Geographic information mapping for monitoring the adverse natural processes in Khanty-Mansiysk Autonomous Area-Yugra

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Abstract. Geographic information systems and technologies play an important role in land monitoring. The data obtained via land monitoring is essential for state authorities and local self-government bodies developing regulatory legal acts, targeted programs, general land-use plans, land-use schemes, implementing the land management procedures and plans, working on the prospects for rational land use and land protection, and making management decisions on the area development. Khanty-Mansiysk Autonomous Area-Yugra is currently facing some adverse and dangerous natural processes that can lead to emergencies and make a negative impact on the quality of land resources in the region. There is an urgent need for monitoring adverse natural processes to take them into account when planning the development of territorial systems. This paper will consider the results of studying natural risk zones and determine the degree of natural hazard in the region. The author will identify flooding zones for several local settlements and analyze the spread of natural fires within the boundaries of municipal regions, forestry and kinship lands in Khanty-Mansiysk Autonomous Area-Yugra. Using the geo-information media, the author develops cartographic material reflecting certain land parameters, essential for assessing the environmental state and supporting economic activity in the region.

1. Introduction
Decisions related to actions on a certain territory should be preceded by an analysis of various reliable and regularly updated data on the local ecological conditions, land characteristics and the likelihood of adverse natural processes that could affect the economic activity and land use. Therefore, systematic comprehensive surveys and observations of environment state are required, with special attention paid to land resources. Presently, geographic information systems and technologies play an important role in land monitoring.

The rational use of land resources is the most important factor in providing the sustainable development of the territory, boosting regional economies, and improving the living standards of the population. Geographic information systems and technologies are an effective means for solving the indicated tasks in Khanty-Mansiysk Autonomous Area-Yugra, characterized by some processes and natural phenomena that must be taken into account when planning the development of territorial systems.
2. Models and methods
Khanty-Mansiysk Autonomous Area-Yugra is located in high latitudes and characterized by extreme climatic conditions, allowing ranking it as a Far North area or area equated to the Far North. The territory’s climatic factors largely influence its ecological systems and social conditions, such as productivity, water supply, infectious disease models, and response actions in case of natural disasters, social shocks, migration processes, and social conflicts. In Khanty-Mansiysk Autonomous Area-Yugra, common adverse processes include floods and forest fires, affecting the quality of land, natural resources, and people’s living conditions [1-3]. Most dangerous and emergency natural situations lead to significant economic damage, including nationwide. During the spring and summer season, the number of adverse natural phenomena causing damage to the population and economic sectors tends to increase [4]. In this regard, there should be monitoring of the territories to plan sustainable development in the region.

This study is based on the following research methods: information analysis, synthesis, comparative geographical and remote monitoring of the territory, and geo-information mapping.

3. Results and discussion
Using geo-information mapping in Khanty-Mansiysk Autonomous Area-Yugra, we have analyzed natural risks and the degree of natural hazards [5]. To study adverse processes and phenomena, as well as to provide for competent territorial planning, we should consider the data on the frequency of natural emergencies and the total degree of natural hazard.

The area is characterized by periods of high water caused by floods. The average maximum water level in the Ob River based on the long-term observation is 850 m (figure 1). In some years, during high water season, some streets, roads, houses, and private vegetable plots are flooded or isolated. In spring 2013, residents of Nizhnevartovsk and surrounding towns and settlements experienced a difficult but not critical situation: parts of some streets and private vegetable plots in Bylino were flooded; ten houses were isolated, though not flooded, the access road to the village of Sosnina was partly flooded, and water levels were close to critical in the village of Vampugol [6-8].

![Figure 1. Maximum water levels (in cm) observed in the Ob River in Nizhnevartovsk district in 1972-2015 [2].](image)

The floods, affecting the urban areas, are the most pressing problem for many settlements of the district. Floods are among the most common natural disasters, exceeding all other emergencies in terms of the area covered and the damage caused, as they can disrupt the sustainable development of the urban landscape [3].

In the spring-summer season of 2015, an adverse hydro and meteorological situation was observed in the region. According to the report on the emergency and threats to life safety made by the Department of Civil Protection in Khanty-Mansiysk Autonomous Area-Yugra, in June, the authorities
declared a municipal emergency regime in some areas of the region due to the high level of floodwaters and significant flooding of private-owned garden associations. On June 19, 2015, the water level in the Ob River (Nizhnevartovsk) reached the level of 1061 cm (figure 2). This situation could have been caused by an abnormally large amount of snow in the winter of 2014-2015 and was somewhat complicated by intense rainfall in the summer of 2015 (in some days, total precipitation reached 24-32 mm per day). Figure 2 shows the daily water level indicators in the Ob River and total precipitation in Nizhnevartovsk (from April 30, 2015 to August 31, 2015). Previously, the maximum water levels in the Ob River in Nizhnevartovsk region were recorded in 1979 (1071 cm), 2007 (1012 cm), and 2002 (994 cm) [2].

Flooding zones may include residential buildings and industrial facilities, which leads to significant material damage. In this regard, it is of great practical interest to identify the areas of possible flooding and develop lists of facilities and buildings that may be flooded with a different probability. Using geo-information technologies and digital elevation models, we were able to largely automate this process. Today, specifying the boundaries of possibly flooded zones is one of the standard tasks applied for land monitoring, which is solved through Geographic Information System [9].

Using geo-information mapping, we have studied the territory exposed to the 2015 flood within the administrative boundaries of Surgut, Nizhnevartovsk, and Megion in Khanty-Mansiysk Autonomous Area-Yugra. The urban areas under study are located in the Ob River valley, with the meandering channel, numerous branches, and creeks. The cities of Surgut, Nizhnevartovsk, and Megion are located within the floodplain of the Ob River, tending to flood during high water season. We have carried out a spatial analysis of the flooded area following the remote sensing data, satellite images before the flood, and during the unfavorable flood situation in June 2015. As the initial information, we have used the data obtained from the physical and geographical analysis of the area, taking into account the urban relief and long-term hydrometeorological indicators. Applying the geo-information system, we have decoded the satellite image of the flooded areas, superimposed the identified flooded zones on the urban zoning map of the city and analyzed the flooded territorial zones (figure 3).

Thus, when analyzing the identified flooded areas according to remote sensing data and the urban zoning map of the city district, we identified the territorial zones that were flooded in Surgut in June 2015. For the most part, the flooded areas are located in the southern part of the city and affect
recreational areas (urban forests), green areas of general use, areas with sports facilities, public and business areas (a zone for secondary and higher professional education institutions, a zone with general education institutions, a zone of a university campus, a zone for business and commercial purposes, a zone for administrative and business purposes, a zone with business, public, and commercial facilities), transport zones (a zone with automobile transport facilities, a zone for air transport), residential areas (private housing), a zone with the municipal engineering infrastructure, industrial zones (a mining zone and a zone with production facilities), and coastal buffer zones.

Using the geo-information environment, we have developed a schematic map of the flooded area within Nizhnevartovsk boundaries of urban planning. The total area of the identified flood zone within Nizhnevartovsk is 7836.9 hectares. Thus, analyzing the zoning map of urban planning and flooded areas observed in June 2015, we concluded that the area exposed to flooding included natural territories of Nizhnevartovsk, the gardening zone, the summer cottage and horticulture zone, the industrial facilities location zone, the urban forest zone, the agricultural land zone, and the pipeline zone [3].

After monitoring the flood situation in some boundaries of Megion using the remote sensing data (figure 4), we have identified the following flooded zones: a green zone of common use, a zone of agricultural land, a zone of agricultural facilities, a zone of urban forests, an air transport zone, a zone of recreation, tourism and spa facilities, a zone of multi-story residential buildings, and a coastal protective strip (figure 5).

Figure 3. Superimposing the flooded zones identified from satellite images within the urban area on the urban planning zones map of Surgut city area in the geo-information system (compiled by author).

Figure 4. A satellite image of Megion in Khanty-Mansiysk Autonomous Area-Yugra during the flood in June 2015 (DigitalGlobe).

In addition, the unfavorable hydrological situation in 2015 affected the productivity of grasslands, located mainly in river floodplains and actively used by farmers and residents to harvest feed for farm animals. The results of monitoring flood zones of settlements should take into account the goals for sustainable development of urban areas. The zoning schemes of urban planning should contain sections of zones prone to flooding, considering the spatial analysis of the current flood situation [3].

The region is also characterized by the spread of natural fires. As a rule, the fire hazard season lasts from early May to late September, for 134 days on average. Such factors as temperature conditions, distribution of precipitation, the timing of the snow formation and melt, and water levels in rivers and ponds have a significant impact on fire hazard. These parameters vary significantly over the years, depending on hydrometeorological conditions [4, 11]. In summer 2012, an abnormal forest fire situation was observed in Khanty-Mansiysk Autonomous Area-Yugra, resulting in 1607 forest fires in the total area of 122586 hectares, which was the worst situation over twenty years. Such an adverse fire situation in 2012 was largely due to the extremely low river water and groundwater levels. Forest
fires cause great economic damage and are the main cause of loss of forest vegetation [4, 11].

Figure 5. Superimposing the flooded zones identified from satellite images within the urban area on the urban planning zones map of Megion city area in the geo-information system (compiled by author).

We have conducted the geo-information analysis of the natural fire distribution in Khanty-Mansiysk Autonomous Area-Yugra using a satellite image of the territory made in 2012. The analysis showed that areas exposed to forest fires in summer 2012 were as follows: the forestries of Nizhnevartovskiy, Surgutskiy, Nefteyuganskiy, Khanty-Mansiyskiy, Kondinskiy, Mezhdurechenskiy, Urayskiy, Komsomolskiy, Sovietskiy, Beloyarskiy, Krasnoleninskiy, Berezovskiy, and Pionerskiy. Additionally, we have identified several forest fire beds in specially protected natural areas, particularly those in the state nature reserves of “Yugansky” and “Malaya Sosva”, and forest fire beds in kinship lands within the municipal boundaries (figure 6).

4. Conclusions
Thus, by using the geo-information method, we have analyzed the natural risk zones and the degree of natural hazard in the territory exposed to adverse natural processes. We emphasize that monitoring the natural hazards of the region is essential for territorial planning.

Geographic information systems and technologies applied for monitoring the environment and territory are to identify new patterns, characterizing land use that meets the needs of society, availability of other resources, dynamics of the population, research and technological achievements, as well as to improve the analysis methods, forecast and plan the use of land resources, determine the efficiency of land use from economic, social, and environmental positions, develop new tasks, raise concerns, reflecting current social development, social production forces, needs and requests for the use of research results, when working on forecast and planning documents.
Figure 6. Distribution of forest fire beds in Khanty-Mansiysk Autonomous Area-Yugra in June 2012: a satellite image [10] and a schematic map (compiled by the author).

Contributing to solving the major land monitoring tasks of systematic land observation, assessment and forecast of territory changes under the impact of natural and anthropogenic factors, geo-
information systems aim to create effective land management, including that at the regional level.

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