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GEOMORPHOLOGICAL CONSTRAINTS IN THE URBAN DEVELOPMENT OF THE GRUIA DISTRICT IN CLUJ-NAPOCA

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ABSTRACT. The development and the territorial evolution of the residential complexes specific to urban areas are restricted by the landscape in the territories split by valley corridors. This also applies to the town of Cluj-Napoca, which has experienced during recent years an unprecedented urban increase. This paper deals with the suitability of the ground for new buildings in Gruia district (Cetătuia Hill), located in the central part of the town. As opposed to peripheral districts where the extension of built areas can be made at the expense of the unincorporated areas, in the central parts this is only possible by using the limited surfaces within the built-up areas. Very often, these areas are restrictive with regard to the construction of new buildings. The existing buildings have been initially logged by using GIS techniques. Subsequently, based on the characteristics of natural and anthropic factors, a map indicating the probability of landslides was drafted. Such a map provides valuable information on the plots of land that could sustain new constructions, as well as with regard to the costs of such constructions. All this information should be taken into consideration in the future, since it represents the basis for current and future urban planning decisions.

Key words: *landslides, constructions, probability, urban planning*

INTRODUCTION

The town of Cluj-Napoca is situated in the western part of the Transylvanian Basin, at its boundaries with the Apuseni Mountains or - to be more precise - in the corridor of the rivers Somesul Mic and Nadăs. Due to the fact that these pieces of land are specific for valley corridors, the broadening of residential areas is dependent on the features of the landscape and the dynamics of the associated geomorphological processes.

Knowing the territory of Cluj-Napoca with regards to its geomorphology has a considerable importance because it provides the chance to outline the extension possibilities of the urban area based on the characteristics of a natural component - which is the landscape. At the same time, the occurrence of geomorphological processes and phenomena which lead to the emergence of new landscapes is associated with hazardous geomorphological phenomena that cause constraints for the development of the urban area.

The landscape is an essential component of the environment and, at the same time, the foundation for the rest of the natural components and anthropic activities. It is the reason why possessing knowledge on the landscape constitutes an important prerequisite for drawing up planning programs, urban development, or environment protection programs.

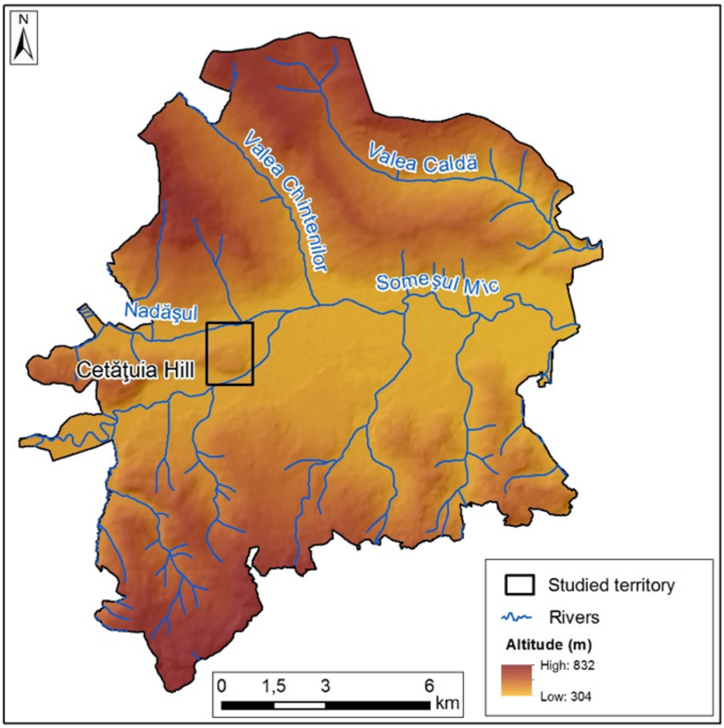

Fig. 1. *The position of the examined territory*

From all the residential areas in Cluj-Napoca, the present work focuses on the Gruia district situated in the central part of the town, which overlaps Cetătuia hill. On this area, the anthropic pressure is increasing, due to the fact that new buildings are being built. The problem is not so much the lack of plots of lands, as their inconvenient features for new constructions.

MATERIALS AND METHODS

In addition to field observations, GIS methods have been used in order to obtain objective results. Initially this consisted in the conversion of information from raster format (from geologic, topographic, cadastral maps etc.) into vector format, so that it could be subsequently used for calculations using the specific functions of the GIS software (ArcMAap10.2.2). For this purpose, the following functions have been used: editor, statistics, extract and export map.

After creating the data base, in order to obtain the map indicating the probability of landslides, the methodology described in the GT-O19-98 (Technical guide for developing landslide risk maps) was applied. It should be added that the data processing has also been carried out using the specific functions of GIS software.

The assessment of the probability of landslides occurring in the central part of Cluj-Napoca (Cetătuia hill) has therefore been conducted based on a methodology that allows the overlapping of several thematic layers. In this case, these are the lithology, the landscape altimetry (the level curves), the landscape parameters (the slant, the fragmentation depths, fragmentation density), the waters, the current geomorphological processes, the use of the lands etc.

After creating the data base, the values from each layer have been assessed according to the existing methodology regulations and to the specific features of the examined territory in order to obtain indicators regarding the vulnerability to geomorphological processes based on which, in the end are established the probability classes for landslides (Bălteanu et al., 2010; Dhakal et al., 2000). The above mentioned calculation is possible due to the fact that the data has a raster format, the operations taking place at pixel level with a size of 5x5m, allowing thus a real and isolated dimensioning of the concerning phenomena.

The centralisation of the values obtained on a single map enables a general assessment of the morpho-dynamic potential, the stability of the areas with regard to the natural balance, or of the risk degree brought on by economic activities (building of roads, residential units, etc.)

In order to draft the map predicting the probability of landslides occurring, the formula given by the GT-O19-98 norm was applied.

$$K_m = \frac{K_a \cdot K_b}{6}\left(K_c + K_d + K_e + K_f + K_g + K_h\right)$$

K_a = lithology factor;
K_b = geomorphological factor;
K_c = structural factor;
K_d = hydrological and climatic factor;
K_e = hydrogeological factor;
K_f = seismic factor;
K_g = forestry factor;
K_h = anthropogenic factor.

The values for the eight factors have been determined as follows: the lithology factor was determined based on geological maps and field investigations; geomorphology factor is based on a high resolution DEM (Digital Elevation Model) from which slope and landform depth maps were obtained; geological structure was extracted from geological maps along with the hydrogeology factor; climatic and hydrological data is obtained from the meteorological station near the study area (included as a constant); seismicity was introduced as a constant value (considering the limited spatial extension of our study area there are no differenced regarding this factor), as specified in the GT-O19-98 Guide; land use and anthropogenic factors were obtained by field investigations and measurement but also using ortophoto data (Sarkar and Kanungo, 2004). In the end of the processing phase all data was converted to raster (5 m spatial resolution) thus resulting 8 raster files. All raster data was reclassified and final scores were assigned according with the 6 classes required by GT-O19-98.

In the final stage all data was included in the formula by using Raster Calculator in ESRI ArcGIS 10.2.2 and the landslide probability map was obtained.

RESULTS AND DISCUSSIONS

After processing the existing data, several graphic materials and statistics ensued. From all the data, the ones referring to geology, landscape, the probability of landslides occurrence, the number and the surface of the properties belonging to each probability class will be presented

The geology

The examined area overlaps a sophisticated geological sub-layer (Fig. 2) with deposits of various ages, from Rupelian to Holocene.

The oldest deposits belong to the Oligocene (Rupelian Age) and these are the Moigrad Formations (consisting of red bed clays with lavender, brown or tile-coloured shades with sand lentils, sandstones or micro-conglomerates), the Dâncu Formations (grey marl clay deposits) and the Gruia Formation (sandstones and sands) (Mészáros and Clichici, 1998; Hosu, 1999; Cristea et al., 2002; Chira and Popa, 2004).

More recent deposits belong to the Pleistocene and Holocene and consist of sands and gravel.

The relief

As one can notice in Fig. 2, the Gruia neighbourhood overlaps with the Hill Cetătuia. The latter is an interfluvial crest between the rivers Somesul Mic and Nadăs (Morariu and Mac, 1967; Pop, 2007). The heights vary from 328 m in the Somesul Mic flood plain to 416 m on the plateau on the upper side. Although the altitude values are not high, with differences of only 88 m, due to the fact that they differ rapidly on distances with low values (120 m at the upper side of the Hill Cetătuia down to the banks of Somesul Mic), the slope exceeds on wide areas 20^{o} (Fig. 4).

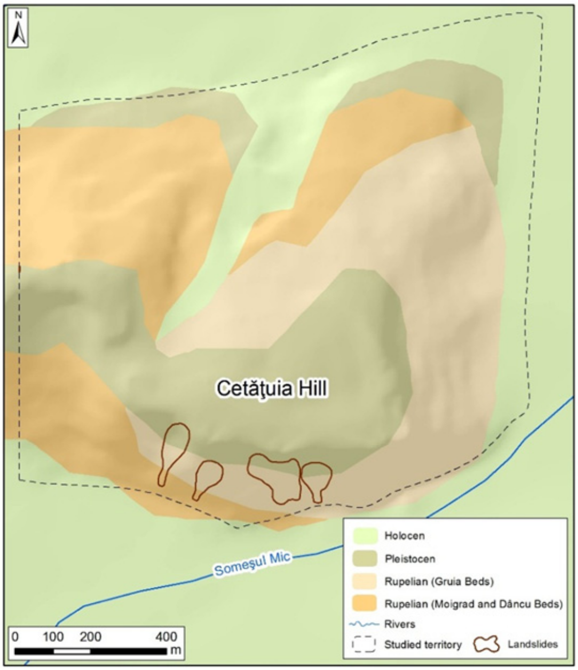

Fig. 2. *Geological map*

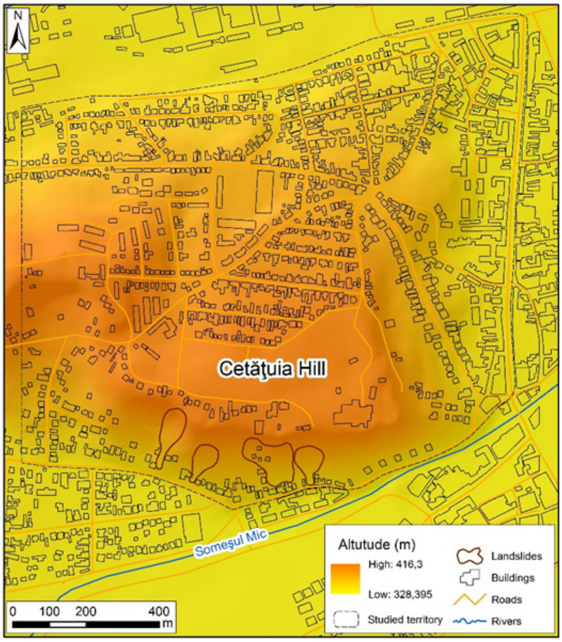

Fig. 3. *Digital elevation model of the terrain*

Put together, geological and landscape-related conditions have been able to favour the emergence of geomorphological processes (GT 019-98, 1998), such as landslides, as it can be noticed (Fig. 2, Fig. 3, Fig. 4), there are four landslides (2.84 ha). They are located on clay deposits belonging to the Moigrad, Dâncu and Gruia Formations.

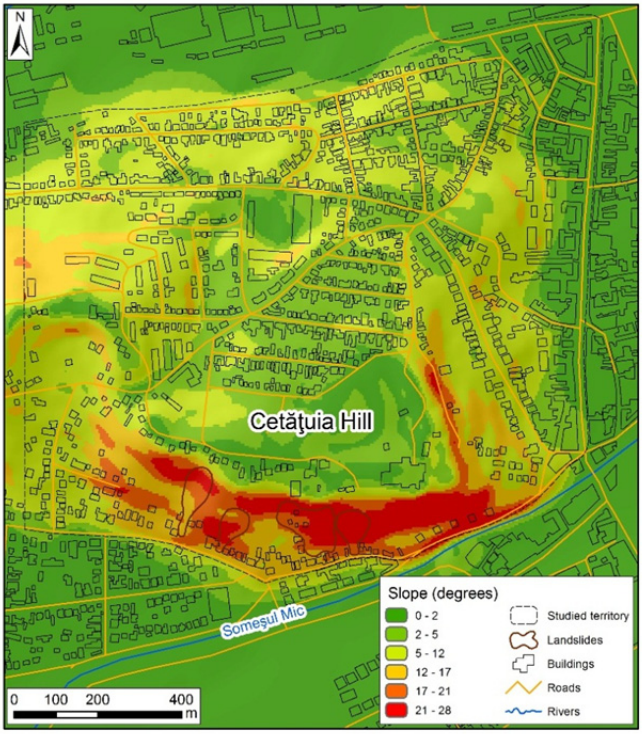

Fig. 4. *Slopes map*

Probability of landslides

From the six probability classes on landslides occurrence established according to Gt-019-98 (virtually nil, low, average, average-high, high, and very high), in the present case five of them can be encountered: low (0-0.1), average (0.1-0.3), average-high (0.3-0.5), high (0.5-0.8), very high (0.8-1).

With regards to the spatial distribution, the following situation can be noticed (Fig. 5, Table 1):

- the low probability class stretches over limited areas, being present in the flood plain of Somesul Mic and Nadăs and in patches on the interfluvial plateau of the Cetătuia hill;

- the average probability class can be noticed on the northern and eastern slopes of the Cetătuia hill;

- the average-high, high, and very high probability classes are only present on the southern slope of Cetătuia hill.

As it can be noticed from the probability map on landslide occurrence, the result of the model is quite balanced: for the flood plain areas the occurrence probability is low (still the values are higher than 0), whereas for the slopes the probability may even reach 0.84 (a very high value) for the surfaces affected by active landslides. It must also be pointed out that, considering that landslides already took place, these have also been included in the drafted model as part of the geomorphological factor.

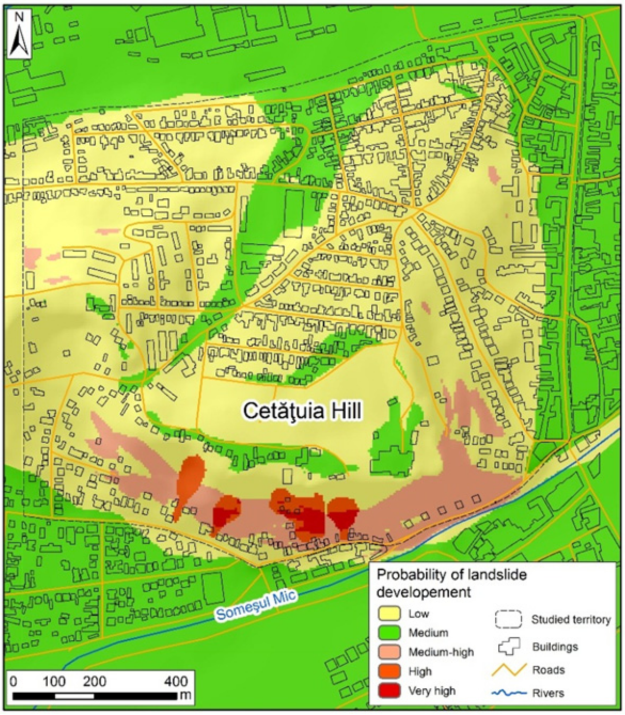

Fig. 5. *The probability map of landslides occurrence*

Table 1. *The correlation between the probability classes and the number of constructions*

Probability class	Surface class probability (ha)	Number of buildings	Surface buildings* (ha)	Surface buildings * (m^2)
Low	33.11	218	9.48	94,800
Medium	104.50	720	19.37	193,700
Medium -high	10.61	39	0.84	8,400
High	1.91	3	0.09	900
Very high	0.87	3	0.02	200
Total	151	983	29.8	298,000

* footprint data (some buildings have several stories)

Surface area of the properties for each probability class

As it can be noticed from table 1, the situation is currently normal in this regard. That means that most of the buildings are located on areas with low (218), medium (720), and medium-high (39) probability classes, whereas for the high (3) and very high (3) probability classes, the number of buildings is very low.

Considering that new spaces for the building of new constructions are needed, the anthropic pressure will increase on lands with high and very high probability classes. This means, that new constructions will be raised on pieces of lands which are ever more prone to landslides. In addition to this, the costs for the new buildings will be higher, considering the necessary additional works needed for their consolidation

Moreover, given that four landslides already took place, measures for their countervailing and for the prevention of new ones are necessary since the land is vulnerable to landslides. Among the works that could counter the occurrence of landslides we suggest the following: works to shape and level the land, support works for unstable areas (retaining walls), afforestation. Prevention works that could be carried out are: works to prevent water access, works to diminish the influence of underground waters, planting of shrubs, drainage works.

CONCLUSIONS

In the Gruia district, the expansion of built areas will take place in the future especially on lands with a medium-high, high, and very high occurrence probability class. Although areas from the classes with low and medium vulnerability are still available, these cannot be used to this purpose due to their special destination (the area around the Parasutistilor Tower, sports grounds, and graveyards). The consequence of the increase of anthropic pressure on fields prone to landslides will reflect in the cost of construction works and in that of the works needed for the maintenance of the constructions.

The building of new constructions requires the expansion of the current road network, which is 17.25 km long in the examined perimeter. These roads also fall within the same probability classes of landslide occurrence (Fig. 5).

The classification of the areas according to the vulnerability to landslides benefits both the territorial planning and development measures, and avoidance to errect buildings in unstable areas. The knowledge of the vulnerability to landslides is useful in order to make a distinction concerning the taxes owed to the local administration, but also for the assessment of their value by insurers. This will force any developer to strictly comply with the local urban plans.

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