerové systémy v Európe a vo svete s kamerovými systémami na Slovensku.Následne sú analyzované výhody a nevýhody jednotlivých detekčných metód. V druhej časti sú uvedené benefity pilotnej prevádzky stacionárneho detekčného systému a navrhnuté odporúčania na nové lokalita ich osadenia, modelové schémy a spôsoby efektívneho prevádzkovania.

Kľúčové slová: *prevencia pred lesnými požiarmi, detekcia, monitoring, kamerový system, lesný požiar.*

Introduction

As follows from the statistics of the Ministry of the Interior of the Slovak Republic, since 2007 [7] only less than 1% of forest fires are caused by natural factors (lightning). Other fires are related to anthropogenic activity on forest lands or land adjacent to these lands (grass burning). For this reason, prevention is a basic way to prevent fires.

Prevention in the field of forest fire protection can be understood on two levels:

- in relation to the general, non- expert audience and professional public,
- in relation to the obligation of the forest owner, administrator or manager in the field of forest protection against fires.

The first level, in relation to the general, lay and professional public, is defined mainly by educational and training activities for the general public, the result of which is not directly influenced by the forest owner, manager or manager. Nevertheless, even in this level, part of the legislation is applied, for example, the Act of the National Council of the Slovak Republic no. 314/2001 Coll. on fire protection, subsequently amended [5], where the provisions of the second part of the Act focus on the obligations of legal entities, natural persons - entrepreneurs, natural persons and municipalities apply to each natural person, including the forest owner, administrator or manager. Violation of these obligations can be addressed depending on their consequences at the offense to criminal level.

From this point of view, as a society-wide order, the area of fire protection must be included in the educational process from basic educational institutions (fire education of children and youth as a part of the educational process, activities of social organizations with this focus - DPO SR, cooperation with self-government through information boards and general radios, information boards in the field, press, film, radio, television - print and non - print media). To support this level in the field of forest protection against fires, even in the conditions of the Slovak Republic, the SHMÚ portal with fire indices for Slovak forests is publicly accessible, as well as the legislatively defined and defined time of increased fire risk. However, all the above measures are related to the internal awareness of a specific natural person. They may or may not be effective in protecting forests from fires.

The following points describe the basic measures which we can take to prevent fires:

- Never underestimate the risk of forest fires due to negligent behavior.
- Depending on the weather, a forest fire may also result from a discarded cigarette butt.
- Never start a fire in the forest outside of specially designated and marked areas.
- Always extinguish the fire safely and make sure that you do not leave rotting residues behind.
- If you find an open flame, try to put it out immediately.
- If you are unable to extinguish it on your own, call 112 immediately and state:

- who's calling,
- where it burns,
- what is burning about,
- about how to get there.

- Never underestimate the speed of a fire in a forest.
- Protect your life and your health as well as the lives and health of those who are with you [2].

The second level, in relation to the obligation of the forest owner, manager or manager in the field of forest protection against fires,

1. Forest fires in Slovakia - characteristics of detection methods currently used

The protection of forests against forest fires in Slovakia is based primarily on preventive measures. These consist of a set of measures:

- legislative,
- forestry,
- organizational,
- technical.

These measures reduce the risk of forest fires, but they cannot completely eliminate it. For this reason, part of organizational and technical measures is a system of early detection of forest fire, also called detection system.

The basic task of detection methods is the early detection of forest fires. The time of fire detection (tsp), following the time of its reporting (toh), together with other variables of the timeline of fire development, which are part of the time of free fire spread (tVR), have a direct impact on its size and further development. A schematic representation of the time course of fire development is shown in Fig. 1.

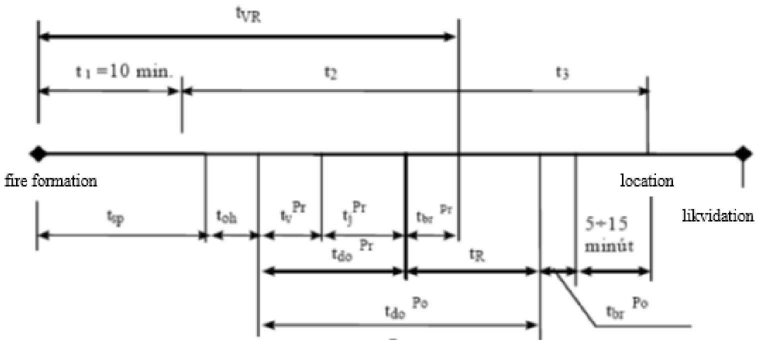

Fig. 1 Time course of fire development. Instruction, 2003 [3]

The basic detection methods used in Slovakia include:

- ground monitoring, provided by patrol activities by forest personnel at the time of increased risk of fire,
- aerial monitoring, provided by legal entities - entrepreneurs doing business in the field of air traffic, on the basis of a contract with the Ministry of Agriculture and Rural Development of the Slovak Republic.

Other detection methods were implemented in pilot operation (camera system).

Activation of detection methods is related to the expected risk of forest fire due to weathering. The SHMÚ (Fire Danger Index) method is used to evaluate this risk, valid for the entire territory of Slovakia. In the past, for the needs of the State Forests of TANAP, after the wind calamity in 2004, the methodology of the Technical University in Zvolen was used.

2. Monitoring, detection, localization

The basis of success in the fight against fires is their early detection and localization. At present, fire monitoring of forests in Slovakia is provided mainly by field walks of foresters (mostly on weekends and holidays) and aerial monitoring. In order to improve the existing methods of fire monitoring, look for and apply alternative methods of monitoring and shorten the reaction time between the occurrence of a fire and the beginning of its extinguishing was launched in 2008 into pilot operation at OZ Kriváň stationary camera system. It is an automated fire monitoring system based on optical cameras placed on high masts.

2.1. Terrain errands

This activity is defined by legislation as follows [4]: *"Patrol activity at the time of increased fire risk is performed mainly on non-working days and non-working hours, in the form of walks, camera system, aerial fire monitoring or other appropriate means . For persons performing patrolling activities in the form of errands, a time schedule is drawn up with the determination of the route of errands or sightseeing terrain places are determined. Persons performing patrol activities must be equipped with telecommunications equipment that can be used to report a fire. Written documentation shall be kept on the patrol activity, which shall contain in particular the names and signatures of the persons who carried out the patrol activity, the date and time of commencement and termination of the patrol activity and findings which have or may affect the forest fire, its spread and destruction. "*

As follows from the definition of the said activity, the patrol activity is performed at a time of increased risk of fire, especially on non-working days and during non-working hours.

The requirements for ensuring patrol activities include:

- trained staff,
- physical presence in the space,

- alternation after certain periods of time,
- equipment with means of transport, telecommunication technology, optical means, fire extinguishing equipment.

The basic problem remains how to cover the risk area of monitoring activities outside the route of the walk, outside the presence of persons patrolling the route or place (relocation of the patrol) or the time of increased fire risk, the individual pros and cons of this activity are listed in Table 1.

Tab. 1 Pros and cons of monitoring activities

Benefits	**Disadvantages**
• relatively low costs • simple equipment (binoculars, mobile phone, map…) • simple observer training • operational deployment	• absence of detection outside of the walking time • detection inaccuracy (fog, twilight…) • location inaccuracy • unavailability of the mobile network, especially in more remote areas, resp. the need to secure a radio connection • demands on the number of staffing and related wage Costs • the need for elevated observation points • limiting factor - sufficient road network

2.2. Aerial monitoring

Aerial fire monitoring has been carried out in Slovakia since 2001. Its introduction resulted from a meeting of the management of the Ministry of Justice of the Slovak Republic, where a report was submitted on the progress of tasks and their financial security related to forest protection against fires. and financial frameworks for carrying out this activity.

The first guarantor in charge of providing aerial fire monitoring and selection of suppliers in the years 2001 - 2004 was Lesy SR, š. p. Banska Bystrica. Declaring and revoking the increased risk of fires in forests was the responsibility of the District Office - OPPLHaP. In the first years of its activity, LPM also participated in firefighting (2003 in the amount of 12,600 euros and 2005 in the amount of 51,300 euros). Later, due to lack of funds, this activity was dropped from the scope of activities.

Success of aerial monitoring in the years 2001 - 2013, which was performed by the operators of Australia, a. s., Nitra and Aeroservis, a. s., Košice is documented in Table 2.

Tab. 2 Success of air monitoring in the years 2001 - 2013

Year	**Flight hours**	**Flight days**	**Control. fires**	**Uncontrolled fires**	**Fires together**
2001	240:00:00	-	-	-	-
2002	483:25:00	90	-	-	-
2003	545:41:00	113	-	57	57
2004	712:20:00	203	747	22	769

2005	662:07:00	121	841	43	884
2006	774:40:00	141	1 327	41	1 368
2007	775:41:00	143	931	113	1 044
2008	751:27:00	131	970	50	1 020
2009	501:27:00	76	540	20	560
2010	500:00:00	79	972	20	992
2011	400:07:00	60	532	6	538
2012	400:07:00	60	210	24	234
2013	80:00:00	14	13	3	16
Together	**6 827:02:00**	**1 231**	**7 083**	**399**	**7 482**

Due to the simplification of the coordination of individual involved components of LPM, this activity has been provided by the NLC in Zvolen since 2005. The declaration of fire danger was transferred from the relevant OÚ to SHMÚ in Bratislava and is carried out on the basis of fire indices.

The flights are performed on the basis of fire indices, which determine the degree of fire hazard in forests in the Slovak Republic. In the period of possible occurrence of forest fires (April - October), SHMÚ updates the degree of fire danger in forests on a daily basis.

The location of uncontrolled fires is carried out in close cooperation with HaZZ units. This means that if the pilot identifies an uncontrolled fire, he has reported it to the relevant HaZZ dispatcher via a radio. It shall state the area, intensity, direction and type of fire, location, location according to GPS and possibly also a more detailed location according to municipalities, significant terrain or other identifiers. In justified cases, pilots cooperate in guiding firefighters to the scene of a fire from the air, which significantly shortens the reaction time of the intervention.

Fig. 2 Footage from aerial monitoring, Source: authors' archive

We consider aerial fire monitoring to be a standard fire monitoring activity, the images of aerial monitoring are shown in Figure 18. It is a very effective activity with a significant action radio. From the point of view of economics, it is comparable to the walks of forestry staff. Smoke, resp. the fire is well visible even from a distance of a few kilometers. The control and evaluation of fire hazards is very operational and the location is accurate. If necessary, HaZZ receives all relevant information, including GPS coordinates and access to the fire. The advantages and disadvantages of aerial fire monitoring are described in tab. 3.

Tab. 3 Advantages and disadvantages of aerial fire monitoring

Benefits	Disadvantages
• in case of good weather, fast and efficient monitoring of a relatively large area • operational verification of information • by changing the flight path • lower demands on staff numbers • assistance to HaZZ in navigating to fire • possibility of extinguishing	• relatively high costs for the operation • of aircraft, executive and service personnel • a limited amount of available aircraft • limited flight ability in case of poor visibility, at night or in poor weather conditions • absence of detection outside of overflight time

2.3. Camera monitoring

Stationary fire monitoring and detection systems are based on the sensing of the environment of interest using optical or other cameras and the subsequent evaluation of the acquired images for the presence of signs of smoke or burning. Based on the evaluation of the received data, the operator of the control center is visually and audibly alerted to the occurrence of a fire and subsequently the warning system of the Fire and Rescue Service (HaZZ) is informed. The system works continuously - with the help of cameras, it observes the area of interest 24 hours a day, 7 days a week, ie also at night, thanks to the high sensitivity of the cameras.

The main parts of the system are observation towers with cameras, possibly extended by other sensors and a control center. Within the control center, special software is installed on servers and computers, a camera, a communication subsystem and an industrial computer are installed on the observation tower.

The advantages and disadvantages of camera monitoring are described in Table 4.

Tab. 4 Advantages and disadvantages of camera monitoring

Benefits	Disadvantages
• fast fire detection (observation), in the order of minutes • size of the monitored area from one center, one worker • exact location of the fire site - GPS coordinates, the possibility of navigation • automatic alarm system - elimination of human factor failure • additional use - protection and supervision of the territory (wood theft, poaching, tourism, etc.) • continuous 24 hour monitoring • Easy modulation and multifunctionality by adding various	• One-off higher entry costs for set-up • Limited use in extremely bad weather conditions • higher demands on operator training

sensors	

3. Camera systems

3.1. *General characteristics*

There are several types of detection and monitoring systems (DMS) in the world and are used, Figure 3 shows the scheme of operation of the FORESTWATCH system. These are mainly observers, whether in the form of walks or on watchtowers, aerial and satellite monitoring. Automatic detection and monitoring systems based on optical cameras, various types of detection sensors or their combinations are increasingly being used. Based on practical experience, the latter prove to be the most progressive option for a technical solution for monitoring forest fires in the future.

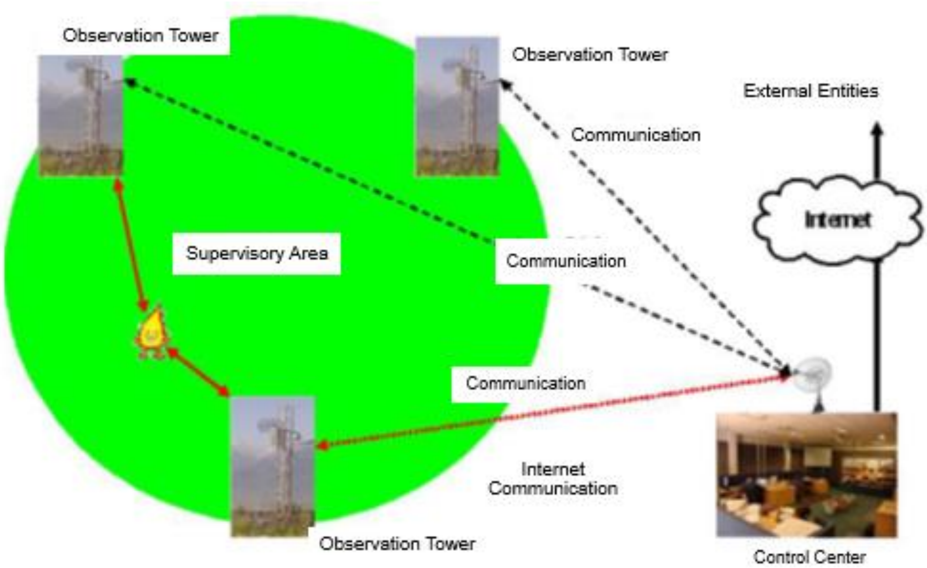

Fig. 3 Scheme of operation of the FORESTWATCH system [6]

Detection and monitoring systems are divided into two basic groups:

a) ground - based (terrestrial) systems based on monitoring from ground – based monitoring stations

b) satellite tracking satellite systems.

Satellite systems are suitable for monitoring large forest areas, such as Canada and Siberia. Their main goal is to monitor the condition and development of the fire. Terrestrial, ie terrestrial, systems are more suitable for monitoring areas in European conditions.

Different types of detection sensors can be used in terrestrial systems:

- video cameras, sensitive to the visible spectrum of smoke recognizable during the day and fire, recognizable during the night,
- infrared (IR), thermal imaging cameras based on fire heat flow detection,
- IR spectrometers that identify the spectral characteristics of smoke,
- LightDetection And Rangingsystems - LIDAR (light and range detection), which measures laser beams reflected from smoke particles.

The use of a camera or sensor type depends on the specific conditions of deployment, but also on the available financial resources. Comparable infrared and laser systems are more sensitive and produce fewer false alarms than CCD (charge-coupled device) cameras, but their price is disproportionately higher. For example, the approximate price of one typical high-quality outdoor moving CCD camera is about 3,000 euros and the price of an IR thermal imaging camera is 25,000 euros. Another feature of CCD cameras that are on the market today is their double sensitivity. These are color cameras sensitive to the visible spectrum during the day and black and white cameras sensitive to the IR spectrum during the night. These features expand the possibilities of their use.

The main problem of all systems is the high number of false alarms, caused by worse atmospheric conditions (cloudy, precipitation, dust), reflection of light and human activity, etc. Because of this, their operation is usually supervised by a human operator until his decision is final. An alarm is generated and suspicious locations on the monitor are automatically marked. The operator decides whether to acknowledge or cancel the alarm. So the task of the operator is not to monitor monitors all the time, such as. with a classic observer, but especially to verify fire alarms. If the operator is unsure, the system can usually switch to manual control and perform additional checks by controlling camera movement and zoom. The use of such an automatic monitoring system in combination with the operator's operation significantly increases its efficiency. In addition, the operator can control more cameras and his fatigue is reduced.

The most common systems include FireHawk (JAR), Forestwatch (JAR) and Firewatch (Germany).

3.2. Stationary fire protection camera systems in Europe and in the world

The overview in Table 5 is informative and includes only the most used 3 systems.

Tab. 5 Camera systems in Europe and in the world

Title	**Manufacturer**	**Wher the system is used**	**Characteristics**
FireHawk	ALASIA Marketing	Republic of South Africa	Firehawk is designed for installation in remote areas, the cameras can cover a radius of 6 to 8 km from the installation site.

AlarmEYE	InnoSys Industries Inc., Thailand	Thailand	-
EYEfi SPARC	EYEfi, Australia	Australia	-
FireWatch	German Aerospace Institute (DLR), Germany	Germany, Estonia, Cyprus, Mexico, Czech Republic, Portugal, Spain, Italy, Greece, USA	FireWatch is able to continuously inspect large areas of wooded areas and, in the event of any smoke, immediately monitor the dynamics of its development. The received data in visual form are then processed and evaluated by dispatching. As soon as the source of the fire is identified, the operator sends the relevant alarms.

3.3. *Stationary fire protection camera system in Slovakia*

A pilot project of stationary fire monitoring was implemented at OZ Kriváň with coverage of approximately 60,000 ha of forests, mainly in the management and use of Forests of the Slovak Republic, š. p. In 2008, work related to the preparation, implementation, pilot operation and evaluation of the usability of the system was performed. The system is functional and suitable for wider deployment in the conditions of the forests of Slovakia.

The Kriváň Branch Plant (OZ) was selected for the pilot project. There were several reasons. It is a trademark located in an area with an increased risk of fires, most forests are owned by the state, a large part of the area is represented by ŠPR Poľana and in terms of terrain morphology is relatively fragmented. In particular, the fragmentation of the territory was important for verification in our conditions, as this system is operationally deployed in the world, mostly in flat areas.

The system monitors more than 60,000 hectares of forests using 3 cameras. The columns of mobile operators were used to place the cameras. Due to the configuration of the terrain, it was necessary to build one column on Ostrůžky, the so-called "Data transhipment". The control center was established in the area of OZ Kriváň. As part of the test operation, the system was also connected to the dispatching center (HaZZ), in cooperation with which the response to the fire was accelerated. The connection was secured several times - by telephone, e-mail and via the web.

Figure 4 shows the location of the cameras in space.

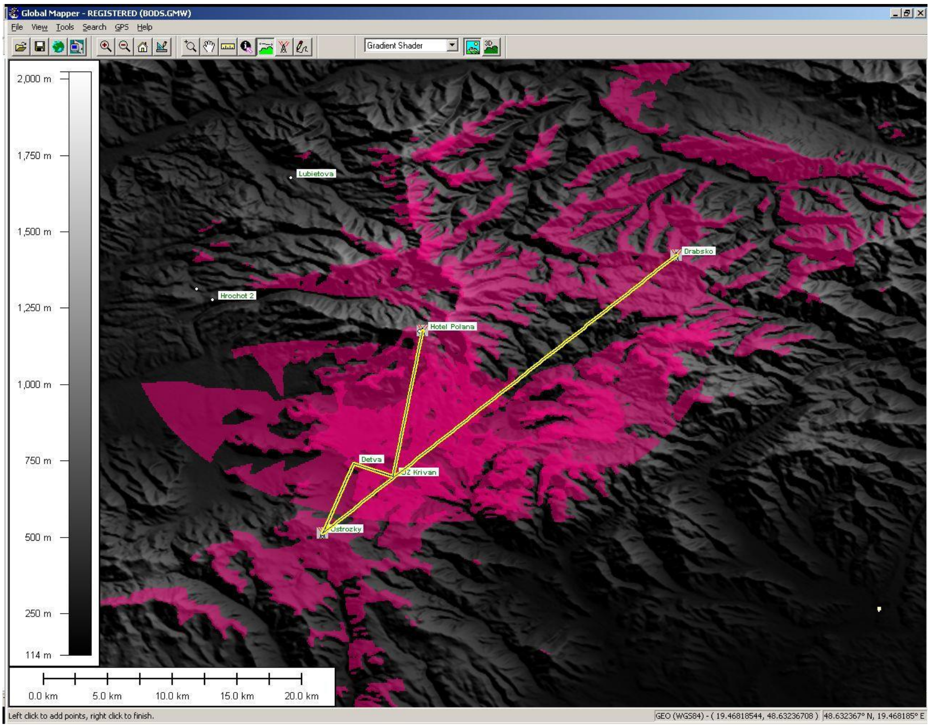

Fig. 4 Location of cameras, data transhipment and direct visibility of cameras [6]

Operation started on 01.07.2008. As evaluation parameters determining the success, resp. The suitability of the solution was used goals and quantifiers, which were set as a priority in the preparation and start-up of the project and which formed a comprehensive and realistic picture of the possibilities, but also the risks of deploying the technology.

The following were taken into account:

- functionality of the system from the point of view of fire protection needs,
- suitability of the system with respect to the territory resp. location of deployment,
- methodology of work and service activities,
- usability of the system not only from the point of view of fire protection, but also for other purposes (eg illegal logging, game migration, etc.).

From the point of view of the staffing of the control center staff, the so-called model was used. mixed staff - during working days it was performed by internal employees of OZ and on weekends and non-working days at the control center trained staff from among the employees of forest administrations. Based on the acquired knowledge, the model of operation was then switched to specially trained workers from the external environment. This change has significantly increased the efficiency and effectiveness of the system.

4. Evaluation of project implementation and pilot operation

During the preparation and implementation of the pilot project of the stationary monitoring system, no significant problems occurred and the system was put into operation according to the planned schedule. The greatest demands were placed on the coordination of activities, as in addition to the already mentioned entities, two foreign partners from Greece and South Africa also participated in the project. Problems caused by severe storms and subsequent power outages have proven to be one of the key but difficult-to-influence factors in successful operation.

The fire monitoring itself was evaluated in terms of the methodology used in two basic divisions, see. picture 4:

- fires reported to the control center (RC),
- fires not reported - so-called detected fires (burning of grasslands, fields, meadows ...) [6].

The reported fires were those about which the RC staff knew in advance and only monitored them as part of their activities at the RC. These types of fires were quite often announced by forest administration workers themselves, and the vast majority were so-called controlled incineration of residues after harvesting directly in the forest stand. Unreported fires were those that were registered on the RC and the operator subsequently took all appropriate measures to eliminate them, respectively. she continued to monitor them.

4.1. System benefits

The benefits of the system can be considered:

- continuous, automated supervision of a defined area,
- continuous evaluation of the condition of the monitored area,
- notification of the operator to the change of the state in the area and indication of changes of the monitored state quantities,
- display information about the cause of the alert,
- defining the indicated problem area using GPS coordinates and displaying it on a digital map,
- the possibility to define areas where there are permanent sources of smoke (factory, dwelling - solitude…),
- possibility of manual control of the system - cameras,
- the operator can supervise several areas - the system is automated and only system alerts need to be addressed,
- reduction of costs for monitoring risk areas [6].

In addition to the above advantages of direct fire protection, the system also provides tools and options for effective management and monitoring of forest stands in relation to:

- the issue of illegal logging,
- the issue of illegal movement of motor vehicles,
- the issue of illegal hunting of game resp. poaching,
- the issue of movement and migration of game and thus to support the protection of forests and forestry as a whole,
- the issue of illegal landfills and others,
- significant psychological effect (e.g. on spring grass burning).

After five years of operation, it can be stated that the system is functional and suitable for wider deployment not only on the plains, but also in the conditions of mountain forests [6].

4.2. *Design of sites for their deployment, model schemes, method of operation and technical equipment*

An analysis of the problems with the current state of forest fire prevention and detection shows that the current means for early detection of forest fires are insufficient. Therefore, we propose for areas with the highest risk of forest fires, respectively. for areas with the risk of major damage (Figure 5 - fire risk map) use fire detection and monitoring systems.

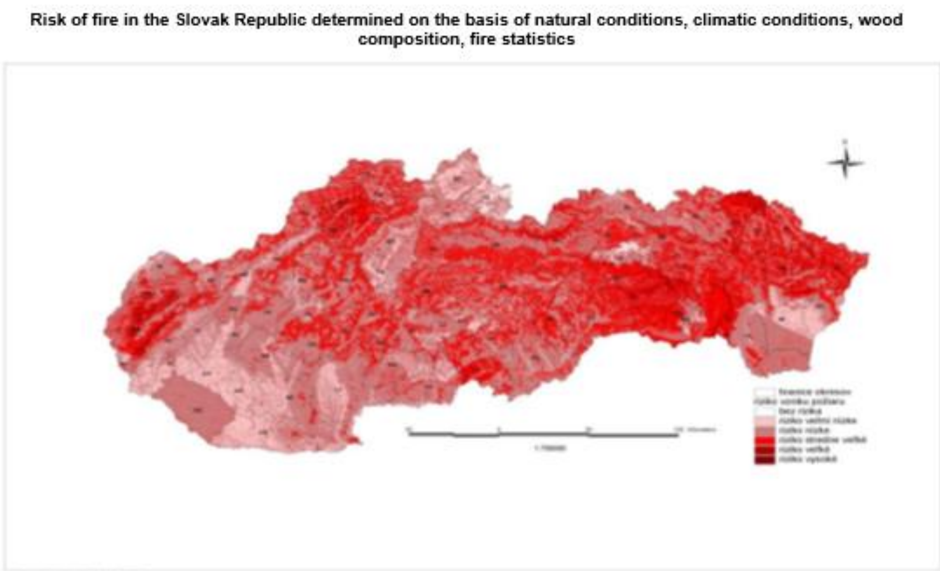

Fig. 5 Risk of fire in the Slovak Republic [1]

Conclusion

In general, we can state that the cause of a forest fire is primarily natural conditions and man himself. In European countries, the human factor accounts for 80-98% of fires. These most often arise from negligence, non-compliance with fire prevention measures, or underestimation of fire danger when using an open fire - burning grass, burning hallucinations, setting fire, smoking, playing children with matches.

Forest fires are all the more dangerous because they often occur in locations inaccessible to firefighting equipment, with insufficient resp. unsuitable sources of water for firefighting, require an enormous commitment of people, special firefighting and sometimes aviation equipment.

Direct damage is related to the deterioration of live trees, processed and unprocessed wood, loss of growth or deterioration of the quality of wood raw material. Indirect damage is caused by the onset of other secondary pests, as well as by the increase in the costs of eliminating the consequences of a fire. In addition, forest fires pose a real threat to human lives and cause ecological and economic damage to settlements and adjacent urban areas.

From the above findings we can state:

- DMS is today one of the standard methods of forest protection, operationally used in many countries,
- represent a fast and accurate way to detect and locate a fire, whether during the day or at night,
- largely eliminate the influence of the "human factor" on fire detection and localization,
- data from monitoring systems are important for improving information during a fire, navigation of emergency vehicles, for modeling the spread of fire, early warning of the population, analysis and evaluation of the causes of fire, resolution of insurance claims, etc.,
- are modulatable and usable for providing multiple activities simultaneously,
- despite higher initial costs, their return is relatively fast.

Automatic and semi-automatic monitoring and detection systems have an irreplaceable place in the prevention and repression of forest fires. In many, especially remote and mountainous localities, but also in large flat areas, they are the only real solution for the early detection of forest fires. In addition, their use is multi-purpose. It can be assumed that with the development of new technologies, their sensitivity and accuracy will increase significantly and their price will decrease, which are the main preconditions for a more massive deployment of these systems.

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