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THE EVOLUTION OF THE AREA BETWEEN VALEA CHINTĂULUI AND VALEA CALDĂ FOLLOWING THE WORKS MITIGATING SOIL EROSION

VIOLETA-ELENA MOIS[1], DANIELA DRĂGAN[2]

ABSTRACT. - The Evolution of the Area between Valea Chintăului and Valea Caldă Following the Works Mitigating Soil Erosion. The study area is located on the left slope of the Someșul Mic River, in the northern part of Cluj-Napoca and is bounded on the north and east by the watershed that separates it from the Valea Caldă River basin, south of the agricultural road that separates the slope from Someșul Mic floodplain and west of the orchard border. The area is called Sfântu Gheorghe Hill, the homonymous peak bordering it to the west, and Țigla Hill to the east. In 1986, the Institute for Studies and Design for Land Improvements implemented a plan to mitigate soil erosion on an area of 600 hectares within the mentioned limits. Of these, 300 hectares represented the arrangement of terraces, 200 hectares the arrangement of landslides and 100 hectares of drainage on slopes. The execution of the works mitigating soil erosion aimed at reducing the annual soil losses, the possibility of applying appropriate agrotechniques in the fruit plantations to be established. The arrangement of the slippery surfaces was done by modeling, eliminating the excess moisture, terracing, grassing or planting and had the purpose of bringing significant areas of land back in the economic circuit. Elimination of excessive water through drains was made for the proper development of future tree plantations. The purpose of this study is to analyze the temporal evolution, over a period of 30 years, of the efficiency of the arrangement works on the slope performed in 1986, first of all. The estimation of the effectiveness of the works executed at that moment was made by the comparative morphometric and morphological analysis of the landslides and the forms of deep erosion on the slopes. Second, the study examines the vulnerability of landslide risk factors in this area, in particular residential and public buildings, road infrastructure and agricultural land. The study starts from the following premises: the geomorphology of the southern slope of Sfântu Gheorghe Hill has been studied over time, as attested by bibliographical sources; 30 years ago, the destination of the lands related to the area was mainly agricultural, and the land use plans included mainly measures for agricultural development; in recent years, there

[1] *„Petru Maior" Theoretical High School Gherla, e-mail: violetaretegan@yahoo.it*
[2] *„Emanuel" Baptist Theological High School Cluj-Napoca, e-mail: daniela.drăgan@yahoo.com*

has been an accelerated expansion of Cluj-Napoca, including on the northern slope of Someșul Mic, both from the base of the slope to the watershed, and along the base of the slope, to the eastern outskirts of the city. The questions that arise are: how did the landslides evolve and how did the slope evolve after the development carried out in 1986? How many of the built elements are located in areas with acceptable risk and how many are located in areas with high risk in terms of slope stability?

Keywords*: landscaping, soil erosion, landslides, torrents, terraces, modeling, vulnerability.*

Introduction

The tendency of a significant part of the population in Cluj-Napoca is to build a house as spacious as possible, in a short time, to take advantage of the current development opportunities. There are many examples, especially events after 1990, which show that haste does not lead to the best results. On the contrary, it can be the cause of unpleasant events, resulting in property damage and / or loss of life. The most relevant examples are the constructions located in areas susceptible to landslides. The northern slope of Someșul Mic River near Cluj-Napoca falls into the category of land that was built long after 1990. The study aims to analyze whether land improvements, built 30 years ago, are still able to stop the evolution of the landslides or if landslides have reactivated. A qualitative assessment of the vulnerability of elements at risk of landslides is also sought.

1. The study area

Sfântu Gheorghe Hill delineates to the north-east the municipality of Cluj-Napoca, between the Chintău Valley, to the west, and the Hot Valley (Valea Caldă), to the east. It is a cuesta, whose front is oriented to the south and south-east, and the reverse to the north, towards Valea Caldă. The southern face of the hill measures 846 hectares. Its altitudes are around 500 m (513 m at the top of Fânațele Satului and 478 m at the top of La Pipă). In the twentieth century, at the base of the slope, the industrial area of the city developed progressively. The artery connecting the area with the center was generically called Labour Boulevard (Bulevardul Muncii). A number of industrial enterprises were closed after 1990, such as the C.U.G. and Therapy. Other constructions have kept their destination and functionality today, such as the Faculty of Mechanics within the Technical University. Private homes and new commercial spaces have emerged, such as Auchan. The buildings of the old factories are currently occupied by the headquarters of new institutions (A.P.I.A., etc.). Some of the constructions occupy slope sectors where the geomorphological risk is considerable.

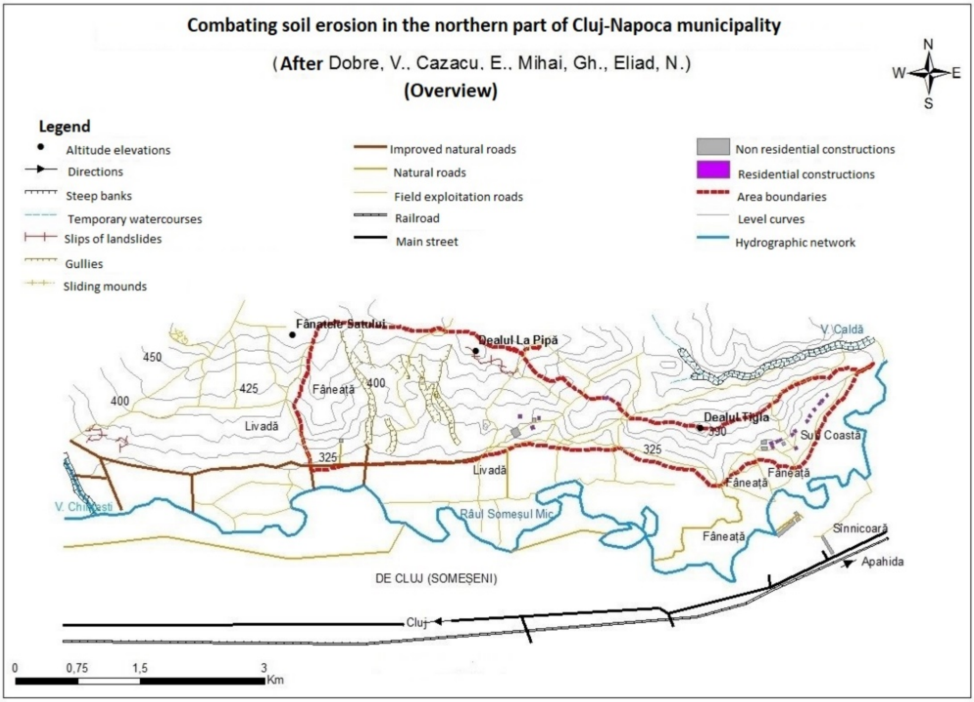

Fig. 1. ISPIF project 6855/1986.
Source: Dobre, V., Cazacu, E., Mihai, Gh., Eliad, N. (1986)

2. Research methodology

2.1. Data used

The following sources were used: a) topographic map, scale 1: 25.000; b) geological map of Romania, scale 1: 200,000; c) The General Urbanism Plan, 2012, regarding the land arrangement; d) APIA, data regarding the land use; e) ISPIF 6855 project from 1986 on mitigating soil erosion; f) field observations and measurements, in 2015 and 2017; g) The land elevation model.

2.2. Specific methodology

In order to determine the susceptibility of the area to landslides, the method of statistical analysis of the landslide frequency rate on five control factors (hypsometry, slope, slope orientation, geology, land use) was used. The method is often found in the studies of authors such as Irimuș and Surdeanu (2003), Goțiu (2007), Bilașco *et al*. (2009).

a. **Landslides** were delimited on the topographic map and on orthophotoplans, then they were identified on the ground. They were located accurately and their area was measured using the GPS application Essentials 4.4.22. The data was exported to Google Earth Pro and then to ArcGIS 10.1.
b. **The digital terrain elevation model** was used in the construction of the following maps: **slope and slope orientation.**
c. **The geological map** was built, and then **the land use map** according to CLC.
d. Each control factor was classified into five susceptibility classes. The area for each susceptibility interval was calculated, as well as the area covered by landslides in each of these intervals. The size of the factor "i" was calculated for all susceptibility ranges, using the formula of Yin and Yan (1988):

   Ii = log (Si / Ni) / (S / N), where
   Ii = statistical value of the factor "i"
   Si = landslide surface over the susceptibility range of the control factor
   Ni = area of the susceptibility range of the control factor
   S = total landslide area of the study area
   N = surface of the study area.

The total susceptibility to landslides was obtained by summing the rasters (grids) obtained on each control factor.

3. Results

3.1. Landslide map

The field measurements show the reduction of landslide areas, from 200 ha in 1986 to 61 ha in 2017. As a result of modeling, leveling, terracing, planting with fruit trees of the terraces, as well as acacia plantations on the mass-supplying areas of landslides, they have been stabilized. Four areas with deep landslides have been found, as well as reactivated landslides in each area (in 10 locations).

Two of the reactivated landslides are around the top of the Fânaţele Satului Peak, in the mass-supplying area, and the third, in the frontal area of the landslide. The immediate risk is lower, in this case, because not many houses have been built in this sector yet.

The second massive landslide is located in the northern and northeastern part of the Auchan shopping center. It has two reactivated sectors. There is a lake behind the wall that delimits the store, as well as cracks in the wall, which demonstrate the movement of materials on the slope. In this case, the risk is high even now, given the considerable number of people in the supermarket every day.

The third deep slip sector, with two reactivated sectors, is located on the line of the watershed between the Fânaţele Satului Peak and La Pipă Peak.

The fourth sector with landslides is located north-east of the former CUG plant. New lenticular landslides have developed over the main body of the landslide, especially those affecting Voroneț Street.

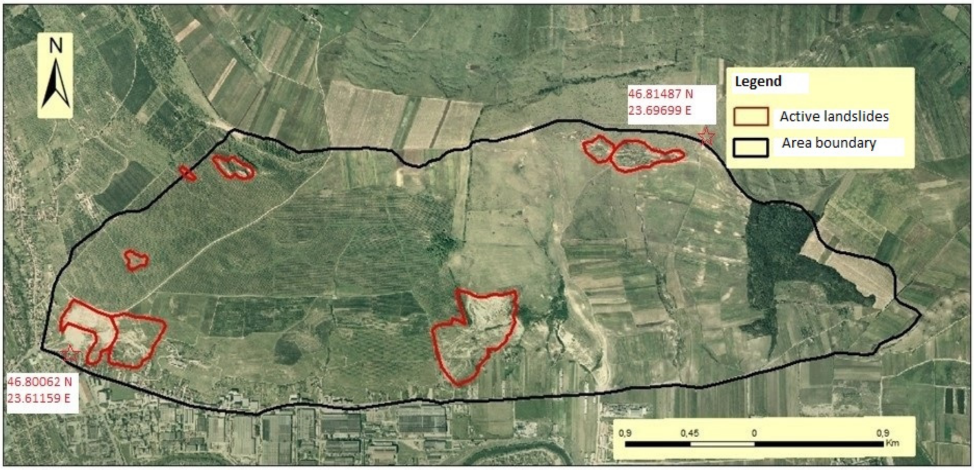

Fig. 2. Landslides on the southern slope of Sfântu Gheorghe Hill.
Source: the authors

3.2. Digital terrain elevation model

Examination of the terrain elevation model reveals that 52.7% of the slippery surfaces are on the level below 400 m altitude, 46.6% are between 400-500 m altitude and 0.7% are at heights of over 500 m (fig. 2).

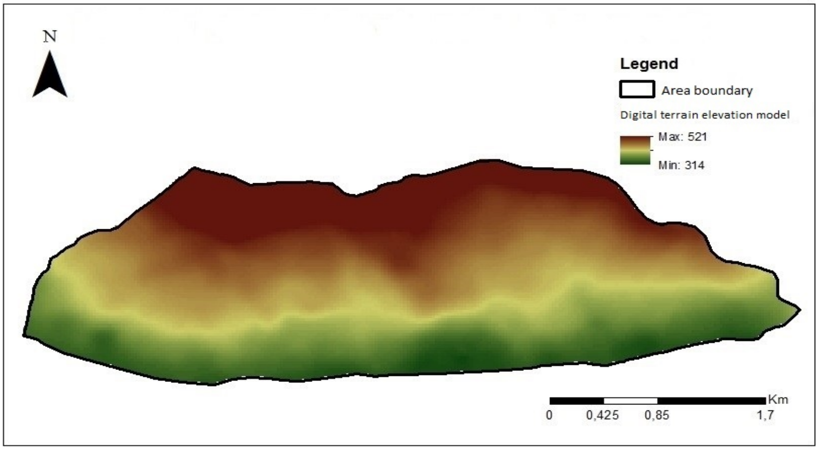

Fig. 3. Digital terrain elevation model.
Source: the authors

3.3. Slope map

After the construction in DEM, the slope map was reclassified, choosing the following classes: 0-2º, 2-6º, 6-17º, 17-32º and over 32º (fig. 4). Most landslides are in the range of 6.1-17º, i.e. 72.29%. The following by weight are the slopes between 17.1 and 32 º, 13.92% of landslides are located here. Lands with a slope of 2.1-6º have 11.35% of landslides. On the quasi-horizontal lands there are 2.37% of the slippery surfaces. On those that exceed the slope of 32º, the percentage is insignificant, 0.07%.

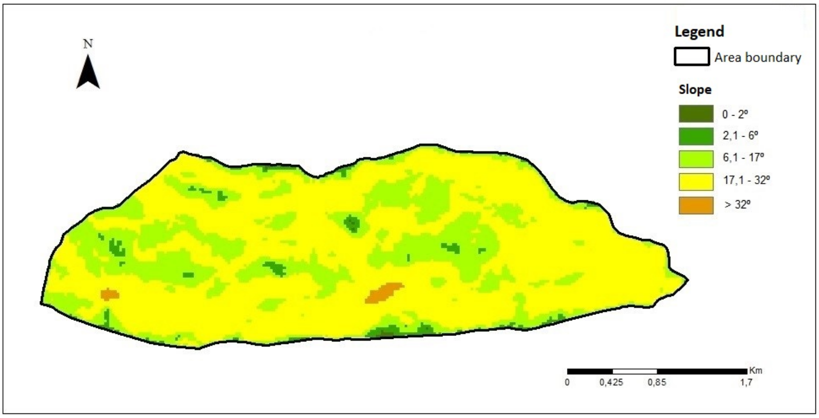

Fig. 4. Slope map.
Source: the authors

3.4. Slope aspect map

The mechanisms of the weathering process take place faster on sunny slopes than on shady ones. As it benefits from a longer duration of insolation, on the southern and south-eastern slopes the disintegration is accelerated, as well as the chemical alteration. The superficial deposits formed are exposed in advance to mass movements on these slopes, rather than on the shaded ones. Therefore, 64.21% of the landslides on the southern facade of Sfântu Gheorghe Hill are found on the southern and south-eastern slopes. On the western and south-western semi-sunny slopes, 23.09% of the existing landslides were identified. In contrast, few landslides were identified on the shady, northern and north-eastern slopes (2.64%) and on the semi-shady, eastern and north-western slopes (4.25%). On the other hand, on the shaded and semi-shaded slopes, where the water stagnates for a longer time, landslides are replaced by creep, compaction and suffusion processes, and linear erosion respectively (fig. 5).

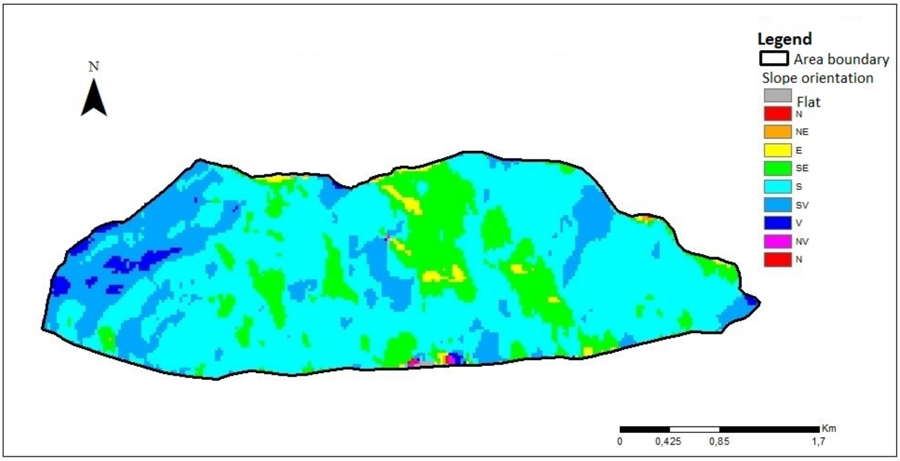

Fig. 5. Slope aspect map.
Source: the authors

3.5 Geology

The analysis of the geological map (fig. 6) reveals the dominance of the Miocene lithological formations. Marl and tuff formations support 77.25% of landslides. 17.03% of landslides lie on the clay deposits alternating with coal sandstones, marls, marly shales and tuffs. These soils are highly susceptible to landslides due to the alternation of layers of clay or marl with layers of crumbly rocks, with high porosity and low internal cohesion. A share of 3.75%

of the landslides are found on the Quaternary gravel deposits, located on the watershed of Sfântu Gheorghe Hill (Pleistocene deposits). These are the mass-supplying areas of the landslides that occurred in this area. On Holocene sands there are 1.97% of the landslides, located in the west of the area, on the eastern slope of Chintău River. In this case, the front parts of some slippery lands parasitize the area that consists of sands.

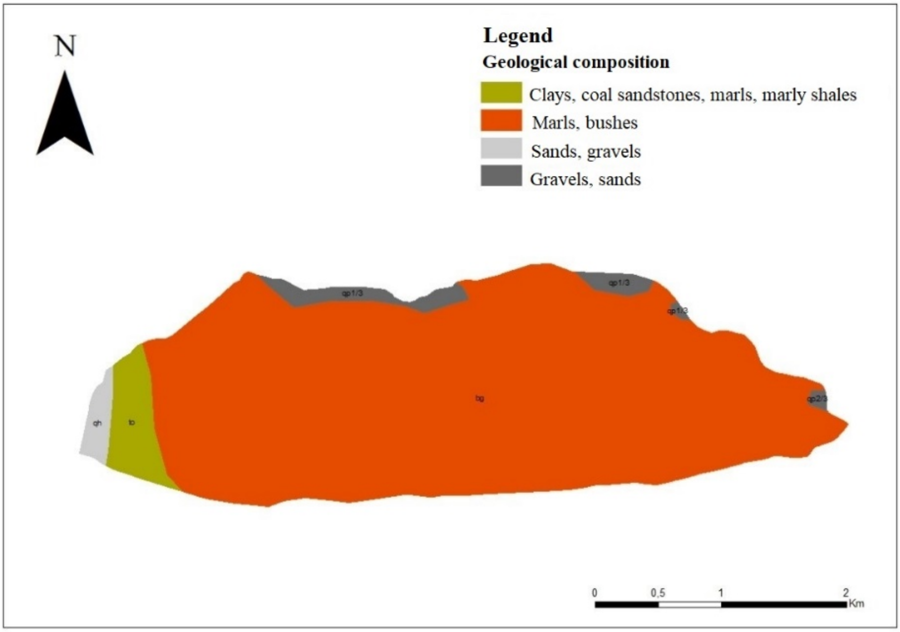

Fig. 6. Geological map.
Source: the authors

3.6. Land use

There are several interesting aspects regarding land use. First of all, the landslides stabilized on the lands with orchards of fruit trees. The transfer of individual ownership of these lands after 1990, determined their subdivision into smaller lots and the cutting of the orchard on many terraces. On some of the cleared terraces, the landslides have reactivated. Then, the undermining of the base of the slope by excavating the land for the Auchan supermarket, determined the reactivation of the landslide in that sector, until then stabilized. Another situation of activation of a deep landslide was on arable land located immediately below the watershed. Finally, the fastest evolution has been shown by the recent landslides on Voroneț Street and in its vicinity (fig. 6).

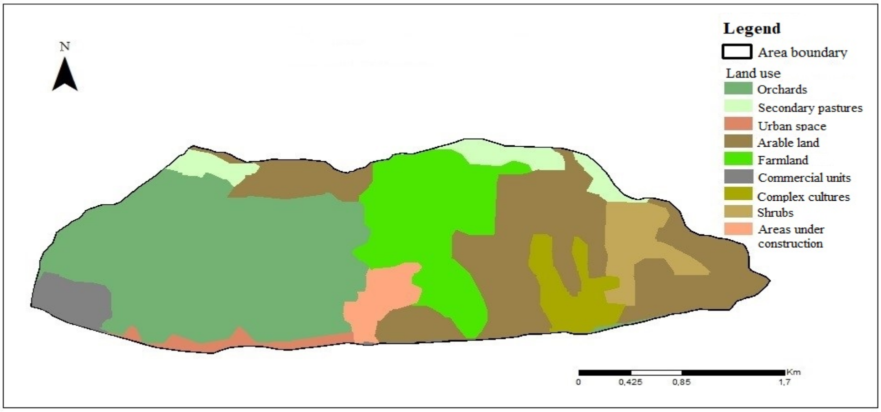

Fig. 7. Land use map.
Source: the authors

3.7. Landslide susceptibility map

The analysis of the landslide susceptibility map reveals the following aspects. First, lands with high susceptibility (16.38%) and very high (6.96%) are those located in the sector U2, distribution, U5, the middle part of the slope and U6, the accumulation area of floods and colluviums (Dalrymple *et al*., 1968). Then, most of the southern slope of Sfântu Gheorghe Hill (39.98%) has an average susceptibility to landslides. The lands with low (28.19%) and very low (8.49%) susceptibility are especially in the "free face" sector of the slope (Dalrymple et al., 1968), on the watersheds, but also in the glacis that connects the slope with the Someșul Mic floodplain.

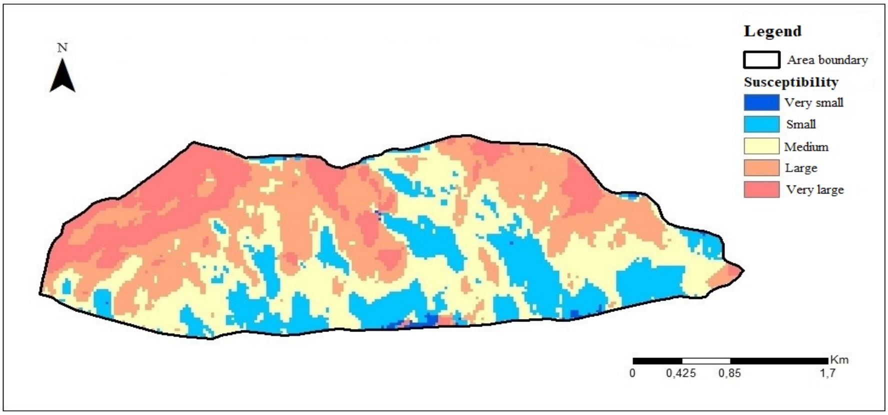

Fig. 8. Landslide susceptibility map.
Source: the authors

4. Vulnerability to landslides

Based on the data from the 2010 orthophotoplan, by digitizing the buildings and streets in the study area, we calculated the existence of a number of 358 residential and non-residential buildings, as well as 66 streets in this sector. Of these, 172 buildings are located less than 200 meters from landslides, 51 buildings at a distance of 200-300 m, and 41 buildings at distances between 300-400 m from landslides. They have a high degree of vulnerability. The most exposed are the Auchan supermarket, being located exactly at the base of one of the reactivated landslides and the private homes on Voroneț Street, as these are right in the perimeter of the active landslide. Assessing the number of people at risk was not possible due to lack of data.

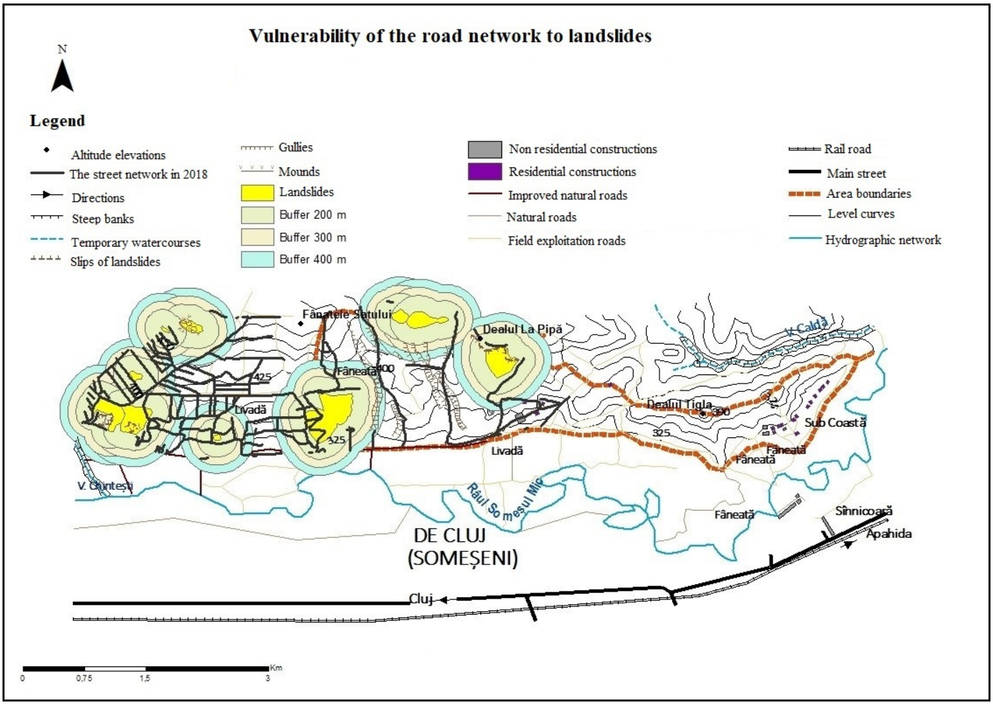

Fig. 9. Vulnerability of the road network to landslides.
Source: the authors

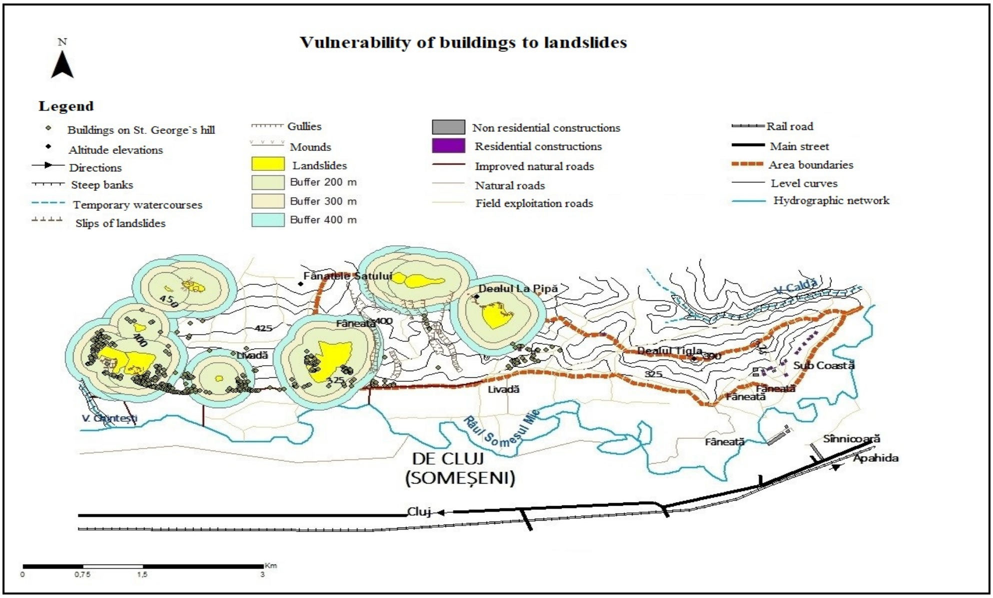

Fig. 10. Vulnerability of buildings to landslides.
Source: the authors

5. Discussions

The residential area to the north of Labour (Muncii) Boulevard, on the southern slope of Sfântu Gheorghe Hill, is expanding more and more. The action is justified on the one hand, taking into account that the flat areas of the floodplain and on the terraces of Someșul Mic River are already occupied by buildings. The attractiveness of this area is given by the predominantly southern exposure of the slope, the relatively short distance from the city center, resulting in a short time to travel to / from the city, and the prospect of living in a more spacious neighbourhood. Aspects that have received insufficient attention relate to the layout of the road network and the construction of more than half of the buildings in areas at high risk of landslides.

6. Conclusions

Compared to the existing situation in 1986, the southern slope of Sfântu Gheorghe Hill has evolved. The slippery land areas were reduced from 200 ha to 61 ha. The executed land improvement works were efficient as long as the maintenance of the terraces cultivated with fruit trees and of the drainage systems of the excess humidity was carried out. After 1990, the surface of the slope was divided into individual properties, thus interrupting the unitary monitoring of the functionality of the land arrangements. Numerous sectors of the agricultural terraces were cleared, on which superficial erosion, ditches, gullies, ravines, torrents and landslides settled in a short time. Some of the stabilized landslides have been reactivated following a change in land use. New streets were laid out and new buildings built, most of them family homes. Most of the houses are at critical distances from landslides in different stages of evolution.

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