Remote sensing monitoring of historical centre of Kyiv for reducing risks from disasters at world heritages properties

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ABSTRACT

Geological aspects of object localization for the cultural heritages in the territory of Kyiv are studied. The monitoring of landslides processes for the Kyiv and landslide risk assessment for the cultural heritage with using remote sensing data is provided. In this paper on example of certain areas of the Kyiv metropolitan area the application of methodological issues are considered in the analysis of cosmic material changes in the landscape and the functional structure of Kyiv are associated with intense development in the valley of the Dnieper river and within the historical part.

Keywords: remote sensing, landslide risk, cultural heritages, morphological analysis, infrared satellite imagery.

1 USE OF MULTISPECTRAL SATELLITE IMAGES FOR RESEARCHES OF LANDSLIDE PROCESSES FOR THE TERRITORY OF KYIV.

The landslide processes on the territory of Kyiv city depend upon the geological structure of the right bank slopes of the Dnieper and valleys of Dnieper’s tributaries cut into the plateau. The areas of landslide are characterized by multi-level geological structure with interlayering water-permeable, water-saturated and watertight sediments. Two zones of development of gravitational processes are located on these territories: Miska (City) and Dnieper’s slope (Pridneprovsk). The overall area of landslide zones is 400 hectares and over 130 slope dangerous areas are there that is presently stabilized with 33 kilometers of prop walls.

Engineering structures were built on the steep slopes of the Dnieper since the beginning of XII century at the development of the Kyiv Pechersk Lavra. The artificial changes of the hydrological regime of the Dnieper, intensive building on slopes and construction of necessary network of communications caused the activation of gravitational processes in the second half of the XIX century [Starostenko et al., 2011].

The rational set of types of space surveys was developed on the base of the authors’ researches of landslide processes for twenty-year period and results obtained by authors during monitoring of the state and development of slope areas. Today, at the study of features of location and structure of landslide areas themselves the authors use the multispectral space images with high spatial resolution (from the satellites Ikonos, Quick Bird).

The important part of geocological researches of gravitational processes is a multiparameter analysis of geodynamic zones. Their linear character is considered as the manifestation of fault systems across the surface. These systems penetrate through the sedimentary cover and basement structure and also manifest themselves in the recent relief. Therefore the use of multispectral SI enables to study the recent geodynamic processes on the interpretation results for zones of geodynamic tension and determination of points of their crossing. In such zones, the change of physical properties of sediments is observed with formation of geothermal, geohydrological and geochemical anomalies and development and activation of recent exogenous processes (landslides, erosion, subsiding of soils and others).

For the interpretation of zones of geodynamic tension at the regional level, the Landsat, SPOT, Resource multispectral images are successfully used for a long time. As a result of interpretation, the spatial models of zones of geodynamic tension were built for on territory of the Kyiv municipal agglomeration. There is certain inheritance of faults in the crystalline basement, faults activated on the neotectonic stage in the
sedimentary cover in relation to the geodynamic zones indicated using satellite images. The faults accordingly geological and geophysical data gradually reduce their amplitudes in the upper sedimentary horizons and quite often become amplitude-less ones forming the zones of higher fracturing. The identification of such zones is outside the possibilities of geophysical methods, but they can be revealed by the results of structural geomorphologic researches and geindication interpretation of satellite images (Fig. 1).

Fig. 1 Geodynamic zones and landslides activated as of July 2013: 1 - zones of geodynamic tensions recognized in the crystalline basement and interpreted on the remote sensing data, 2 – zones of geodynamic tensions on the same data, 3 – activated landslides.

The results of carried out investigations showed that landslide-dangerous territories of city mostly tried the technogenous influence from the end of past century, and stabilization of some areas that reached an equilibrium and activation of others, where stability was disturbed, took place. The development of landslides caused by several factors, among which the most important are the hydrometeorological conditions and anthropogenic impact on the geological environment.

The maximum of landslide activity is at the intense spring snowmelt and during heavy rainfall. This became evident in landslide-dangerous areas of the city of Kyiv, where the new eighteen landslides are appeared in spring 2013, about half of which are located in the central historical sector of the Pridniprovska landslide zone related to the Kyiv neotectonic fault. In this case, the dominant role in the development of landslides belonged to the natural factors against the background of the anthropogenic influence.

The recent activation of gravitational processes is provoked by the mass building on the slopes of small rivers and large dry creeks in the Kyiv Historical Centre know as World heritage, in the landslide-dangerous zone with complicated relief. The slide processes of the slopes of the hardrock plateau caused by slope cutting, disturbance of drainage, excess loadings of the building structures at the so-called Kyiv Mountains (Batyiva Hora, Zamkova Hora, Zamkova Hora, Lysa Hora, Cherepanova Hora etc.) are observed.

The top-priority importance in solving of many environmental problems belongs to the morphological and morphodynamic analyses of relief within the urban area. The matter flows by the action of gravitation processes lead to the considerable changes and transformation in the natural and man-made system. The relief controls the flows of matter and energy, concentrating and dispersing them. The defining principle of the exogenous processes is their tendency to the surface smoothing.

The methodic base of the morphodynamic analysis is the division of the relief into some skeletal elements (keel and crest lines, line of concave and convex bends). These lines separate the plane elements with different circulating, insolation and gravitational exposures. The keel lines are represented as vectors, which gives them a physical importance in the determination of matter flows over ground surface. The locations which are characterized by the certain structural features, plan configuration, the density of skeleton relief elements are considered as individual locations.

The highest density of skeleton elements is characteristic of the city center, which structurally corresponds to the Pechersk horst (Fig. 2).

Fig. 2. Skeleton relief of the Pridniprovska landslide zone in Kyiv: 1 - keel lines; 2 – crest lines

Altitudes are up almost 200 m, and the topographic prominences over the Dnieper river channel reach 100 meters. It’s these hypsometrical gradients and covering loams have created the network of closely spaced, short skeleton lines. In this area, the erosion and gravitational subsidence processes reached the most development,
which formed the natural relief. The morphodynamic analysis of relief skeleton structure enabled to identify some individual locations in Kyiv with characteristic structure and density of keel and crest lines and its own list of the exogenous relief formation processes causing the disturbances in the natural and man-made system of the city.

Ignoration of the features of the geomorphological structure and relief forming processes under conditions of unjustified increase of the anthropogenic load may be dangerous similarly to those that formed on the northeastern slopes of the Batyiva Hora in the spring of 2013. After analyzing a series of high spatial resolution SI, the preconditions of their formation were determined. In 2002-2003, during the erection of apartment house buildings on Kudryashova street, 3, the Batyiva Hora slope was cut, but it remained stable until the start of intense building of private multi-floor houses with the underground engineering structures and communications, artificial watering. This caused a disturbance of the natural drainage of the slope.

The influence of intense rainfalls led to excessive watering of upper loamy diluvial deposits and slide of them. In some older homes, which practically have not downpour drainages, cracks, landslides and destruction are occurred. The road was destructed. The height of the slope from the top of Batyiva Hora over the Lybid river valley is 68 m. The slope is complicated by landslide platforms and narrow terraces, which provided the base for streets and near-home garden area placing. For many years, the slope surface passed through planning, leveling, cutting off under the influence of anthropogenic factors and was rapidly built up (Fig.3). Currently, forming of the so-called "Heat island" is typical for urban areas; it associated with the surface temperature difference between the center of the city and its periphery. Seals of urban development and reducing urban green areas in the historical part of Kyiv lead to increasing surface temperature of man-made objects, which contributes to their physical weathering and gradual destruction. With heavy construction related to so-called "Sealing" of soil from concrete and asphalt, which violates the natural circulation of groundwater and surface water, evaporation and moisture. On the natural circulation of groundwater also affects the construction of high-rise buildings with multi-depth foundation and underground parking, which form barrage lockup and groundwater, causing flooding surrounding areas, and in some cases, provoke the development of landslides.

This activation of slope processes took place also for the Zamkova Hora (Vozdvidzenka area) (Fig.4), slopes of the Dnieper (near Kyiv Pechersk Lavra, St Andrew's Church and on Andriyivskyy Descent). In spite of a number of preventive anti-landslide measures, which were always performed here, the slopes did not withstand heavy snowfalls and their dynamic equilibrium was broken.

2 THE STUDY OF THE DISTRIBUTION OF SURFACE TEMPERATURES IN THE HISTORICAL PART OF KYIV.

Currently, forming of the so-called "Heat island" is typical for urban areas; it associated with the surface temperature difference between the center of the city and its periphery. Seals of urban development and reducing urban green areas in the historical part of Kyiv lead to increasing surface temperature of man-made objects, which contributes to their physical weathering and gradual destruction. With heavy construction related to so-called "Sealing" of soil from concrete and asphalt, which violates the natural circulation of groundwater and surface water, evaporation and moisture. On the natural circulation of groundwater also affects the construction of high-rise buildings with multi-depth foundation and underground parking, which form barrage lockup and groundwater, causing flooding surrounding areas, and in some cases, provoke the development of landslides.

There are many works in different countries on topic of study the thermal field of urban areas using satellite data subject. Preferably, they addressed to issues related to energy conservation and identification of heat losses in public services, and contribution of big cities to climate change. The aim of this work is to study the thermal field within the historical part of Kyiv (St. Sophia Cathedral, Kyiv Pechersk Lavra) and determine its trends [Filipovich & etc., 2014].

Processing and analysis of thermal data obtained by the Landsat satellites show that the historical part of Kyiv (Center, Pechersk, Podol, etc.) is characterized by the sustainable increase in surface temperature (Fig. 5, 6). On the other hand, the heating over the green park belt and other vegetated areas remains almost the same.
Table shows the statistical data for change dynamics of the maximum surface heating-up for the areas in the vicinity of the National Preserves "St. Sophia of Kyiv" and "Kiev Pechersk Lavra" for the period 1987-2014. Data comparison shows that the area of maximum surface heating-up within the buffer zone of the National Preserve "St. Sophia of Kyiv" have increased more than 10-fold (Table).

Table. The areas of maximum surface heating-up

<table>
<thead>
<tr>
<th>№</th>
<th>Year</th>
<th>Area (km²)</th>
<th>St. Sophia</th>
<th>Lavra</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1987</td>
<td>0,1001</td>
<td>0,07811</td>
<td>0,17821</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1992</td>
<td>0,1252</td>
<td>0,05743</td>
<td>0,18263</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2014</td>
<td>1,2700</td>
<td>0,07563</td>
<td>1,34563</td>
<td></td>
</tr>
</tbody>
</table>

Within the buffer zone of "Kiev Pechersk Lavra" the warm-up surface area increased insignificantly (Fig. 7, 8). The reason for this "inequality" lies, in our view, in increasing number of new buildings and renovations in the city center, where the area of green space has been cut a lot and the lawns were paved with artificial materials (tiles, asphalt, concrete). It especially concern the Independence Square and streets that go up from the Khreschatyk street to Sophia of Kyiv.

Analysis of the received data for the buffer zone of the National Preserves "St. Sophia of Kyiv" shows the maximum increase in surface heating-up just coincides with the above mentioned places (south-eastern part - Fig. 6, 9-A). In the northwestern part (Fig. 9-A) the emergence of new large surface heating-up contour is connected with dense housing of Vozdvizhenska street and surrounding areas. While this contour is outside the buffer zone, its effect is spreading to the adjacent sites of protected area.

Significant changes in the surface heating-up for the buffer zone near the reserve "Kiev Pechersk Lavra" (Fig. 8, 9-B ) was not observed in 2014 in comparison with 1987. This is due to the large forest- park zone with natural soil - vegetation cover as well as the minimum new construction objects over these years.
Fig. 9. Comparative cartogram of the changes of surface heating-up within the buffer zone of the Reserves: A - "St. Sophia of Kyiv", B - "Kyiv Pechersk Lavra" for the period 1987-2014;
1 - conservation area, 2 - buffer zone boundaries, 3 - the area of maximum surface temperature in 1987, 4 – the area of maximum surface temperature in 2014.

3 CONCLUSIONS

These data indicate that the use of satellite data in monitoring urban landscapes can quickly track the changes of landscape and the functional structure of urban areas, identify the dangerous trends in their development and control the violations of environmental legislation that can result in optimal management decisions in environmental and urban planning.

Monitoring of the thermal field within the historical part of Kyiv shows that a decrease of natural land cover and densification of urban areas cause the increase of surface heating-up in that area. As local microclimatic conditions this can cause violation within protected areas and promote climate change at the regional level. The latest refers to the growth of the "heat islands" over the towns that attract close attention of almost all developed countries. The local disturbance of microclimate as one of the factors affects the physical weathering and the decay of the historical monuments from the World Heritage (Fig. 10).

Fig. 10. The wall around of St. Sophia’s Cathedral.

Thus, protection of vegetation cover and the growth of its areas in the historical part of Kyiv is a priority task to preserve the ancient architectural ensembles. Also, in our opinion, it is necessary to introduce the European countries experience for the construction of the buildings with "green roofs" that reduce the negative impact of high temperature on the urban environment in summer and reduce heat and energy losses in the winter. Germany and Switzerland are the most advanced in this issue. These countries have adopted a new bill, which states that any new building constructed with a flat roof should have greenery on it.

In 2014 the City Council Resolution were adopted, according to which the buffer zone is created in the historical center of city and the construction of new buildings there are prohibited. The area of buffer zone is 441 ha. It includes the Dnieper River slopes and the streets in the city center (Fig. 11).

Fig. 11. New buffer zone of Kyiv historical part.

REFERENCES