КАРТОГРАФІЯ І АЕРОФОТОЗНІМАННЯ

CARTOGRAPHY AND AERIAL PHOTOGRAPHY

УДК 528.952

N. HRYTSKIV*, L. LAYKUN, L. BABIY

Department "photogrammetry and geoinformatics", Lviv Polytechnic National University, 12, S. Bandery str., Lviv, Ukraine, 79013, *tel. +38(032)2582616, e-mail Nazar.Z.Hrytskiv@lpnu.ua

MAPPING OF AVALANCHE DANGEROUS TERRITORIES USING GIS TECHNOLOGIES

Purpose. Avalanching is a natural phenomenon that can cause loss of life, destructions of residential and industrial buildings, inflict losses on forestry, agriculture and tourism development in mountainous areas. Monitoring and research of potential avalanche dangerous territories is an urgent task. Geoinformation modeling plays leading role for its solving. The purpose of this paper is to create raster thematic maps of avalanching hazards on the base of analysis of certain morphometric and environmental factors of avalanching in the territory of the mountain ridge Polonyna Borzhava. **Methodology.** Digital terrain models were obtained by vectorization of cartographic materials. This created vector models were interpolated into raster model, which became the basis for classification of geomorphometric factors of avalanching. The following factors of avalanche formation have been selected: fixed (hillside slopes, curvature and hills exposure) and variable (direction of winds). Resulting rasters were reclassified for further operations using the tools of map algebra, such as raster calculator. The classes of avalanche dangerous areas, depending on the combination of values of slope and exposure, were sorted in the resulting summation of rasters of slopes, curvature and orientation of slopes and generalization of the number of received classes. **Results**. A digital elevation model and raster thematic map of avalanche dangerous territories of mountain ridge Polonyna Borzhava were created. **Originality.** A comprehensive approach that includes integration of cartographic material, statistical meteorological data and some geomorphometric data about surface in a unified geographic information system allocates the territories with consistent snow avalanche phenomena of mountain ridge Polonyna Borzhava. **Practical significance.** Certain geomorphometric parameters of relief of mountain ridge Polonyna Borzhava were considered to determine areas with different degrees of avalanche hazard. Mapping of snow avalanche phenomena of Polonyna Borzhava ridge in scale of 1 : 50000 was implemented. The thematic map of relative avalanche hazard will allow professionals to focus on specific territories during the planning activity considering potential threats caused by snow avalanches.

Key words: avalanching hazard, thematic mapping, geomorphometric parameters of surface, digital elevation model, GIS-technologies, ArcGIS.

Introduction

Avalanches are a spontaneous natural phenomenon that shift a large masses of snow on mountain slopes. Their movement downwards at high speed can cause a loss of life and significant destruction of residential and industrial buildings, inflict losses on forestry, agriculture, and tourism development in mountainous areas. There are two groups of avalanching factors: fixed and variable. Fixed factors include conditions associated with the terrain relief and underlying surface: relative altitude, multipartite relief, steepness and exposure of slopes, curvature, and surface roughness. Variable factors include: weather (snow intensity, type of new snow and its daily increase, rain, wind); thermal conditions; solar radiation; condition inside of snow cover (total height of snow and its stratigraphy) [Kolotukha O. V., 2008; Baran Ya., 2015]. The slope and exposure are the main morphometric parameters that are most commonly used for predicting the emergence of avalanches can be obtained from topographic maps. Various meteorological factors are more difficult to map and visualize because of their inherent variability in time, dynamics and lack of unique space reference [Kriz, 2001]. Therefore, authors attempt to build a simplified model taking into account certain factors of avalanching and on its basis to create a thematic raster map of avalanche danger.

Analysis of literary sources

The basic method of geomorphometry is geomorphometric analysis, which includes obtaining quantitative characteristics of the earth's

The tool Topo to Raster interpolates hydrologically correct raster surfaces using point, linear, and polygonal data. The tool uses an interpolation method specifically designed to create a continuous surfaces using data of contours that represents more precisely natural drainage surface and better recreates the networks of structural and streams lines. Isolines are reliable indicators of streams and watershed lines (ridges). For such type of input data as a contour the algorithm first creates a generalized surface morphology based on contour curvature. After determining the general morphology of the surface we used contour data for the interpolation of elevation value in each cell.

This method was chosen because it is specifically designed to create DEM using contours data that are the main part of input vectorized data. This method has some advantages over other methods of interpolation. It is optimized to have the computational efficiency of local interpolation methods, such as interpolation by the method of inverse weighted distances (IWD). DEM, created by this method, corresponds to sharp surface changes (such as canyons, mountain ridges, steep cliffs) [Help ArcGIS (10.2, 10.2.1 and 10.2.2)].

To display the DEM there were assigned 7 elevation classes (from 1,000 m to over 1,600 m) with a step interval of 100 meters. Relief washing tools with translucency element had been used for better visual perception. This raster DEM (Fig. 4) was used as the basis for creation of a series of raster geomorphometric parameters of the surface of Polonyna Borzhava ridge.

Hills slope (steepness) raster was created using the tool Slope. The slope of the surface - the angle at the point between the horizontal plane and the plane tangent to the earth's surface; defines the intensity of height change (gradient) between two given points. If the earth surface is presented as function (1), then the slope is calculated taking into account changes in the values of z in two directions:

$$a = \tan^{-1}\left(\sqrt{\left(\frac{\partial z}{\partial x}\right)^2 + \left(\frac{\partial z}{\partial y}\right)^2}\right), \qquad (2)$$

where $\frac{\partial z}{\partial x}$ and $\frac{\partial z}{\partial y}$ – first-order derivatives, which determine changes of the absolute values of z in directions: west–east (x) and north–south (y) [Svidzinska D. V., 2014].

The value of slope is given in degrees with a step of 15°. Such classification allows us to determine the areas of the ridge which are potentially avalanche dangerous (parts with slope 15°–45°) and the areas where avalanches are unlikely or impossible. Fragment of created raster is shown on Fig. 5.

The raster of hills orientation in relation to the cardinal (compass) directions, a hill exposure raster was created using the tool Aspect. For the earth surface presented as function (1), the exposure is calculated on the formula:

$$b = \tan^{-1}\left(\frac{\partial z/\partial x}{\partial z/\partial y}\right), \qquad (3)$$

where $\frac{\partial z}{\partial x}$ and $\frac{\partial z}{\partial y}$ – first-order derivatives, which determine changes of the absolute values of z in directions: west–east (x) and north–south (y) [Svidzinska D. V., 2014]..

The raster was classified by the equal interval method with the step 45°, which give possibility to distinguish 8 classes of slopes according to cardinal and secondary compass direction. Different colors represent slopes with corresponding orientation. (Fig. 6).

Curvature raster of the ridge surface was created using the tool Curvature (Fig. 7). Plane (horizontal) curvature is curvature of the line created by intersection of the earth surface with the plane which is perpendicular to the direction of exposure of maximum gradient. It describes gradient of exposure along given line.

If the earth surface is presented as function (1), then the plane curvature is a function of its partial derivatives and is calculated by the formula: [Svidzinska D. V., 2014].:

$$C = \frac{\left(\frac{\partial z}{\partial y}\right)^2 \frac{\partial^2 z}{\partial x^2} - 2\frac{\partial z \partial z}{\partial x \partial y}\frac{\partial^2 z}{\partial x \partial y} + \left(\frac{\partial z}{\partial x}\right)^2 \frac{\partial^2 z}{\partial y^2}}{\sqrt{\left(\left(\frac{\partial z}{\partial x}\right)^2 + \left(\frac{\partial z}{\partial y}\right)^2\right)^3}}. \qquad (4)$$

For its representation there was used stretch function: concave areas are shown with black color (depressions with river valley); convex areas are shown in white (watershed zones).

Fig. 1. Object of study – Polonyna Borzhava ridge

Snow cover appears in early November, and sometimes even in September. The reduction of snow cover begins in March, but on some areas it is stored until June. At altitudes of over 1,000 meters above sea level snow cover reaches a capacity of 1.0–1.5 m, and in some places snow accumulation is more than 3.0 m. In average about 1700 mm of precipitation per year falls in this area. It is far more than on other parts of the Ukrainian Carpathians. More than 30 % of this precipitation fall during the cold season. Snow is blown out by wind (mostly south-western rhumbs constituting more than 50 % of the total amount) from near crest and forestless areas of mountains onto slopes and are accumulated as large mass in different lowlands (denudation basins, erosion furrows, thalweg) and in the upper forest areas. On the slopes of Polonyna Borzhava ridge there are recorded 36 avalanche dangerous sites continuously active in which 539 avalanching's had been recorded from 1970 till 2009. [Mjagkov S. M., Kanaev L. A., 1992; Kolotukha O. V., 2008; Tavrov Yu. S. , Grishchenko V. F., 2011; Tykhanovych Ye. Ye., Bilanyuk V. I., 2015].

Data accumulated over the years allows one to highlight some areas of the Polonyna Borzhava ridge where avalanching occurs more often. However, to cover all areas of this rather large territory under the field conditions with adverse weather is difficult. Therefore for forecasting of avalanches it is advisable to use geo-modelling techniques.

Purpose

Monitoring and researches of potential avalanche dangerous territories is an urgent required task, and means of geoinformation modeling play leading role in its solution. The purpose of this paper is to create a raster thematic map of avalanching hazards on the base of analysis of certain morphometric and environmental factors of avalanching in the territory of the mountain ridge Polonyna Borzhava.

Methodology

The main geomorphometric parameters that determine the possibility of avalanches formation on some territories are hillside slopes, hill exposure and surface curvature. We used theses geometric factors as the basis for modeling. The study was conducted according to workflow presented in Fig. 2.

The experimental works that used were cartographic material and data of meteorological observations: raster topographic map of Svaliava district in scale 1 : 50.000 with contour interval 20 meters published by SSPE "Kartographia" in 2010 (Fig. 3), which was the basis for DEM creation. Data for the climatic conditions of the area of research was obtained from statistic meteorological observations of the prevailing wind directions from the weather station "Plaj" for a period of 30 years.

All subsequent stages of the work had been done using geographic information system AcrGIS. This is a fully functioning Geographic Information System software product used for geodata analysis and for solving applied problems, that include mapping and spatial analysis.

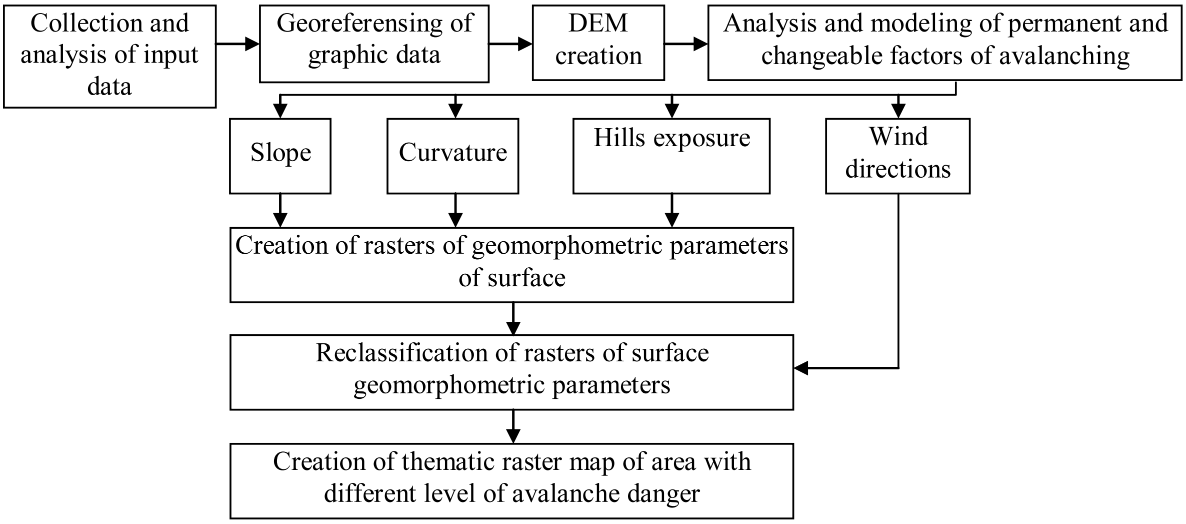

Fig. 2. General workflow of study

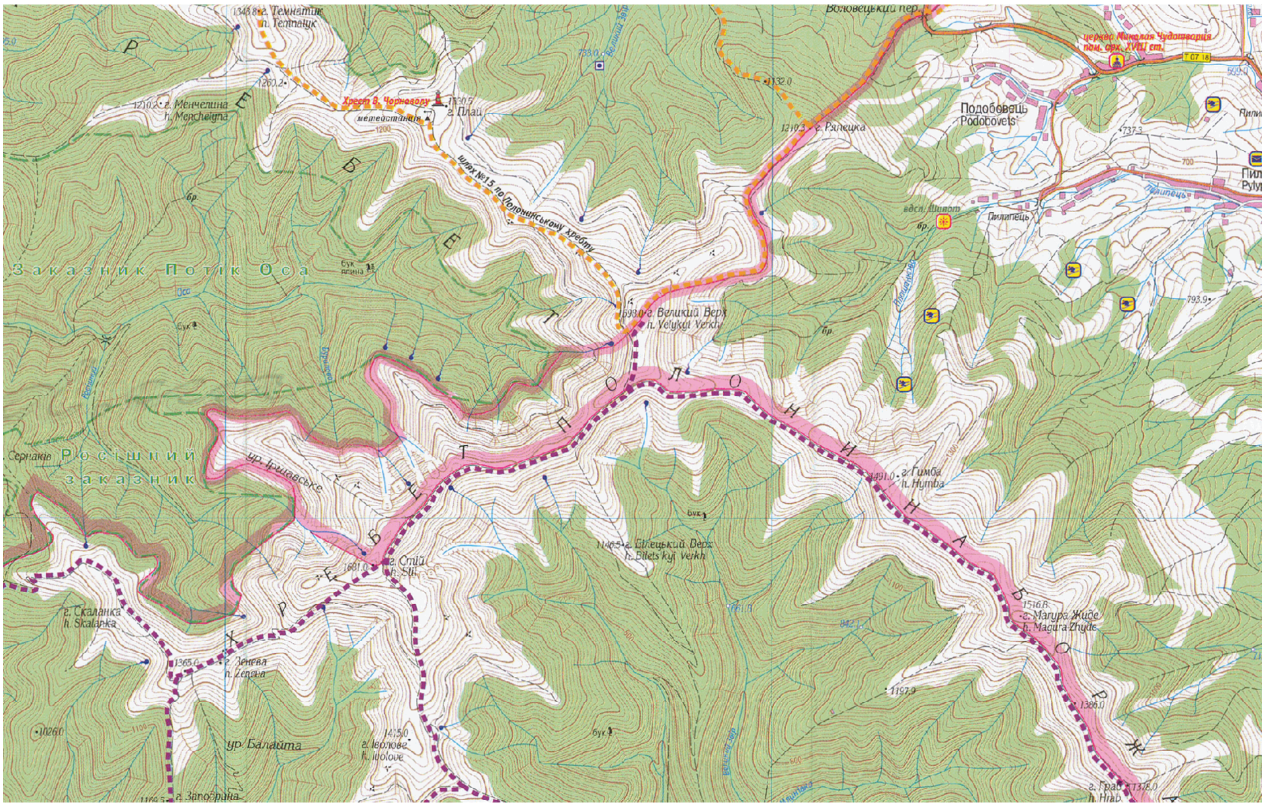

Fig. 3. Fragment of topographic map of Polonyna Borzhava ridge

An input topographical map was scanned with the resolution of 256 dpi, the size of one pixel corresponds to 5 m on the ground. Map georeferencing was done using the tool Georeferencing. As result map has coordinate system WGS_1984_UTM_Zone_34N.

A digital elevation model was built on created vector layers of contours and elevation marks ranging from a height of 1.000 meters, that covers the territory including the upper tier of the forest. For a better visual perception the hydrographic network and the upper area of the forest were vectorized.

Further works were implemented using tools of surface analysis (Spatial Analyst Tools). With Topo To Raster tool, the raster DEM had been created using vectorized contours and elevation marks.

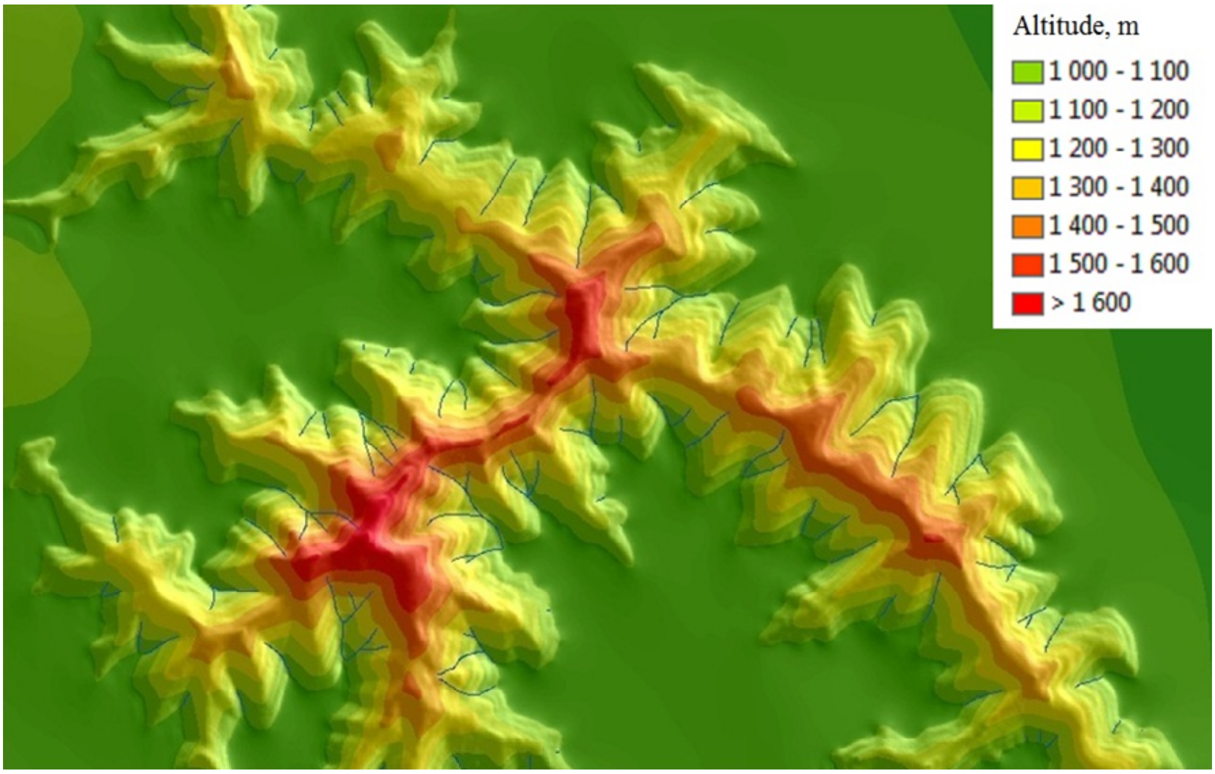

Fig. 4. Fragment of DEM raster with hydrographic network

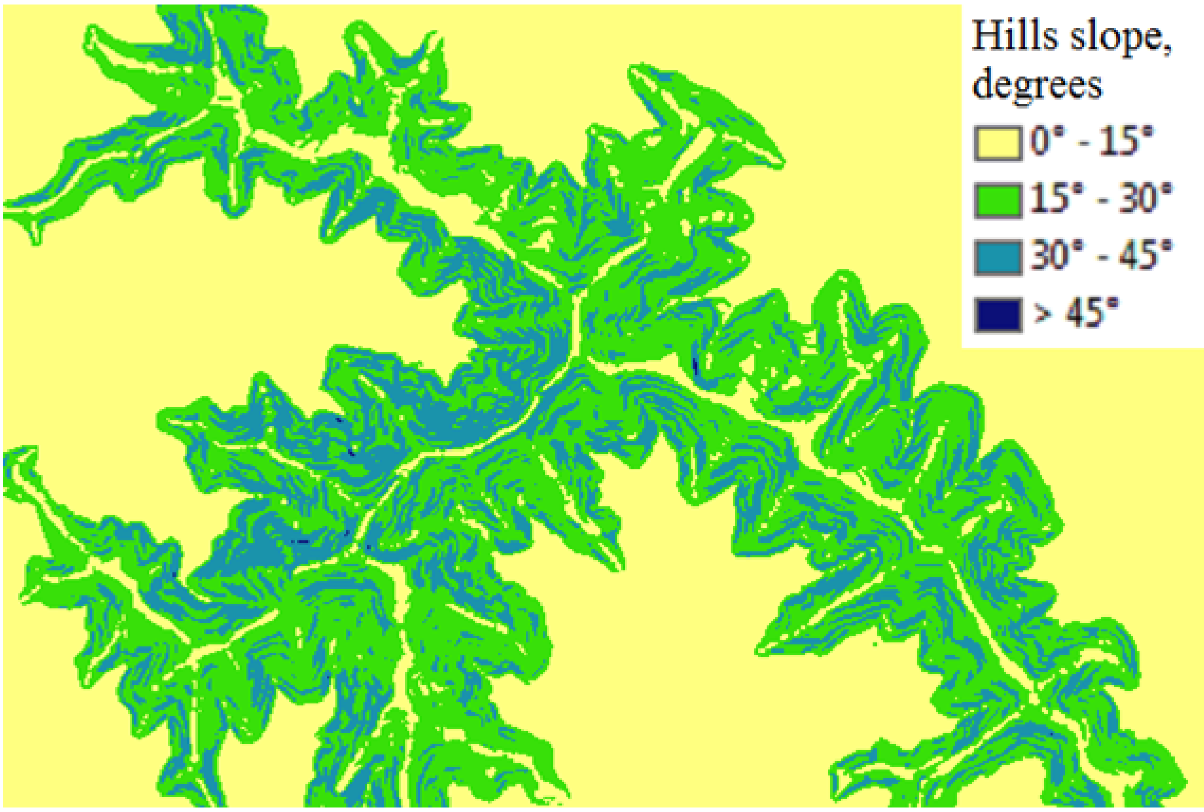

Fig. 5. Fragment of hill slope (steepness) raster in degrees

The tool Topo to Raster interpolates hydrologically correct raster surfaces using point, linear, and polygonal data. The tool uses an interpolation method specifically designed to create a continuous surfaces using data of contours that represents more precisely natural drainage surface and better recreates the networks of structural and streams lines. Isolines are reliable indicators of streams and watershed lines (ridges). For such type of input data as a contour the algorithm first creates a generalized surface morphology based on contour curvature. After determining the general morphology of the surface we used contour data for the interpolation of elevation value in each cell.

This method was chosen because it is specifically designed to create DEM using contours data that are the main part of input vectorized data. This method has some advantages over other methods of interpolation. It is optimized to have the computational efficiency of local interpolation methods, such as interpolation by the method of inverse weighted distances (IWD). DEM, created by this method, corresponds to sharp surface changes (such as canyons, mountain ridges, steep cliffs) [Help ArcGIS (10.2, 10.2.1 and 10.2.2)].

To display the DEM there were assigned 7 elevation classes (from 1,000 m to over 1,600 m) with a step interval of 100 meters. Relief washing tools with translucency element had been used for better visual perception. This raster DEM (Fig. 4) was used as the basis for creation of a series of raster geomorphometric parameters of the surface of Polonyna Borzhava ridge.

Hills slope (steepness) raster was created using the tool Slope. The slope of the surface - the angle at the point between the horizontal plane and the plane tangent to the earth's surface; defines the intensity of height change (gradient) between two given points. If the earth surface is presented as function (1), then the slope is calculated taking into account changes in the values of z in two directions:

$$a = \tan^{-1}\left(\sqrt{\left(\frac{\partial z}{\partial x}\right)^2 + \left(\frac{\partial z}{\partial y}\right)^2}\right), \qquad (2)$$

where $\frac{\partial z}{\partial x}$ and $\frac{\partial z}{\partial y}$ – first-order derivatives, which determine changes of the absolute values of z in directions: west–east (x) and north–south (y) [Svidzinska D. V., 2014].

The value of slope is given in degrees with a step of 15°. Such classification allows us to determine the areas of the ridge which are potentially avalanche dangerous (parts with slope 15°–45°) and the areas where avalanches are unlikely or impossible. Fragment of created raster is shown on Fig. 5.

The raster of hills orientation in relation to the cardinal (compass) directions, a hill exposure raster was created using the tool Aspect. For the earth surface presented as function (1), the exposure is calculated on the formula:

$$b = \tan^{-1}\left(\frac{\partial z/\partial x}{\partial z/\partial y}\right), \qquad (3)$$

where $\frac{\partial z}{\partial x}$ and $\frac{\partial z}{\partial y}$ – first-order derivatives, which determine changes of the absolute values of z in directions: west–east (x) and north–south (y) [Svidzinska D. V., 2014].

The raster was classified by the equal interval method with the step 45°, which give possibility to distinguish 8 classes of slopes according to cardinal and secondary compass direction. Different colors represent slopes with corresponding orientation. (Fig. 6).

Curvature raster of the ridge surface was created using the tool Curvature (Fig. 7). Plane (horizontal) curvature is curvature of the line created by intersection of the earth surface with the plane which is perpendicular to the direction of exposure of maximum gradient. It describes gradient of exposure along given line.

If the earth surface is presented as function (1), then the plane curvature is a function of its partial derivatives and is calculated by the formula: [Svidzinska D. V., 2014]:

$$C = \frac{\left(\frac{\partial z}{\partial y}\right)^2 \frac{\partial^2 z}{\partial x^2} - 2\frac{\partial z \partial z}{\partial x \partial y}\frac{\partial^2 z}{\partial x \partial y} + \left(\frac{\partial z}{\partial x}\right)^2 \frac{\partial^2 z}{\partial y^2}}{\sqrt{\left(\left(\frac{\partial z}{\partial x}\right)^2 + \left(\frac{\partial z}{\partial y}\right)^2\right)^3}}. \qquad (4)$$

For its representation there was used stretch function: concave areas are shown with black color (depressions with river valley); convex areas are shown in white (watershed zones).

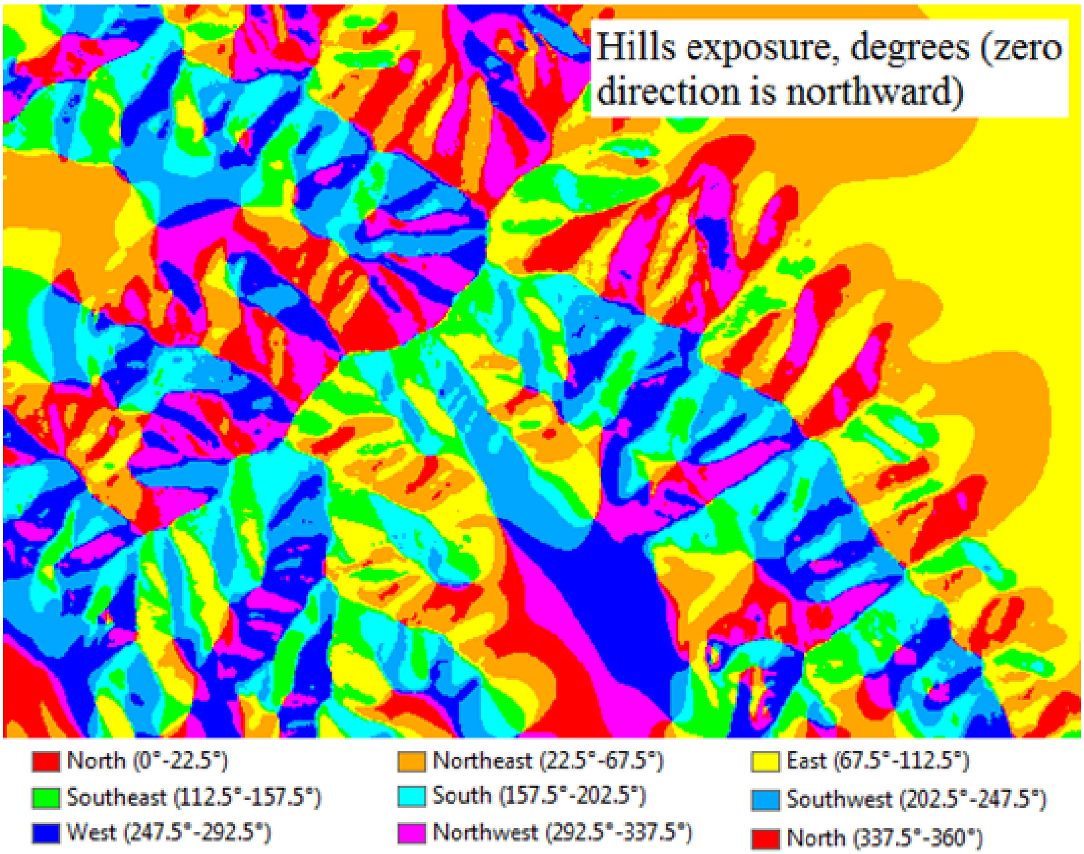

Fig. 6. Fragment of hill exposure raster in relation to the cardinal and secondary compass directions

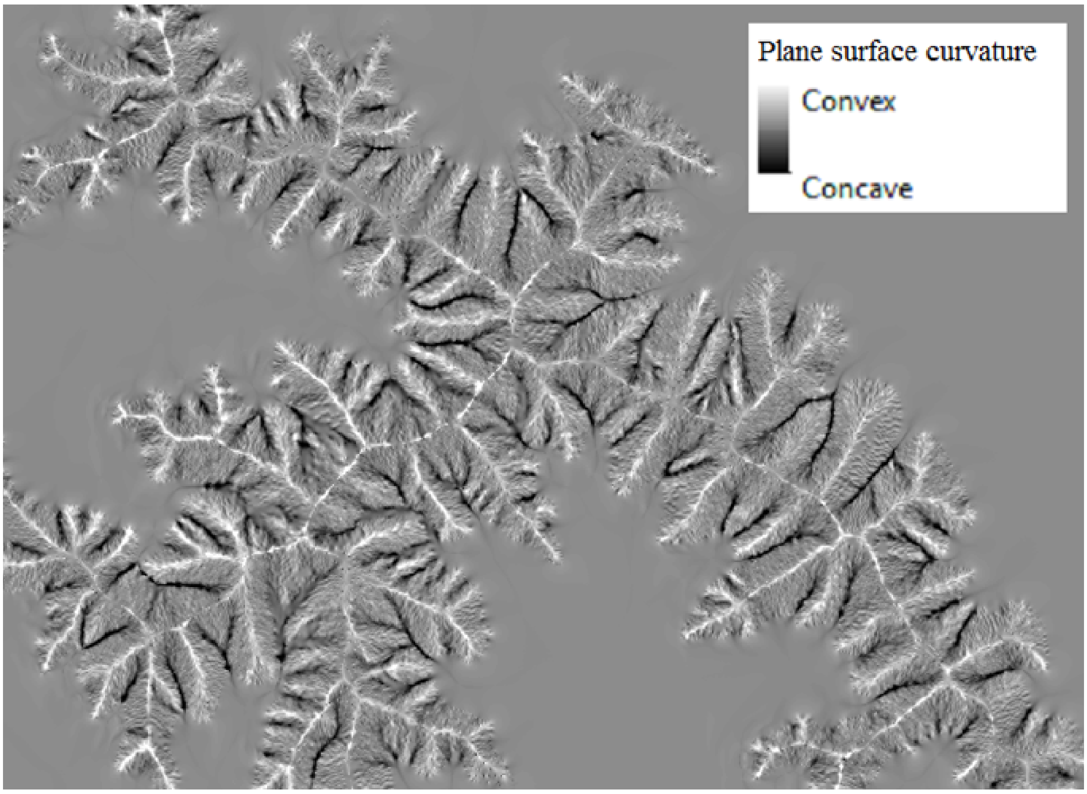

Fig. 7. Fragment of plane surface curvature raster

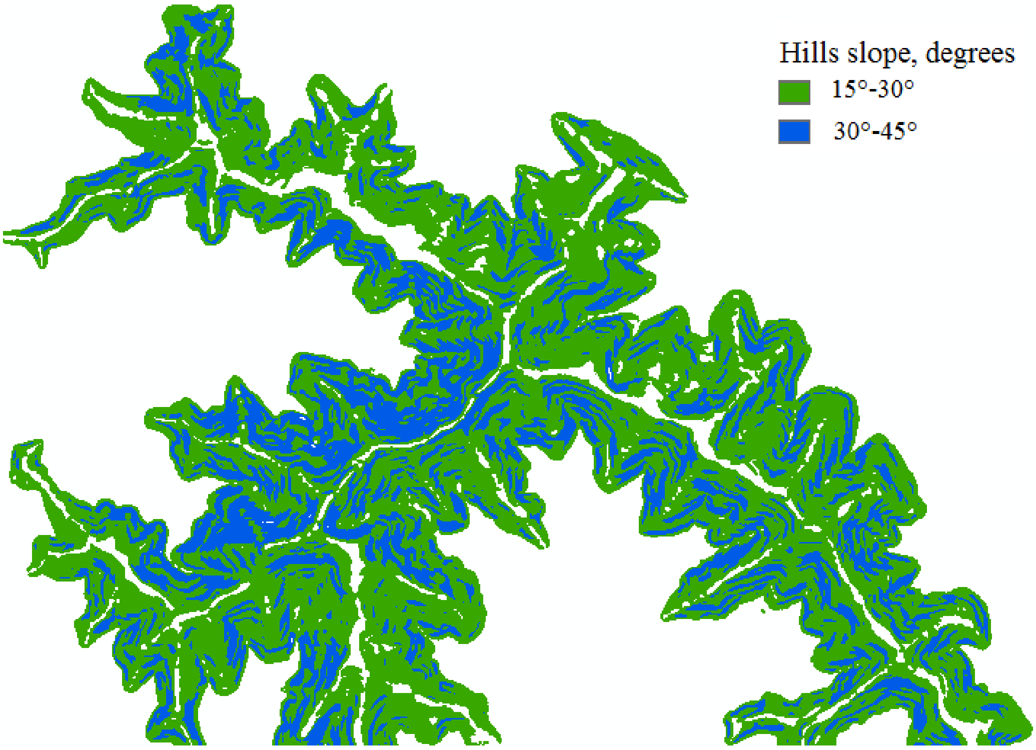

Fig. 8. Fragment of reclassified hill slope (steepness) raster in degrees

The next stage of the study is reclassification of created raster images for processing using the map algebra tool (namely, raster calculator). For hill slope raster there were allocated 2 classes – hills with slopes 15°–30° and 30°–45° (Fig. 8). These limits were chosen due to the fact that breaking of stability of snow cover and formation of avalanches are often observed on slopes from 15° to 45°. On steeper slopes snow is weakly held, as most snowflakes slip down during snowfall and rare great masses of snow are deposited relatively rare. For slopes less than 15° a load is not large enough for the occurrence of avalanches [Kolotukha O. V., 2008].

Table 1

The frequency of winds with a speed over 20 m/s according to data of Play weather station depending on rhumbs

Rhumb	% relative on total number of winds in all directions
N	5
N-E	9
E	3
S-E	6
S	17
S-W	53
W	4
N-W	3

For reclassification of the slope exposure raster we used data of winds with a speed over 20 m/s. For these winds we determined % of winds of eight rhumbs relative on total winds (Table 1). The data is captured for the period of observations 1968-1999 at the weather station Play [Lavnyy V. V., 2009].

The results show that winds of southwest direction account for 57 % and south 17 % of the total cases of recorded winds with speed more than 20 m/s. The frequency of winds of all other directions is relatively small and for each of the directions it is less than 10 % of the total. As shown in Fig. 9, the wind rose for studied territory is very asymmetric.

South-western and southern winds cause active snow transfer from windward hills. In our case snow is transferring from south-western and southern hills on the leeward north-eastern and northern hills. According to these data we allocated 4 classes of hills exposure (Fig. 10): North, North-East (with most active snow accumulation); North-West, East and West, South-East – intermediate exposure hills; South-West, South (with most active snow transfer).

Raster of plane curvature of surface (Fig. 7) was reclassified for visual evaluation of potential areas of snow accumulation and trajectories of avalanches movement on hills. Numerical values of curvature: for concave surfaces – negative and for convex surfaces – positive were assigned for the cells of output raster [ArcGIS Help (10.2, 10.2.1 и 10.2.2)]. Reclassification is made with allocation of two classes (Fig. 11): concave surface (negative values are shown with black color) and convex (positive values are shown with white color).

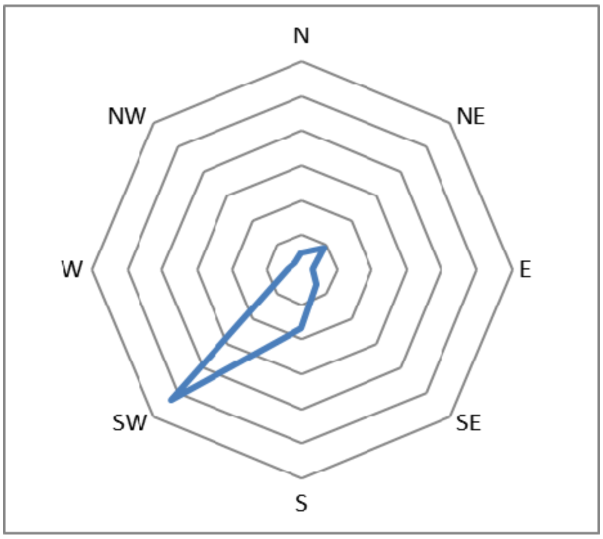

Fig. 9. Wind rose, compiled according to the data of Play weather station

Territories with positive curvature values correspond to convex areas – the so-called areas of divergence (in our case they are convex near crest areas, from which snow masses are transferred), the territories with negative curvature correspond to concave areas – convergence area (in our study they are valleys and depressions accumulating snow masses) [Svidzinska D. V., 2014].

Areas of relative avalanche danger of Polonyna Borzhava ridge had been allocated on the base of reclassified rasters and by using expressions of map algebra. For creation of the resulting raster image we used AcrGIS Raster Calculator tool. In result of summing of hill slopes raster, hills curvature raster and hill exposure raster, followed by generalization of number of received classes, we allocated four classes of areas depending on the combination of the values of slope and exposure. The high degree of avalanche danger was assigned to the hills with most active snow accumulation and largest slope value; middle level was assigned to hills with intermediate exposures relative to the prevailing wind direction and the average value of slope; low level corresponds to the hills with most active

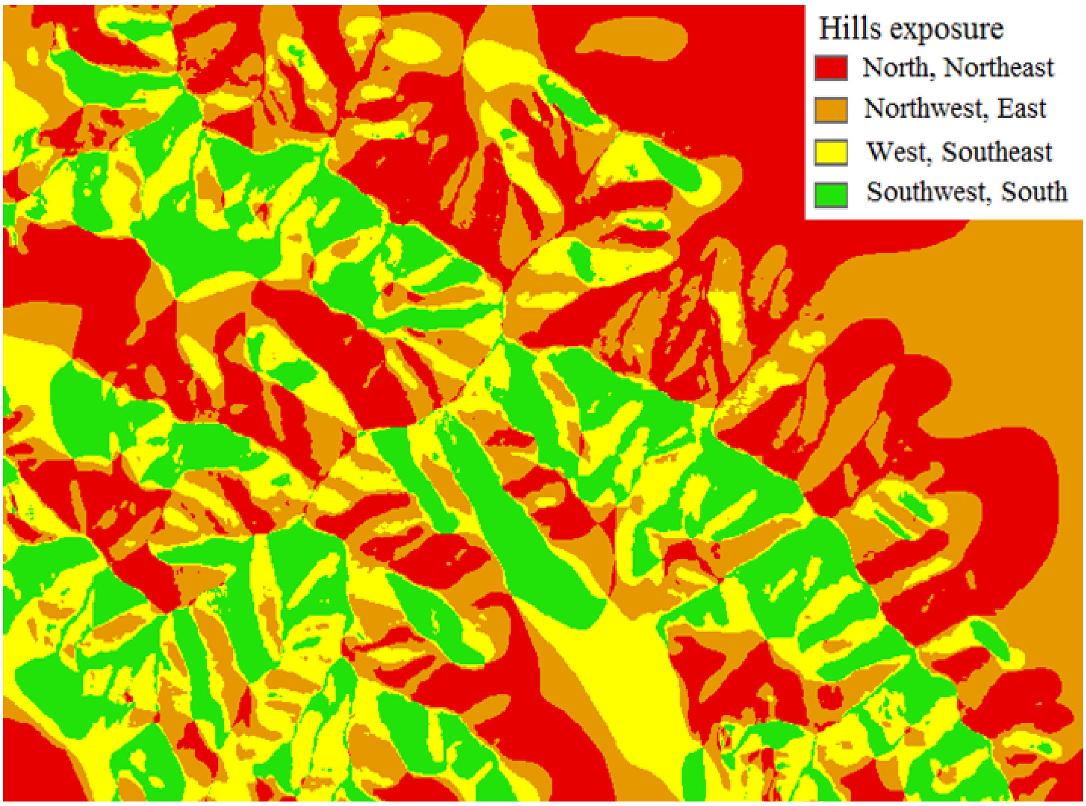

Fig. 10. Fragment of reclassified hill exposure considering directions of winds

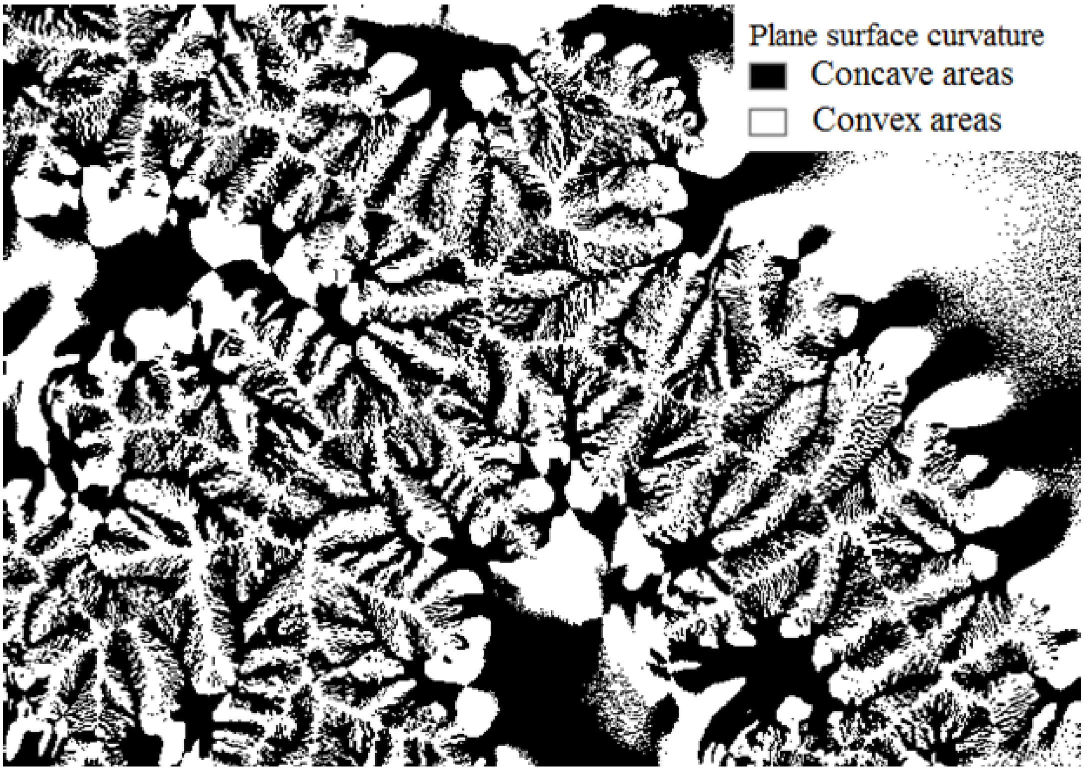

Fig. 11. Fragment of reclassified plane surface curvature raster

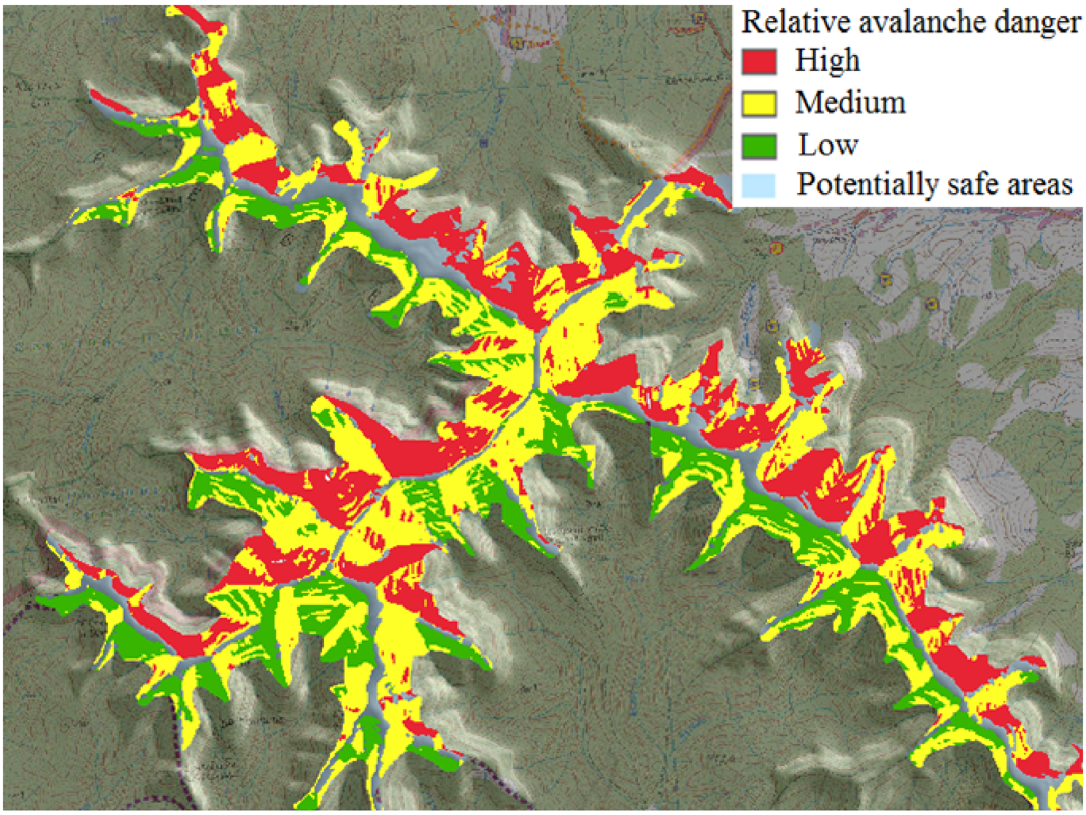

Fig. 12. The resulting relative avalanche danger raster thematic map

snow transferring and hills with small slopes. The resulting raster was cut along the upper border of the forest spread, which is also considered the lower border of spreading of avalanche phenomena. On the resulting raster of relative avalanche danger (Fig. 12) the most potential avalanches are shown in red. An average degree of potential avalanche danger is shown in yellow, and the low level relatively to the overall situation is green. Areas that are not avalanche dangerous due to too low values of hills slopes for avalanches formation are shown in blue.

The otal area of the ridge above the upper boundary of forest is 39.4 km^2. The area of avalanche area is 33.4 km^2 (84.8 %). It includes according to the classification: 10.6 km^2 (31.7 %) – areas with high level of avalanche danger; 15.6 km^2 (46.7 %) – areas with medium level of avalanche danger; 7.2 km^2 (21.6 %) – areas with low level of avalanche danger. The area of potentially safe areas is 6.0 km^2, representing 15.2 % of the total area of the ridge above the upper boundary of forest.

Results

Digital elevation model and raster thematic map of avalanche dangerous territories of mountain ridge Polonyna Borzhava have been created.

Originality and practical significance

A comprehensive approach that included integration of cartographic material, statistical meteorological data and some geomorphometric data of the surface in a unified geographic information system allowed us to allocate the territories with consistent snow avalanche phenomena of mountain ridge Polonyna Borzhava.

Certain geomorphometric parameters of relief of mountain ridge Polonyna Borzhava were considered to determine areas with different degrees of avalanche hazard. Mapping of snow avalanchephenomena of Polonyna Borzhava ridge at a scale of 1: 50,000 was implemented. The thematic map of relative avalanche hazard can be used by professionals working in forest, building, and tourist organizations and in Emergency Situations Ministry. The proposed technology can be applied for thematic mapping of other similar objects and phenomena.

Conclusions

1. A raster thematic map of avalanche dangerous areas of the Polonyna Borzhava ridge was created based on the analysis of morphometric parameters and frequency of winds on this mountain ridge.
2. The aggregated area of avalanche dangerous territory on the ridge is 84.8 % of the total research area. This confirms the fact that the Polonyna Borzhava ridge is very avalanche dangerous.
3. The thematic map of relative avalanche danger will allow professionals to focus on specific areas during the planning of different activities and appearance of potential threats from avalanches.

REFERENCES

Baran Ya. Dekil'ka sliv pro lavyny v Karpatakh [A few words about avalanches in Carpathians] Available at: http://www.drogmedia.net.ua/index.php/ dozvillia/ 2269. (Accessed 2015)

Kolotukha O. V. Lavynna nebezpeka dlia turystiv v horakh Ukrainy [Avalanching hazard for tourists in the mountains of Ukraine]. Kyiv, Federatsiia sportyvnoho turyzmu Ukrainy. Kyiv, Federation of sport tourism of Ukraine, 2008, 38 p.

Lavnyy V. V. Sylni vitry v Ukrainskykh Karpatakh [Strong winds in Ukrainian Carpathians]. Naukovyi visnyk NLTU Ukrainy [Scientific bulletin NLTU of Ukraine], 2009, no. 19.14, pp. 239–246.

Mjagkov S. M., Kanaev L. A. Geografija lavin [Geography of avalanches]. Izdatel'stvo MGU, Moscow, Publishing house of MSU, 1992, 332 p.

Svidzinska D. V. Metody heoekolohichnykh doslidzhen: heoinformatsiinyi praktykum na osnovi vidkrytoi GIS SAGA: navchalnyi posibnyk [Methods of geoecological researches: geoinformation practicum on the base of open GIS SAGA: study guide]. Kyiv, Logos, 2014, 402 p.

Spravka ArcGIS (10.2, 10.2.1 i 10.2.2) Elektronnyi resurs [ArcGIS help (10.2, 10.2.1 and 10.2.2) Electronic resource]. Rezhym dostupu – Access mode: http://resources.arcgis.com/ru/help/main/10.2/

Tavrov Yu. S., Grishchenko V. F. Sniholavynnyy rezhym Ukrayins'kykh Karpat [Snow avalanche conditions of the Ukrainian Karpathians]. Hidrolohiya, hidrokhimiya i hidroekolohiya. Kyiv, Hydrology, hydrochemistry and hydroecology. The scientific collection. Obrii, 2011, Vol. 1(22), pp. 68–74

Tykhanovych Ye. Ye., Bilanyuk V. I. Lavynni protsesy v Ukrayins'kykh Karpatakh [Avalanche process in Ukrainian Carpathians]. Journal of Education, Health and Sport. 2015, Vol 5(7), pp. 96–104. [Electronic resource]. Rezhym dostupu – Access mode: https://zenodo.org/record/19307

Sharyiy P. A. Geomorfometriya v naukah o zemle i ekologii, obzor metodov i prilozheniy [Geomorphometry in earth sciencies and ecology, an overview of methods and applications] Izvestiya Samarskogo nauchnogo tsentra Rossiyskoy akademii nauk. [Proceedings of Samara Scientific Center of the Russian Academy of Sciences], 2006, Vol. 8 (2), pp. 458–473. [Electronic resource]. Rezhym dostupu – Access mode: http://www.ssc.smr.ru/media/journals/izvestia/2006/2006_2_458_473.pdf

A. Covăsnianu, I. R. Grigoraş, L. E. State, D. Balin, S. Hogaş, I. Balin Mapping snow avalanche risk using GIS technique and 3D modeling. Case study – Ceahlau National Park. – Romanian Journal of Physics, Vol. 56, Nos. 3–4, pp. 476–483, Bucharest, 2011, 30 p.

I. M. Simea The avalanche from Rodnei Mountains. PhD Thesis. Cluj-Napoca, “Babeş-Bolyai” University, 2012, 30 p.

Maggioni M., Gruber U. The influence of topographic parameteres on avalanche release dimension and frequency, Cold Region Science and Technology, vol. 37 (2003), pp. 407–419.

Н. З. ГРИЦЬКІВ*, Л. Ю. ЛАЙКУН, Л. В. БАБІЙ

Кафедра фотограмметрії та геоінформатики, Національний університет “Львівська політехніка”, вул. С. Бандери, 12, Львів, Україна, 79013, тел. +38(032)2582616, ел. пошта Nazar.Z.Hrytskiv@lpnu.ua

КАРТОГРАФУВАННЯ ЛАВИНОНЕБЕЗПЕЧНИХ ТЕРИТОРІЙ З ВИКОРИСТАННЯМ ГІС-ТЕХНОЛОГІЙ

Мета. Лавиноутворення є природним явищем, здатним зумовити загибель людей, спричиняти руйнування житлових та виробничих будівель, завдавати збитків лісовому, сільському господарствам та розвитку туризму у гірських районах. Моніторинг та дослідження потенційно лавинонебезпечних територій є актуальним завданням, одну з провідних ролей у вирішенні якого можуть відіграти засоби геоінформаційного моделювання. Тому метою цієї роботи є створення растрової тематичної карти лавинної небезпеки на основі аналізу окремих морфометричних та природних чинників лавиноутворення на території хребта Полонини Боржави. **Методика.** Через векторизацію картографічних матеріалів отримано цифрову модель місцевості. Створену векторну модель інтерпольовано у растрову, яка стала основою для класифікації геоморфометричних чинників лавиноутворення. Чинниками утворення лавин обрано з постійних – нахил схилів, кривину та орієнтування схилів і один змінний природний чинник – напрямок вітрів. Отримані растри перекласифіковані для виконання подальших операцій над ними із застосуванням інструментів алгебри карт, а саме растрового калькулятора. У результаті суми растрів нахилів, кривини та орієнтування схилів і генералізації кількості отриманих класів, виділено класи територій лавинної небезпеки залежно від поєднання величин нахилу та експозиції. **Результати.** Створено цифрову модель рельєфу та растрову тематичну карту лавинонебезпечних ділянок хребта Полонини Боржави. **Наукова новизна.** Комплексний підхід, який передбачає інтеграцію картографічного матеріалу, статистичних метеорологічних даних та окремих геоморфометричних даних про поверхню в єдину геоінформаційну систему, дає змогу виділити території постійної дії сніголавинних явищ хребта Полонини Боржави. **Практична значущість.** Для визначення територій з різним ступенем лавинної небезпеки враховано окремі геоморфометричні параметри рельєфу хребта Полонини Боржави. Проведено картографування сніголавинних явищ Боржавського хребта у масштабі 1:50000. Наявність тематичної карти відносної лавинної небезпеки дасть змогу фахівцям зосередити увагу на конкретних територіях під час планування діяльності та виникнення потенційних загроз від сходження снігових лавин.

Ключові слова: лавинна небезпека, тематичне картографування; геоморфометричні параметри поверхні; цифрова модель рельєфу; ГІС-технології; ArcGIS.

Received 01.03.2016