

## NATURAL RISKS REGIONALIZATION IN THE DISTRICT OF CLUJ

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**ABSTRACT** - The geomorphologic processes are usually limited as area of occurrence. They can be localized punctually, but the transformations they induce are irreversible and can produce very important environmental changes such as landscape transformations, loss of human lives, destructions of elements of the cultural heritage or taking agricultural lands out of use. In this paper, we tried to establish a regionalization of the geomorphologic processes at risk by applying a weightening method that considers both the favourable and triggering factors for this type of processes.

**Key words:** natural risks, susceptibility, sample, regionalization, Cluj

### 1. CAUSATIVE FACTORS FOR THE GEOMORPHOLOGIC PROCESSES AT RISK

#### 1.1 The geological factor

As far as the implication of the geological factor in producing some processes and phenomena of natural risk is concerned, we have to express our opinion that this one asks a different type of approach when speaking of the district of Cluj. First, the presence of some groups of rocks that are very old (starting with the Paleozoic to the Quaternary), with physical and chemical properties that coordinate their mechanic behavior has to be pointed out within the area of the district. Second, we emphasize the differentiated tectonic types according to the place of their occurrence. In the mountainous area there are pleated, faulted rocks, which even if hard as entities, can become fragile when they get in contact with the atmospheric agents. The presence of the young sedimentary rocks (from the Neozoic age) in rhythmical alternation and in a monoclinial architecture, favoured a fast reorganization and an inconsistent geotechnical behavior even if, apparently, they are spread in a homogeneous manner. The presence of salt and gypsum at the border of the study area, in sedimentary basins, led to an increased susceptibility of some groups of clays to the manifestation of mass moving processes (especially in landslides), through the geochemical transfer – a fact proved also by the frequency of processes in such areas. Some clay minerals have a different behaviour depending on various climatic conditions. Therefore, during the long periods of drought, they present deep cracks, while in the presence of water they get inflated and increase their volume considerably (reaching 150%). This upright game ends, in built-up areas, in fissures of the buildings (oblique cracks) that can lead even to their destruction. This phenomenon is also possible in the pile of rocks nearby, in such a manner that, through a slow circulation of the water from rainfalls, those critical cases that lead to the release of the mass movement process can be realized.

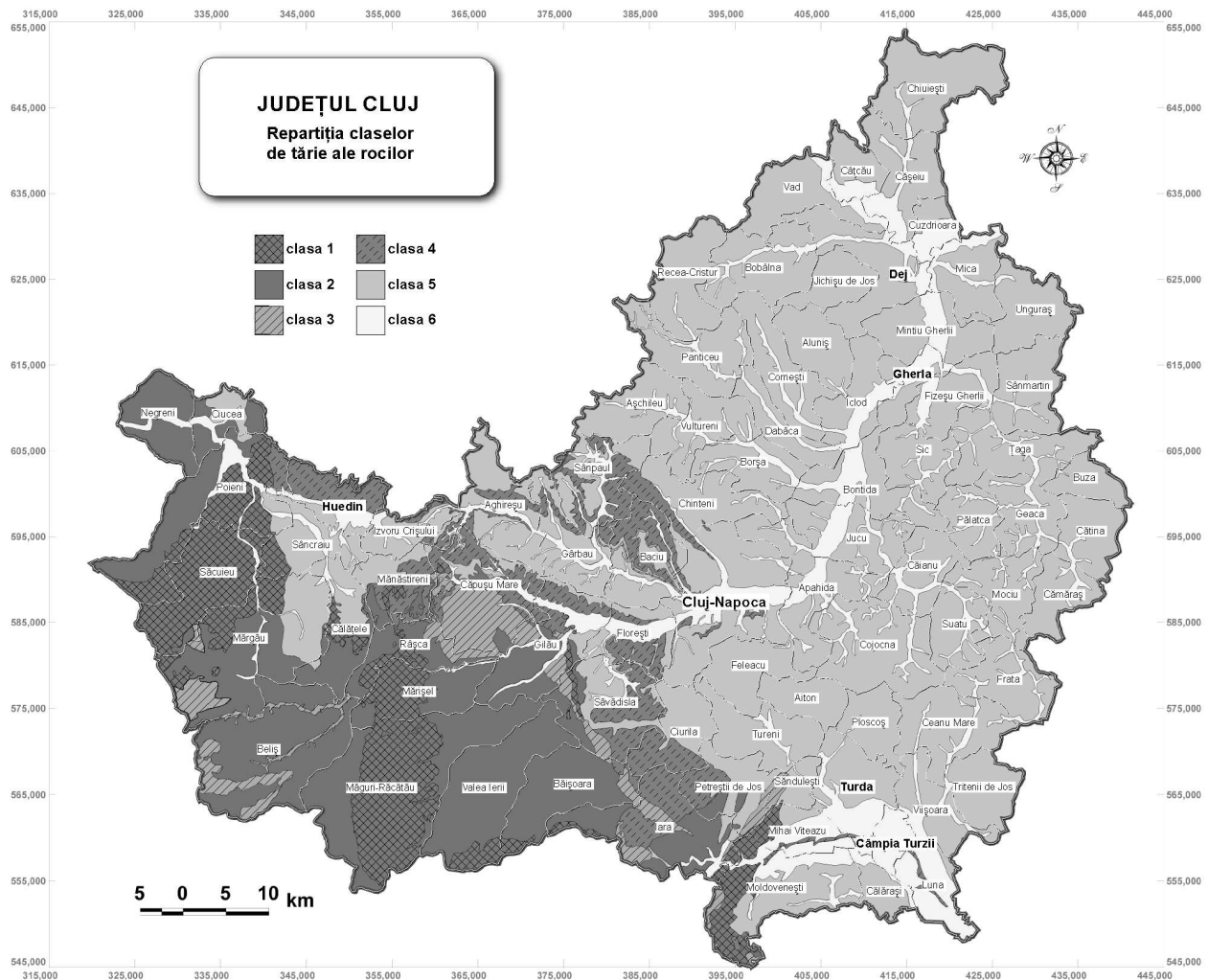
As far as the disposing of the young rocks (from the Quaternary era) is concerned, their presence along the valleys should be emphasized. These rocks (group 6) consist of sand, mud, weakly consolidated gravel, with a large mobility in time and space. In this group there are also the slope deposits (dilluviums, colluviums, proluviums and illuviums) that are of variable thicknesses (frequently over 3-4 m), that frequently “mask” the bedrock. This phenomenon is pointed out even in the case of mountainous interfluves, the deposits from volcanic and crystalline rocks containing a high degree of fine clayey fragments in which pieces of rock are disseminated. This fact enables them with a differentiated geotechnical behaviour compared to the primary rocks.

Regarding the behavior of the types of rocks that occur in the study area, we can notice the following: the communes situated in the hilly area have within their territory a high percentage of rocks that are prone to the manifestation of the mass movements (for instance, a frequency of 10% at Aiton). These processes are frequently accompanied by gully and sheet erosion; the weakly consolidated rocks can also be found at a high rate (10-30%), emphasizing the capacity of the valleys of receive materials from the slopes, and on the other hand, “the clogging” of the channels of natural drainage, that can favour floods and processes of over-moistening; in the mountain area, due to the hardness of the rocks, the mass movements are superficial. Here, the rock falls are frequent – especially in the sheer zone or inside the quarries. The

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narrowness of the valleys can interfere into the transit of water resulted from rainfall, and the process of “clogging” of the valleys can produce serious damages to the roads or to the residential areas. According to the geological substratum a frequency analysis of the landslides at the level of the district of Cluj can be realized. The analysis was based on 100 subjects of landslides that have been quantified in terms of percentage according to the type of rock on the basis of known landslide typologies. Thus, one can ascertain that on a complex lithology, the most frequent are the rotational ones, followed by the furrow type and of the pseudo terraces type of slides. The volcanic tuff associated with marls and sandstones render a high frequency of the pseudo terraces type of slides, followed by the rotational and the furrow type. The clays are not very susceptible to this type of slides, their frequency being very low (waves-6%, pseudo terraces – 8%).



#### Legend:

1. Very hard rocks (diorites, andesites, magmatites)
2. Hard rocks (mica-schists and gneisses)
3. Compact rocks (massive limestone, marly-limestone, diorites)
4. Consolidated rocks (sandstone, compact clayey sandstone alternating with clays)
5. Weakly consolidated rocks (pudding stones, sandstone, gritty marls, clays, sands, gypsum, salt in rhythmical alternation)
6. Unconsolidated rocks (sands, gravel, quaternary clays)

**Figure 1.** Rock hardness classification

For the purpose of quantifying the contribution given by the geological structure at the release of the geomorphologic processes of risk, a valuation matrix of the most frequent processes according to the territory of the district of Cluj (figure 1), which were given weighting points from 1 to 5 according to the

methodology presented in the following section. By summing these degrees with those corresponding to the land use and the morphometric characteristics the risk can be classified in five categories.

### 1.2 The relief factor

**The slopes analysis** – as a result of the analysis of the slope map, we conclude the following: the horizontal and quasi-horizontal areas (slopes of  $0-2^\circ$ ) are frequent in two cases: along the rivers, as riverine areas, being susceptible to floods; and the phenomena of over-moistening due to prolonged stagnation of water on the fields. It is necessary to emphasize the fact that the floods must not be understood only as overflows of the rivers over their banks, but also as flash floods, from the slopes of some tributaries of some rivers as the Someș, Arieș, Fizeș, Gădălin, Borșa, etc. In the second case, these slopes characterize the watershed surfaces that show no processes and phenomena that might cause natural risks.

A special type of slopes is that of  $2-5^\circ$ , that borders the edges of the slopes (glacis slopes). These slopes are usually the most favorable for constructions (places free of floods) and for agriculture. However, they are submitted to over humectation and frequently they are affected by the accumulation of allochthonous material (alluvial cones of the torrents, accumulations of sliding delluviums).

In the study area, the most frequent steepness is the one between  $5-17^\circ$ , which is the most favourable for the development of the sliding processes. As far as its distribution is concerned, we notice that in the communes that developed in the hilly region of the Someșan Plateau and in the Transylvanian Plain, the lack of forests and the domination of clayey-sandy rocks have a very important contribution to the increase of slope susceptibility. In the arable lands, the sheet erosion is also present, and it contributes to the degradation of the soil layer by eliminating the A stratum.

Frequently, in the case of cuestas, these slopes are accompanied in the upper part by slopes of  $17-32^\circ$  (Chiuești, Cășeu, Mintiu Gherlii, Unguraș, Sânmartin, Mica, Fizeșu Gherlii, Țaga, Sic, Vad, Dăbâca, Pânticeu, Iclod) that, beside landslides and mud flows, also favour the development of torrential organisms with a very fast evolution when forestry vegetation is absent, or when they are affected by overgrazing. In the mountainous area the slopes covered with forestry vegetation are not exposed to major risks, and if the case, they are of low frequency and usually cover small areas.

A special type of slopes is the one that is characteristics to the mountainous regions, with values that range between  $32-45^\circ$ . Here, debris flows can obstruct valleys or the road infrastructure. Even if they are very rare, the damages can be important due to the big transit of material. In most cases the forest enforces certain restrictions that decrease the intensity of the processes.

The slopes higher than  $45^\circ$  are specific to the mountainous area, especially on limestones and hard rocks (crystalline schists, volcanic rocks). They occupy small areas and are characterized by specific processes – rock falls. The events are spasmodic and their release compete, beside the natural factors, the anthropic activities too (quarry exploiting).

**The energy of fragmentation (the depth of fragmentation)**- in the hilly regions of the studies area, in the Someș Hills, but also in the Transylvanian Plain, differences of 50-150m in elevation prevail, being sufficient for an accentuated dynamics of the landslides or for the gully erosion. In the areas with cuestas, the difference in elevation is above 150 m. This fact leads to an increased velocity of the cuesta processes and to a shorter interval for the preparation, self release and relaxation time of the fragile systems. In the south-eastern part of the Transylvanian Plain, the elevation differences less than 100 m dominate. This fact can be observed in the time by the dynamic evolution of the process that can last for years or dozens of years. The mountainous area is characterized by high relief energies, over 250 m, thus the access, as well as the evacuation of the inhabitants and of the resources in case of disasters become more difficult. In addition to that, the length of the valleys leads to material losses in case of disasters, which become considerable through the restrictions imposed by the elevation of relief.

**The density of fragmentation** – from this point of view, we notice a dominant rate of values under  $0.5 \text{ km/km}^2$  in the study area. On this account, in the areas of contact with the mountainous region the horizontal fragmentation increases, until it reaches values of  $2.5 \text{ km/ km}^2$  (Huedin, Aghireșu, Mănăstireni, Căpușu Mare, Gilău, Săvădisla, Iara). The same phenomenon is emphasized in the northern area of the Cluj county, where the cuestas are more frequent (Chiuești, Cățcău, Cășeu, Mintiu Gherlii) or along of the Someșul Mic valley (Gherla, Iclod, Bonțida, Jucu). In the mountainous the fragmentation values of  $1.5-2 \text{ km/ km}^2$  increase in frequency, due to the resistance of rocks to infiltrations and to the existence of a permanent drainage system.

The high values of the horizontal fragmentation in the Transylvanian Plain represent a factor of destabilization for the processes that imply natural risks. In the areas with a high fragmentation, the landslides and the gully erosion are frequent.

### 1.3 The climatic factor

In analyzing the climatic factors at risk, we focused our attention upon the rainfall dynamics. The territory of the district of Cluj receives medium quantities of precipitation that exceed 1,000 mm in the mountainous region; range between 600-700 mm in the hilly area along the Someș river and between 600-650 mm in the Transylvanian Plain. In most of the elaborated studies regarding the precipitations one can notice the fact that, for the hilly areas, rainfall has obvious torrential characteristics. The smallest quantities fall in the autumn - spring period (Turda - 37%, Cluj-Napoca - 41%, Dej - 42%). During the summer, there are heavy rainfalls that have torrential characteristics.

The natural risks induced by precipitations imply, however, an analysis of the periods of rainfall that contributes to the state of fragility of the systems. Such an analysis allows us to underline the periods of rainfall with medium quantities on a period of 40 years (1961-2000). The dates for the analysis allow the drawing of the following conclusions for the Cluj-Napoca and Dej weather stations: high frequency of three successive days of rainfall (9.4 – Cluj-Napoca, 8.0 – Dej) during one year, with daily average amounts of 4.1 mm, that are enough for producing sheet erosion, gully erosion, landslides and even floods; four successive rainfall days are frequent (five periods/year with averages of 4.1-4.5 mm); at least once a year precipitations of seven successive days have been registered, with quantities close to 5.0 mm on average per day, which is sufficient for triggering gully erosion, slope undermining or floods.

### 1.4 The anthropic factor

In order to quantify the degree of man-made intervention in the natural systems, the environmental index has to be calculated and the land use has to be analyzed.

**The environmental index** – along with the trend of landscape artificialization, the forestry ecosystem, with its well-known protective functions, still represents a balance in the system. The forest is a factor of equilibrium in the environment, an element that confirms the degree of preservation of its natural potential. For this reason, we have chosen the calculation of the index of naturalness of the landscape and of the index of environmental transformation that is related exactly to this factor.

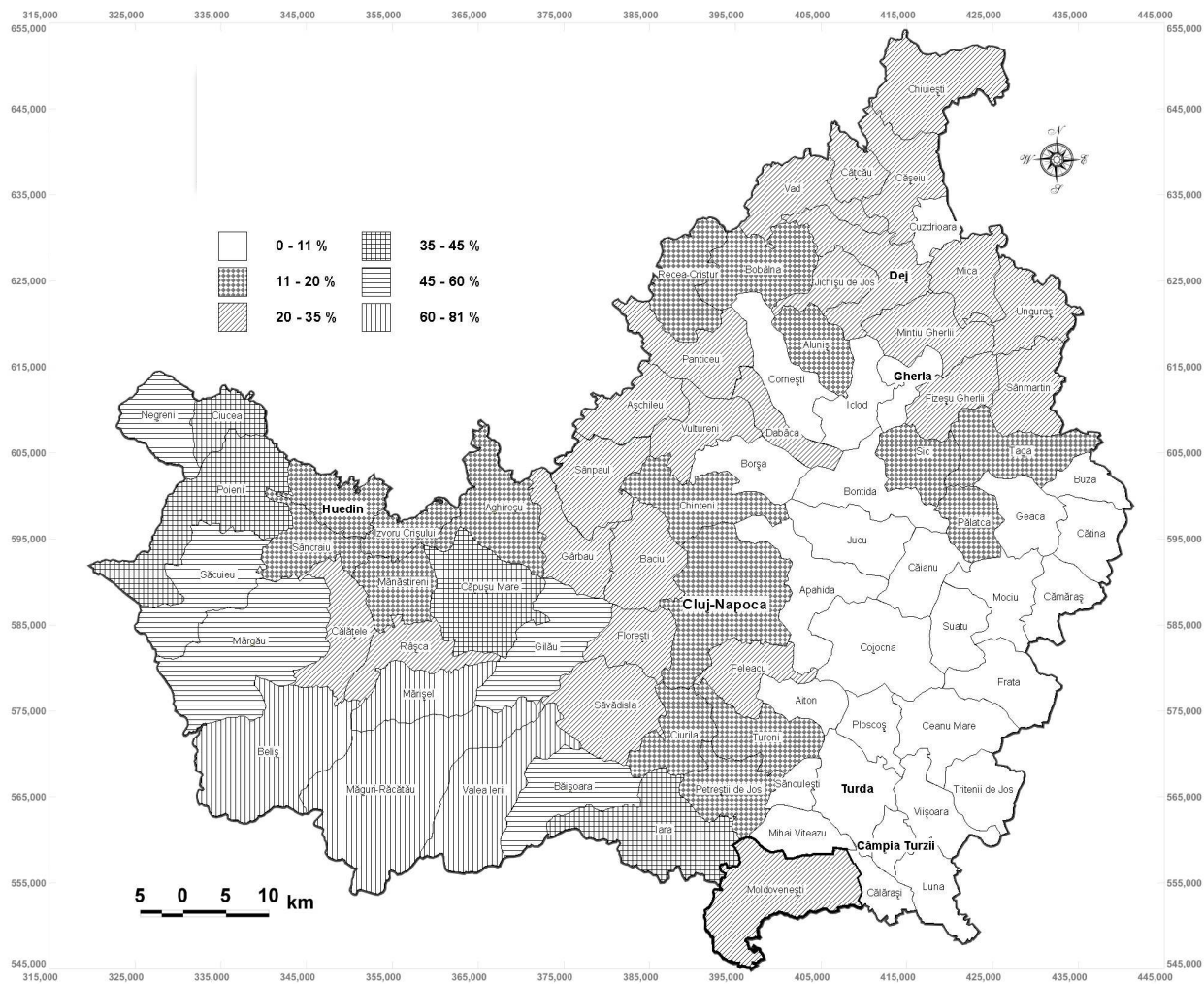
*a. The index of naturalness of the scenery* is defined by the predominance of the forested areas related to the entire surface of a commune ( $In = (A_{\text{forest}}/A_{\text{total}}) \times 100$ ). Taking into consideration the classification of the landscapes after Ionescu, Săhleanu, Bândiu (1989), a characterization of the types of landscapes can be made, according to the calculated value of the index of naturalness for each administrative unit (table 1).

**Table 1.** *The correlation of the index of naturalness with the type of landscape*

Current no.	Index of naturalness	Type of landscape
1	60 – 100 %	Landscape with ecological equilibrium close to the initial one
2	45 – 60 %	Landscape with ecological equilibrium relatively stable
3	35 – 45 %	Landscape with ecological equilibrium slightly affected by the human pressure
4	20 – 35 %	Landscape at the limit of the ecological equilibrium
5	11 – 20 %	Landscape with ecological equilibrium severely affected
6	0 – 11 %	Landscape with ecological equilibrium affected in an extremely strong way

We can ascertain that, at the level of Cluj district, from the total of 75 communes, a number of 40 communes have the ecological landscape severely and very severely affected; 24 communes are at the limit of the ecological equilibrium or are slightly affected by the human pressure, 9 of them have an ecological landscape relatively stable or close to the initial one. The municipal towns and the town of Huedin can be found on the same scale, that is between 0-25.9%.

## NATURAL RISKS REGIONALIZATION IN THE DISTRICT OF CLUJ



**Figure 2.** *Index of naturalness of the landscape*

The most dramatic situations are registered in an area bordered by the communes of Cornești, Iclod, Bontida, Căianu, Mociu, Geaca, Buza (in the north); Borșa, Apahida, Aiton, Săndulești, Mihai Viteazu, Călărași (west). This situation comes to mark the man-made pressure exerted upon the territory through massive deforestation and the dispersion of the residential areas.

Another critical area is that of the communes that develop in the contact areas where a rudimentary subsistent agriculture is practiced, the forest areas being affected (Huedin, Sâncraiu, Mănăstireni, Aghireș, Chinteni, Ciurila, Tureni, Petreștii de Jos) or in the nearby of the Someș Hills (Recea Cristur, Bobâlna, Aluniș) and in the Transylvanian Plain (Sic, Palatca, Țaga).

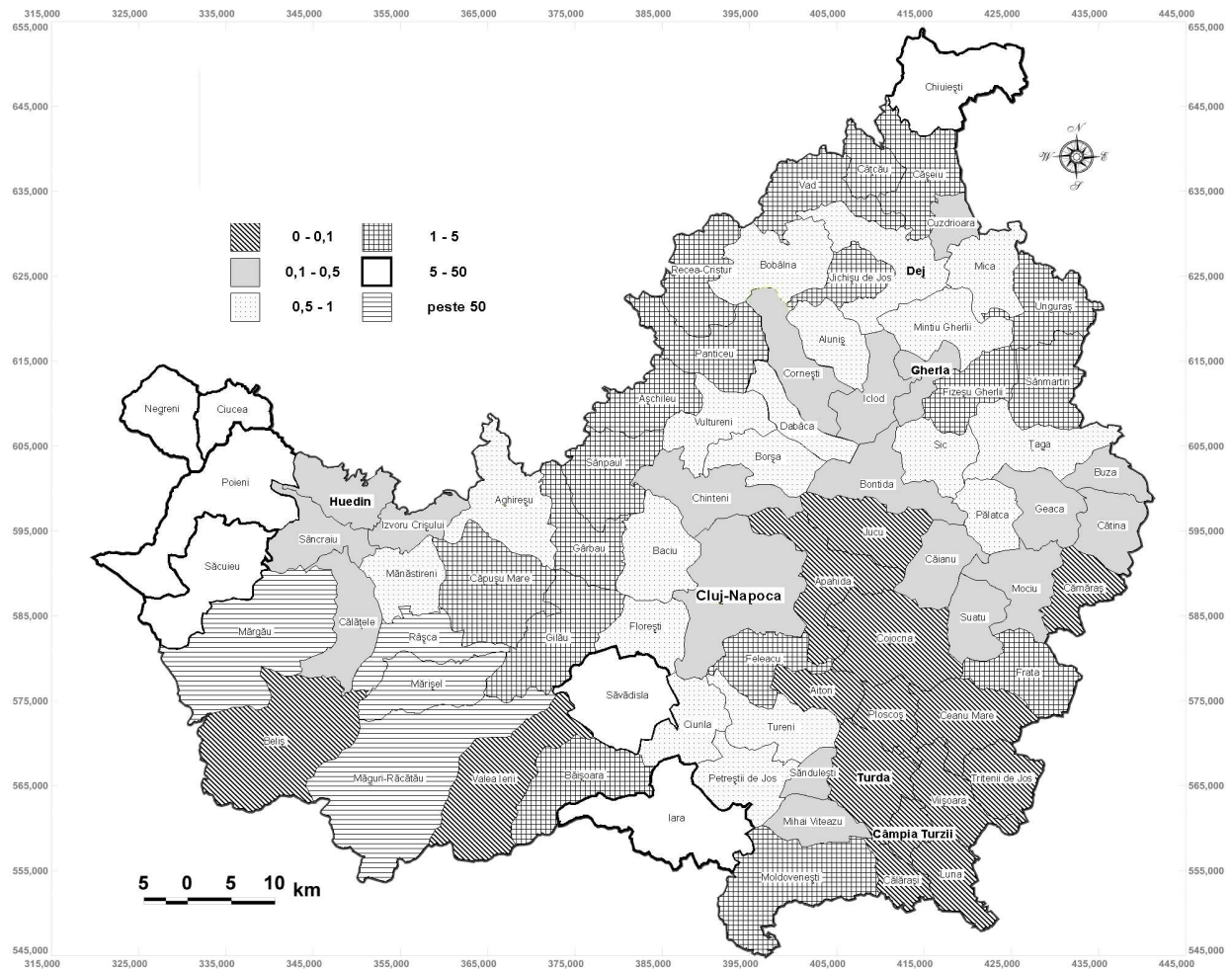
The highest values are registered in the mountainous localities, where the woody surfaces prevail and the index has values over 60%. In these areas, the constructed areas are either disseminated within the territory (Beliș, Măguri Răcătau) or gathered on the bottom of the valley (Valea Ierii).

In figure 2, we tried to emphasize the state-of-the-art in the study area. As related to the values of the index of naturalness, a number of 24 communes and the town of Dej are situated at the limit of the ecological equilibrium, most of them being situated in a contact area, and less in the Transylvanian Plain; the ecological equilibrium of 40 communes and 5 towns was severely or very severely affected.

In conclusion, we consider the frequency of the processes that cause risks to be higher in the areas with very severely and severely affected landscapes, where the forest, as an element of protection and of filtration of the climatic elements, is missing or is present in a very low proportion.

*b. The index of environmental transformation* (figure 3) represents the rate between the surface of the forests and those occupied by agricultural and built-up areas, to which the utilities (ways of transportation) are added. It has been selected as an indicator because the forest reflects the naturalness of the

landscape, while the built-up areas represent a factor of man-made transformation of the landscape ( $I_{\text{environmental transformation}} = A_{\text{forest}} / A_{\text{agricultural \& built-up}}$ ).



**Figure 3.** Index of environmental transformation in Cluj

After calculating this index we noticed an area with a strong environmental transformation disposed in the communes of the Transylvanian Plain and in the lowland region of Huedin. There were surfaces occupied by the forest that are very reduced compared to those used for agriculture. A number of 10 communes (Apahida, Jucu, Cojocna, Aiton, Ploscoș, Ceanu Mare, Trittenii de Jos, Viișoara, Călărași and Luna) and Câmpia Turzii have the value of this index close to zero. This fact indicates big quantitative and qualitative modifications (large arable surfaces, the dispersion of the villages, ways of transportation). The least affected ones (index over the value of 5) are the mountainous areas and a few communes from the lowland surfaces (Săvădisla, Iara), or hilly ones (Chiulești), where the surface of forest still remains significant.

**1.5 Land use in the district of Cluj** represents an important indicator for the characterization of the geomorphologic processes at risk, and for analyzing this indicator we used the CORINE Land cover database that provides precise and updated data concerning land use particularities.

**1. The built-up areas** – in the case of the district of Cluj, the weight of the built-up areas varies horizontally (from urban to rural), as well as vertically (along with the rise of the elevation, the dimensions of the habitat and of the adjacent built-up areas decreases). Thus, the highest values (the percentage of the built-up areas reported to the total surface of the commune) correspond to the urban areas (Cluj-Napoca-20.8%, Câmpia Turzii-15.5%, Turda-12.1%, Dej-11.0%, Gherla-10.9% and Huedin-5.7%). Values that are approximately the same with those of the urban areas are registered also by some rural localities, with values



ranging between 9.6% and 17.9% (Aghireș, Feleacu, Buza, Mihai Viteazu, Cuzdrioara, Săndulești), due to their size or to the industrial activities displayed there. At the opposite pole are the mountainous localities, with values that do not overcome 4.5% (Măguri-Răcățău, Mărgău, Băișoara, Mărișel, Negreni, Ciucea, Călățele and others).

**2. The agricultural fields** include non-irrigated arable lands (211), vineyards (221), fruit trees and forest fruits (222), pastures (231), complex cultivated patterns (242), lands principally occupied by agriculture, with important areas of natural vegetation (243). The pastures need special attention because they are very susceptible to geomorphologic processes. They represent the fields that are permanently used (at least 5 years) for the production of fodder. These areas are submitted to permanent man-made pressure through their irrational use, due especially to overgrazing (a high density of animals per unit of surface, and non-application of the rotation of parcels for grazing, etc.).

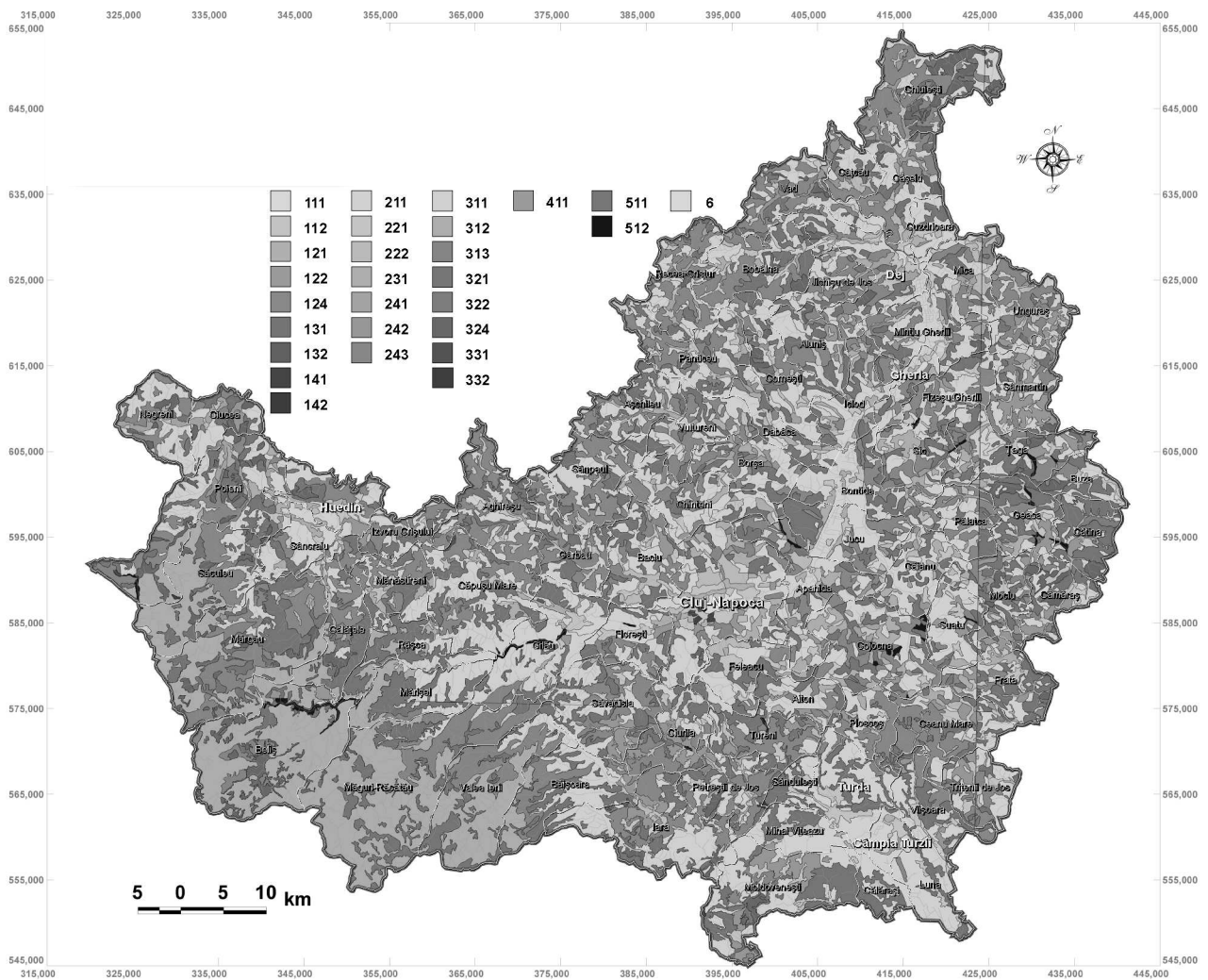
Generally, the agricultural fields occupy more than one third of the total surface of the district of Cluj, with differentiation according to the elevation of relief (it increases along with the altitude) and the type of localities (rural or urban). A series of localities possesses more than 70% agricultural fields (Apahida, Cojocna, Izvoru Crișului- Luna, Ploscoș, Suatu, Trittenii de Jos and others). At the other extreme we find the mountainous localities: Beliș-1.7%, Gilău-18.5%, Măguri-Răcățău, Valea Ierii-0% (because of the very small surfaces, the agricultural fields have not been considered), Mărișel, Râșca and others. Surprisingly, the urban areas are characterized by a large extension of the agricultural fields (Dej-43.2%, Cluj-Napoca- 54.4%, Huedin-62.9%, Turda-67.1%, Gherla-67.3%, Câmpia Turzii-77%). Around these urban nuclei, an accentuated mixture of the land use can be observed. The fields cultivated with vegetables, cereals, fodder crops alternate with the surfaces occupied by orchards, in order to supply agricultural products for the urban centers in the proximity.

**3. The areas occupied with forests and semi-natural fields** include broad leaved forests (311), coniferous forests (312), mixed forests (313), natural grassland (321), moors and heath land (322), woodland shrub (324), sands (331), bare rock (332).

The weight of the surfaces occupied by forests increases proportionally with the altitude. Thus, the high values (>70%) will be found in the mountainous localities: Gilău, Mărgău, Săcuieu and so on. Values higher than 90% can be found in Băișoara, Beliș, Măguri-Răcățău, Mărgău, Valea Ierii. We find small values in the case of localities with large agricultural surfaces from the low altitudinal area of the district of Cluj (Câmpia Turzii, Izvoru Crișului, Trittenii de Jos, etc.). The other localities are characterized by medium values that range between 30-50%. In the case of the cities, we find values below the average (Câmpia Turzii-7.5%, Turda-20.8%, Gherla-21.8%, Cluj-Napoca-4.8%, Huedin-31.4%), except Dej-45.3%. In this case, the forest has also a leisure purpose, beside the economic one, these green oases being preferred for spending free time by the inhabitants of the cities, especially at the weekends.

**4. Inland marshes** (411) occupy small and insignificant areas within the territory of the district. An exception is the Sic locality, where we identified an area of 2.1 ha of marshes.

**5. The aquatic surfaces** include lakes (511) and rivers (512) with a width higher than 100 m. The lakes occupy small surfaces in general (between 0.1-1%: Cătina, Chinteni, Capușu Mare, Mica, Săcuieni, Sic, Râșca, Ciurila, Cășei, Tureni, Cățcău, Poieni, Suatu, Apahida). Higher values correspond to the localities where there are artificial lakes for the production of the electric energy, fish-breeding or leisure activities (Cuzdrioara, Țaga, Geaca, Băișoara).



**Figure 4.** Land use particularities in Cluj

## 2. GEOMORPHIC RISK ASSESSMENT

For assessing susceptibility to slope processes, we elaborated a valuation model of the geomorphologic processes at risk (MOBOPRIG) that will take into consideration the morphometric characteristics of the slopes, the land use and the geological structures.

In order to characterize the first indicator (the morphometry of the slopes), we took into consideration the defining morphometric elements of the slopes: the slope, the density of fragmentation, the depth of fragmentation and the elevation. For each indicator we established defining categories for the characterization of the relief of the study area. Thus, there were drawn maps for the slope degree, for the density and the depth of fragmentation and the elevation map, which were the basis of the weighting system.

For each category, a certain value was ascribed as follows: 0-non-existent process, 1-insignificant occurrence (as number and affected area), 2-low frequency on a large surface, 3-remarkable frequency on a large area (25% of the territory), 4-remarkable frequency and affected areas (50% of the territory), 5-outstanding frequency and affected area (all over the territory).

The weighting points were attributed after a very detailed study on the basis of 500 specific and punctual geomorphologic processes at risk and based on the observation of their defining characteristics and of their differentiated behaviour in time and space. On the same methodology the matrix for the land use and that for the geological structures are also based.



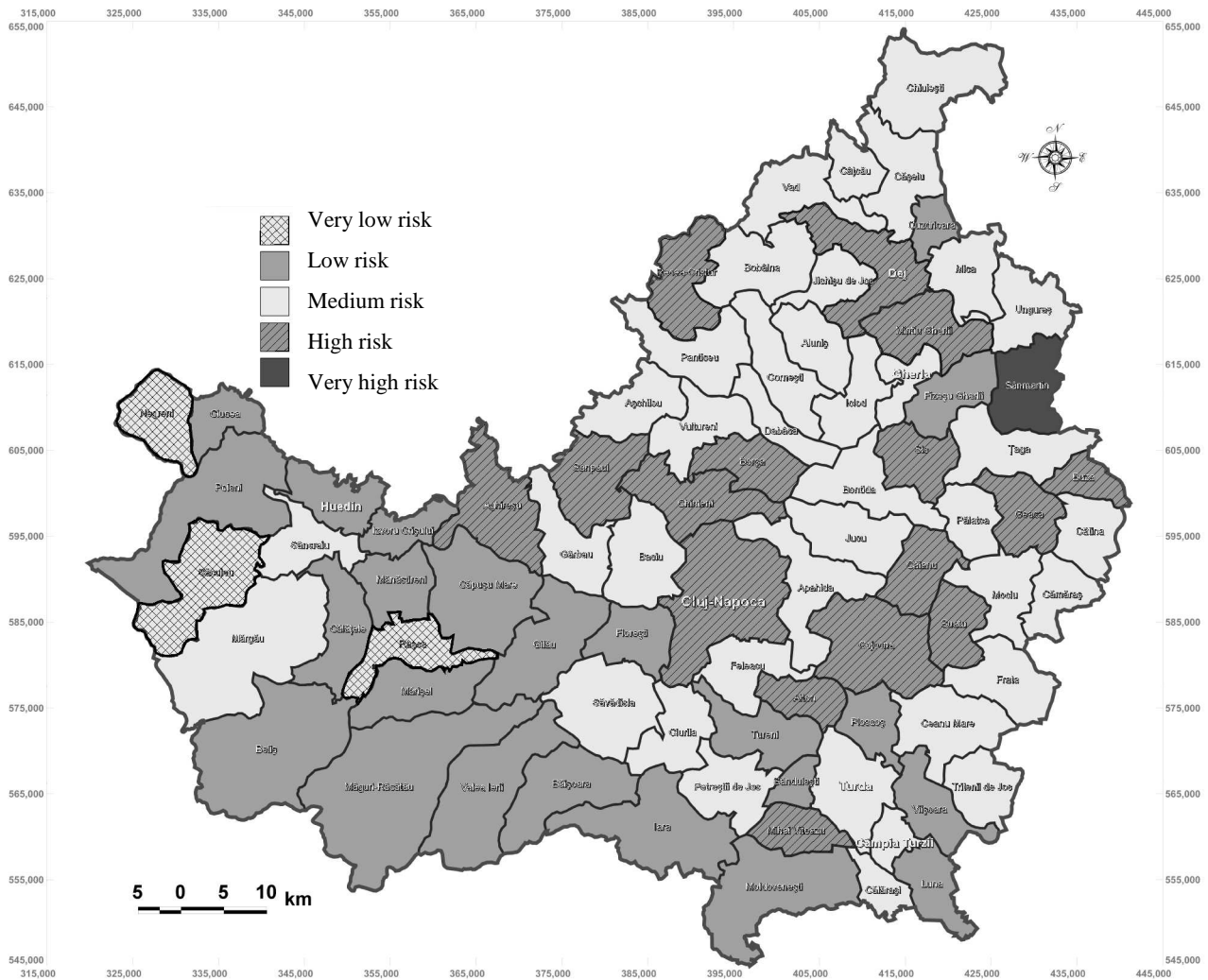
## NATURAL RISKS REGIONALIZATION IN THE DISTRICT OF CLUJ

Subsequent to valuation, an analysis of every site that is prone to geomorphic hazards can be made, according to its characteristics and the corresponding weighting points. Through the summation of the weighting points, a score is obtained, according to which the process can be assigned in a certain class of susceptibility and in a certain category of risk. These categories are: 0-5=very low risk; 5-10=low risk; 10-15=medium risk; 15-20=high risk; >20=very high risk.



**Figure 5.** Land suceptibility on the basis of a posteriori risk assessment

*The analysis of the geomorphologic risks is based upon the susceptibility assessment of the territory. After the performed analysis on the basis of the triggering variables for natural risks, the risk map has been elaborated. We can notice from the very beginning that the analysis was obstructed for several reasons: the inventory of the extreme events was performed especially for the residential areas, where the material losses were registered as affecting in a direct and inherent way the quality of life; there is no methodology for quantifying the differentiated damages per administrative units and we cannot generalize the value of a damaged inhabitation on the entire district and also not on natural units; there are no available insuring systems to operate for the evaluation of the damages; the value of damages varies on a very large scale on natural units too, but also at the level of rural and urban residencies; there are no extended studies at the level of the district that endorses the accuracy of the extreme phenomena that cause natural risks, being well known the fact that in their realization a certain periodicity-continuity cycle has been pointed out.*



**Figure 6.** *The classification of natural risks in the district of Cluj*

After performing the multifactorial analysis we elaborated a thematic risk map, and the following conclusions can be drawn:

- large areas in the mountains have small risks at the level of villages. The restrictive factors are the bedrocks, the land use and the fact that the residential areas are scattered in such a way that the probability of affecting a large number of inhabited areas is reduced. The same thing can be observed in the case of villages disposed in areas where the appearance of hard lithological entities on large surfaces or major riverbeds on glacia, which mainly decrease the effects produced by the extreme events (Tureni, Sândulești, Viișoara, Luna, Florești, etc.)
- the medium risk is associated to the mountain areas and to the areas situated at the foot of the mountains: Mărgău, Sâncraiu, Săvădisla, Ciurila, Turda, Câmpia Turzii, Călărași. Here, the restrictive factor is given by the rocks in formation, predominantly hard or with restrictive physical-mechanical characteristics. In these areas floods are frequent in the valleys, and on the slopes, small extended landslides and sheet erosion could appear. The same medium risk is recorded in 31 villages in the hilly areas of the Someș Hills and in the Transylvanian Plain. If the probability of occurrence of extended floods is more reduced, the process of landslides and rainfalls increase both in frequency and extension. A peculiar phenomenon that occurs at the valley bottom is that of over-moistening through water, resulted from rainfall and snowmelt, bogging over an extended period of time. The rock-factor is favorable; the restriction is a result of the disposition of forest areas and that of agricultural practices.

## NATURAL RISKS REGIONALIZATION IN THE DISTRICT OF CLUJ

- the high risk can be identified in 14 villages and two large cities (Cluj-Napoca and Dej). In the afferent areas of these towns, local floods, large-size landslides, extended rainfalls (Aiton), and erosion due to over-moistened soil cover are frequent. Some of the effects of the processes are amplified by the old or present day manmade activities (Mihai Viteazu, Cheia village), Dej (Ocna Dej), which amplify the value of damage. The grouping of houses also constitutes an amplifying factor of damages.
- in a single village the risk is very high (Sânmartin), because of the multiple events produced and the material losses that were caused.

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