Prospects of application of modern technologies of remote sensing of the earth in the forest industry

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Abstract. Currently, forest enterprises are characterized by depletion of forest resources and their significant remoteness. To solve a whole range of tasks related to forest management, monitoring of the environmental situation, control of the forest fire situation, remote sensing systems of the Earth have been developed and, to date, are successfully used. At the moment, such systems are located in almost every region, allowing dispatch centers to quickly perform their work. On the basis of the centers there are several operators who transmit information to the forestry and monitor a lot of video surveillance cameras in real time. Cameras help to detect fires and various smoke points much faster and more efficiently than satellite photography. However, the existing methods for detecting fires in forests have long been outdated and require the introduction of modern auxiliary engineering software solutions in this process. Research and development of systems that allow tracking fires that may be located far from human habitats, and their implementation in the work of forest protection enterprises is a top priority in the Ministries of Forestry.

1 Introduction

The problem with reducing the area of forests has existed for many years. At the same time, little attention was paid to important issues of environmental protection and compensation for damage caused to nature. The volume of timber harvesting in Russia exceeds 300 million cubic meters, and in a few years hundreds of thousands of hectares of forest have turned into lifeless open spaces, the soil of which is mangled by heavy machinery, and low-quality wood and stumps have been left and not removed. Deep ruts created by forest machines turned into ditches and ravines, and the disturbed hydrological regime led to the formation of swamps in forest areas. Uncollected wood debris has become a breeding ground for pests and the cause...
of forest fires. The invasion of man and modern technology into forests and their continuous deforestation quickly led to the depletion of flora and fauna, which caused the irreversible loss of many species of birds, animals and plants in their natural habitat [1].

Environmental problems related to forest management are becoming more serious and urgent due to the proven direct link between the green cover of the planet and global warming. The world is beginning to realize that irrational deforestation can further worsen an already alarming situation, which is fraught with unpredictable consequences. The countries where forest resources form the basis of the economy (Canada, USA) saw the light in the ecological plan much earlier and gradually began to form forest management systems with wood harvesting technologies, which are characterized by the processing of all wood biomass completely without waste (or with a small amount of it) and with minimal damage to the environment. As for Russia, positive changes are just beginning in the timber industry [2].

People have been looking for solutions to these problems for many years, using various methods of influence. Unfortunately, the human factor in most cases acts as a source of danger. Figure 1 shows an infographic showing the reasons for the reduction of forest areas.

Fig. 1. Reasons for the reduction of forest area.

In the XXI century, solving the problem of forest death from fires is an urgent task. To eliminate this problem, people have started using satellite images, as this allows them to detect fires faster. Specialized organizations are being created all over the country that are able to receive satellite signals and process them with the help of computer programs into images of fires. These systems allow you to quickly respond to emerging fires for their further localization. Based on the above, it is possible to formulate the purpose and objectives of the study.

2 Purpose and objectives of the study

The purpose of the study is to substantiate the prospects of using modern technologies of remote sensing of the Earth in the forest industry of the Russian Federation to minimize forest fires.

Tasks:
1. To study the structure of the work of Forest Fire centers in the regions of the Russian Federation;
2. Consider modern systems used for remote monitoring of forest fires;
3. To identify the possibility of reducing the number of forest fires in the Russian Federation using GIS systems.

To date, there is a regional dispatch service in the Russian Federation that uses several methods of early detection of forest fires: CCTV cameras and satellite images. For more efficient operation of forest fire monitoring centers, these systems are interconnected. In these centers, remote monitoring of forest fires is carried out, and tasks are also solved, which consist in timely detection of smoke from forest fires near settlements. In order to facilitate the tasks of finding fires, operators provide round-the-clock online monitoring.

3 Results and discussion

Let’s consider the work of the Forest Fire Center on the example of the Krasnoyarsk Territory. The Forest Fire Regional Center is a center for coordinating the activities of all forest fire services within the federal District for the prevention and elimination of forest fires. The activity of the KGAU "Forest Fire Center" consists in performing works, providing services for extinguishing forest fires and implementing certain fire safety measures in forests, as a specialized institution to ensure the execution of the powers of the Russian Federation transferred to the state authority of the Krasnoyarsk Territory.

Today, the total number of specialized fire equipment of the Forest Fire Center is about 500 units, which made it possible to increase the efficiency of detecting forest fires in small areas up to 6 hectares (more than 97%) and eliminate about 92% of fires on the day of detection in the ground zone. Aircraft and helicopters of various types, including modern light aircraft – Cessna, Eurocopter, Robinson44 - are involved in carrying out aviation patrols and extinguishing forest fires under lease agreements. In 2015, the staff of the Forest Fire Center is more than 1,500 people. To ensure the monitoring of fire danger in forests, a regional control center and 20 points on the territory of the region have been created on the basis of the Forest Fire Center, which allows for high-quality communication with all aviation departments engaged in extinguishing forest fires.

Since the beginning of the fire season, the employees of the regional control center are transferred to the round-the-clock mode of operation. Two dozen ground-based satellite stations have been installed to ensure uninterrupted communication via the Internet. In addition, the Forest Fire Center is armed with a unique unmanned aerial vehicle, which allows patrolling the local territories of the forest fund in order to detect forest fires, as well as providing information about existing fires to ground fire extinguishing teams.

Currently, remote sensing systems are widely used in the forest industry of the Krasnoyarsk Territory. Fire monitoring and detection of smoke points using high-tech and expensive cameras in real time allows us to say that these systems can find their application in other areas of the forest industry.

The ultimate goal of remote sensing data processing is to recognize objects or situations that fall into the field of view and determine their position in space. Space photography occupies one of the leading places among various remote sensing methods [3].

Due to the fact that roads (railways, automobile, forest, etc.) run through the forests, this area is considered the most at risk of forest fires. To reduce the risk of an emergency (emergency), there is a system of space monitoring of forest fires in the vicinity of railway lines [4]. This system is a round-the-clock duty station with qualified specialists-decoders of space photography, who receive information from the images. The duty post receives information about the heat point, analyzes it and determines whether it is a potential threat of a forest fire. If the duty officer detects signs of a fire, he immediately contacts the end user of the information – the forest fire brigade, which takes measures to quickly extinguish the fire. Satellites cover from 10 times a day any point of the railways. The diagrams show observations of thermal points grouped by day and night satellite observations. The railway
line and a 10-kilometer buffer zone are displayed on the schematic maps. All objects of the Russian Railways infrastructure can also be applied, in agreement with the customer, a table of thermal points is additionally formed indicating geographical coordinates, links to the infrastructure of the Russian Railways. In case of detection of fires, an overview image is sent that most accurately captures the burning edge (Figure 2).

Fig. 2. Example of displaying wildfires on standard sheets of map diagrams in the vicinity of railway lines.

The shape of the burning edge of the fire is visible from the schematic maps and survey images, and the direction of the development of fires is visible from the smoke plumes (Figure 3). Information is sent to the consumer by all available means, for example, via e-mail or messengers.

Fig. 3. An example of high-resolution overview images of wildfires in the vicinity of railway lines.

In addition to remote sensing technology, there are other ways to detect forest fires:
1. The use of unmanned aerial vehicles (drones): drones are equipped with thermal imagers that allow you to find and report sources of ignition before their direct visual detection by humans. This allows continuous monitoring of the state of forests, and in the event of a fire – to quickly eliminate the sources of ignition.
2. Country surveillance cameras: they are installed on towers around woodlands. They are able to detect fires and notify the fire department about them in a timely manner.

3. Sound recognition: Tomsk Polytechnic University [5] has developed an effective technology for detecting forest fires, which allows you to recognize the sounds of a forest fire, such as crackling and burning of foliage and trees. Gorenje The system can be installed in places where fires are most likely to occur.

4. Patrolling: Patrolling should be carried out in woodlands in order to detect fires at the early stages of their development, especially during periods of high fire danger.

5. Vigilance of the population: people living near woodlands can also help in detecting fires. If they notice suspicious sources of smoke or burning odors, they can report their observations to the fire department [6].

To date, more powerful cameras have been developed, capable of shooting in an online format with a width of up to 300 km of the resulting image [7]. A large number of spectral shooting ranges and a small radiometric resolution of bits per pixel make it possible to obtain images in various contrasting forms. These models of shooting equipment are now being installed on small-sized satellites that are specially launched into space for universal needs. The possibility of using satellite images at different spectral frequencies makes it possible to more clearly identify illegal logging. Control over the development of forests is one of the most important tasks of forest funds. The further accounting of forest lands depends on how efficiently and, from the point of view of the boundaries of the cutting areas, the work of the tenant will be done correctly. If the established boundaries in the cutting area are violated, then persons engaged in development in this place may face serious material or criminal liability.

Eventually, on the basis of the NestGIS QGIS program [8, 9], a map of the Krasnoyarsk Territory was compiled, on which towers with video surveillance cameras of the ISDM system and the coordinate points of fires noticed by satellites were displayed. Figure 4 shows a fragment of this map in the QGIS program, where information about all fires noticed is displayed on the left, and on the right – about fires noticed in the camera ranges.

**Fig. 4.** A fragment of a map of the Krasnoyarsk Territory in QGIS with coordinates of points of forest fires.

From the data provided by the Ministry of Forestry of Krasnoyarsk, the coordinates of all fires detected by the ISDM system were taken. Also, a layer with the camera radii of the "Forest Guard" system was applied on top of the points, which made it possible to visually compare the similarity of the data obtained in the future. It was noticed that some of the points of fires fall into the 30 kilometer visibility zone of CCTV cameras. To further substantiate
the prospects for the development of the ISDM system, methods for detecting forest fires in the region were studied. Figure 5 shows a pie chart in the percentage of ways to detect forest fires. The total number of recorded forest fires is 645.

**Statistics on the number of forest fires**

**The total number of recorded forest fires is 645**

![Diagram on methods of detecting forest fires](image_url)

*Fig. 5. Diagram on methods of detecting forest fires.*

According to the diagram (Figure 5) it can be noticed that quite often it is possible to detect the source of ignition of a forest fire with the help of ground patrol. The low percentage of the effectiveness of video monitoring, in our opinion, may be due to its insufficient development and implementation in the forest protection system. In the future, we removed all points that are not included in the viewing radius of the cameras, which allowed us to evaluate their effectiveness in more detail compared to other detection methods. The resulting number of recorded fires in these radii was 293. This is approximately 45% of the total number of registered fires. Figure 6 shows the changes by detection methods in percentage.

![The number of fires in the Krasnoyarsk Territory within the viewing radius of cameras is 293](image_url)

*Fig. 6. Modified diagram on methods of detecting forest fires.*

Comparing the two diagrams, it can be seen that the number of forest fires recorded by the ISDM system has increased almost 2 times (from 4.7 to 9.1). However, ground patrol is still the main method of detection.

Based on all of the above, it can be concluded that the security cameras of the Forest Guard system may well compete with other methods of detecting forest fires. However, their insufficient development and a small percentage of coverage of the survey, today does not allow them to be effectively used for remote monitoring of the forests of the Krasnoyarsk
Territory. Also, it is necessary to understand the financial cost of installing and maintaining security cameras. According to the Ministry of Forestry, the cost of a camera alone can reach up to 200 thousand rubles. Further installation, maintenance, and technical support may include the cost of several more cameras. However, if we take into account the cost of damage from only one burned hectare of wood, for example, birch, then the amount can reach up to 3.5 million rubles. Therefore, it would be most logical to agree on cooperation with a company engaged in remote monitoring of forest fires. All this will help to receive information in advance about the fires nearest to the leased cutting area for further prevention of their spread. Information can be obtained very quickly; research experience [10] indicates the high efficiency of the technology. The technology is also promising for monitoring carbon monoxide emissions as a consequence of forest fires [11].

Modern remote monitoring systems allow not only to track fires, but also to record various other violations. The possibility of installing cameras near illegal landfills or near illegal logging will allow tracking and further punishing violators.

4 Conclusion

A Forest Fire Center is successfully functioning in the Krasnoyarsk Territory, which coordinates the activities of all forest fire services in the region. The activity of the center consists in the detection of fires and the implementation of individual fire safety measures in forests. The center has about 500 units of fire equipment and uses aircraft to patrol and extinguish fires. The center employs more than 1,500 people. A control room and 20 points on the territory of the region providing communication with aviation have been created to monitor fire danger. Satellite stations have been installed to ensure constant and uninterrupted communication, and the Forest Fire Center has a unique unmanned aerial vehicle that allows patrolling local forest fund territories in order to detect forest fires, as well as promptly providing ground fire extinguishing teams with information about existing fires.

Remote sensing systems are widely used in the forest industry of the Krasnoyarsk Territory. They provide control over fires, preventing their uncontrolled spread based on the principle of early detection of smoke points. Such systems can also be applied in other areas of the forest industry, for example, to control the development of forests. The main purpose of remote sensing data processing is to recognize objects and determine their position in space. Satellite images are one of the leading methods of remote sensing and are more preferable compared to expensive cameras that, in addition to detecting smoke, react to various nebulae. In addition, there are other ways to detect forest fires, such as the use of unmanned aerial vehicles with thermal imagers, the installation of CCTV cameras, recognition of fire sounds, patrolling and vigilance of the population.

The study of the effectiveness of the "Forest Guard" system revealed some positive and negative aspects of its work.

Positive aspects:
- the system is capable of recording up to 50% of all forest fires;
- cameras can be installed near settlements or illegal landfills to record violations of citizens;
- with the data received by the system, you can conveniently work in the Microsoft program, as well as display fires based on the QGIS program;
- the radius of the cameras is up to 30 km;
- compared to satellites, the cameras are able to work in real time;

Negative sides:
- high cost and maintenance of the camera;
- a small percentage of camera visibility coverage in the Krasnoyarsk Territory;
inefficiency of the system over other detection sources.

References


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