

POPULATION VULNERABILITY TO GEOMORPHOLOGICAL HAZARDS IN REGHIN HILLS

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ABSTRACT. *Population vulnerability to geomorphological hazards in Reghin Hills. Vulnerability assessment of population to the actual geomorphological processes are an essential tool in disaster management planning, assessment and loss estimation, and is an important aspect in geomorphological risk reduction to the safety of the population, settlements and human activities. In this paper we propose an analysis of Reghin Hills population vulnerability to the current geomorphological processes through physical, spatial and demographic indicators.*

Key words: *Vulnerability; population; geomorphological process; Reghin Hills;*

1. Introduction

The vulnerability is the second element of risk, and in a broader context it represents the susceptibility of a system to be affected by an internal or external factor that can cause an imbalance. The vulnerability is an indicator of a future state of a system, which depends on the vulnerable elements, the degree of exposure, the systems sensitivity and resilience to the hazards are exposed (Treweek, 1999).

Elements at risk can be grouped into structural and non-structural elements. Structural elements are those that are directly exposed to the hazard, the losses they cause being closely correlated with the magnitude of the hazard. Non-structural elements include all activities that are indirectly affected by the manifestation of a hazard. By the elements and factors' nature, vulnerability indicators may be included in several categories: spatial, physical, demographic and human, socioeconomic and environmental (Sorocovschi, 2010).

In our study, in order to assess the population vulnerability in the Reghin Hills to actual geomorphological processes, the

indicators taken into account were grouped into spatial indicators (demographic size of settlements, density of settlements, the areality coefficient, index of dispersion, land usage and road network) and demographic and human indicators (demographic potential, population dynamics, the share of female population, population structure by age, degree of demographic aging).

2. Evaluation risk exposed elements

2.1 Population

Demographic potential. The population of Reghin Hills, between 1880 and 2011, increased from 56109 to 88735 inhabitants. This increase was differentiated by time intervals, respectively by media. The analysis of population number evolution highlights two specific intervals: 1880-1992, characterized by a steady growth in population number, the growing rate for this period being 69.9%, and the average annual growth rate of 3.8%; and 1992-2011, when the numerical evolution of the population decreases, with a drop of 6.9%, at an average annual rate of 10.7% (Figure 1).

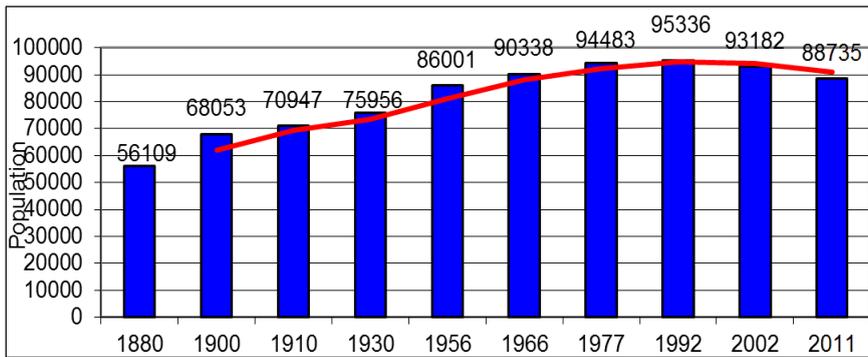


Fig. 1. Numeric evolution of the population from Reghin Hills

The evolution of the population by media has a similar situation (Figure 2). Within the Reghin city, it can be observe that between 1966 and 1992, the population increased from 23295 to 39420 inhabitants.

in almost all municipalities. The highest values of the population growth rate were recorded in the municipalities Petelea (10.77%), Suseni (9.68%), Solovăstru (8.11%), Ideciu de Jos (3.86%),

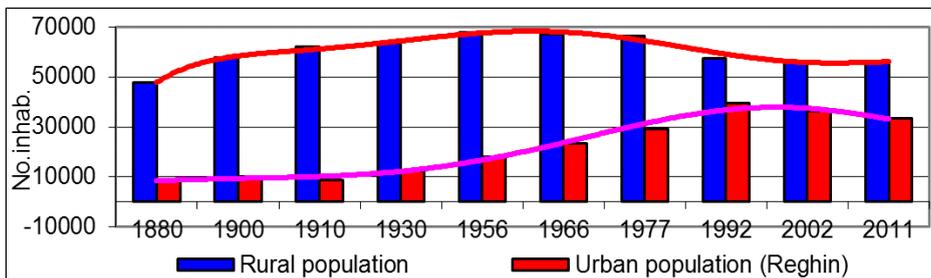


Fig. 2. Numeric evolution of population by medium

This increase was due, on one hand, to the high natural growth rate determined by the pronatalist policy promoted after 1966 and, on the other hand, by the social – economical context focused on forced industrialization and urbanization policy that has generated a pronounced rural-urban exodus that reflects also the decline rural population in this period.

Beginning with 1992, after the decrease of birth rate, the abolition of industrial centers, which resulted in increased migration growth, the numerical evolution of the city's population decreases, the population registering a fall of 15.5%. In rural areas, for the same period, the rate of population increase recorded negative values

municipalities located in the proximity of Reghin municipality, where they developed a series of non-agricultural profiled companies.

Population structure by gender. *Femininity index (FI)*, for the year 1992, indicates a relatively balanced situation with a slight higher percentage of the male population (50.1%) than of female population (49.9%), the femininity ratio being of 100 women to 100.3 men. After 1992 it can be observed a tendency towards the feminisation of the population, the share of female population by 2011 reaching 50.8%, with the femininity **index reaching** 103.4%. At the level of administrative units, with the exception of five municipalities

(Batoș - 96.1%, Chiheru of Jos - 98.5%, Gurghiu-96.8%, Ibănești - 98.6%, Ideciu de Jos – 94.9%), the femininity index shows values between 101.1% and 108% (Fig. 3).

aging population trend. (Surd, 2001).

In 1992, the young population had a share of 34.5%, 53.1% were adults and the elderly only 12.4%. This confirms that at

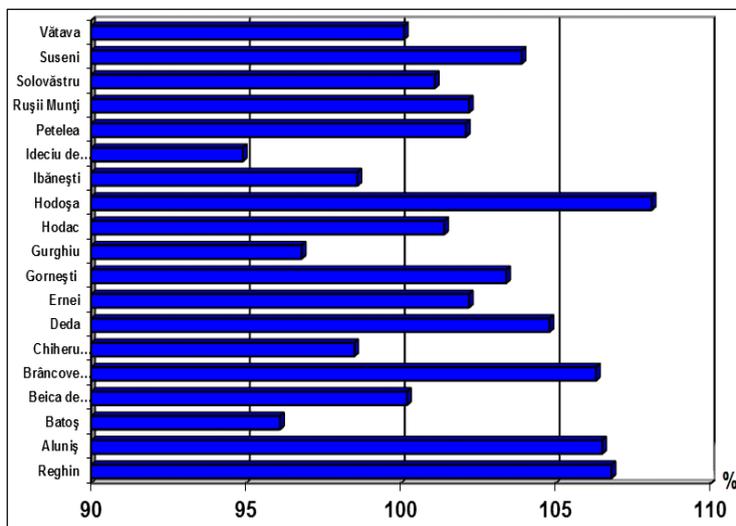


Fig. 3. Femininity index at the level of administrative territorial units

Population structure by age groups. In the analysis of vulnerability, a particular importance is given to the analysis of elderly population and young population from the total population number, the ratio between these two revealing the aging population trend. Thus, it is considered a population as young when the age under 20 years account for over 33% of the total population, and when the percentage of population over 60 years exceeds 13%, we can talk about an

that time the young population was declining, but without being able to talk about aging, the share of elderly population being under 13%.

The comparative analysis of the age pyramid made based on the 1992 and 2011 censuses shows a regressive population trend for the next period, characterized by a continuing decreasing trend of young population and an increasing trend of elderly population (Figure 4).

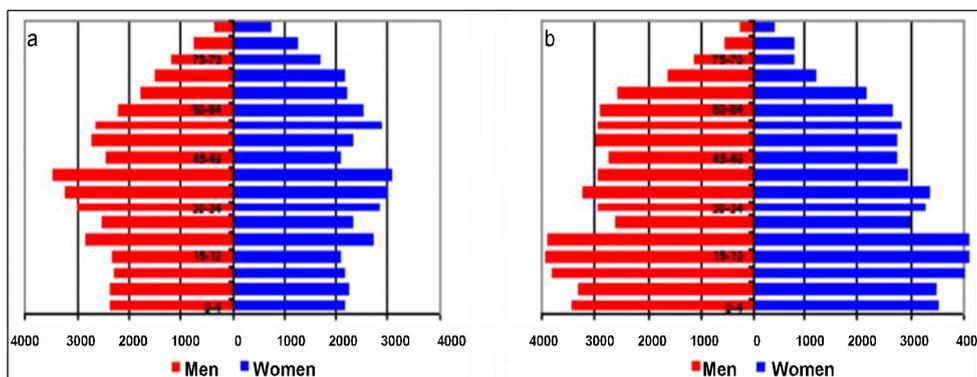


Fig. 4. Population structure by age groups and gender in 1992 (a) and 2011(b)

In the analyzed period it can be observed the decline in share of young population (0-19 years) with 12.3%, from 34.5% to 22.5%, and growth of the elderly population (> 60 years) by 9.9%, from 12.4% to 22.3%. The share of the adult population, aged 20-60 years, registered a continuous increase, from 53.1% in 1992 to 55.2% in 2011 (Figure 5).

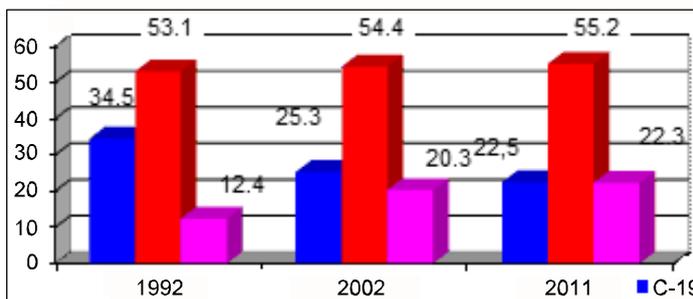


Fig. 5. Population structure by major age groups

The degree of demographic aging can be most expressively highlighted by the index of demographic aging, obtained by comparing the aging population with the young population, thus setting the share of elderly population that lies to 100 young people.

Following the evolution of this index between the last two censuses in the Reghin Hills, there may be observed an increase of the aging index from 79.6% to 98.1%. Reported to the level of administrative units, demographic aging index remains above the area's average in most cases, with values generally between 100-150%.

But if we extend the analysis to localities, it can be seen that in most cases (60.5%) the value of this index is between 110-160%, even with values of more than 200% in the localities Râpa de Jos (200%), Ilioara (202.7%), Sâmbriaș (211.4%), Teleac (223.8%), Nadă a (323%) and Deleni (366.5%), where the age group of over 60 years holds a share of over 36% of the total population.

The pressure of potentially dependant population over the potentially active

population is given by the age dependence rate (index) and was calculated by the formula:

$$Rdv = \frac{P_{0-19} + P_{60 \text{ and over}}}{P_{20-59}} \cdot 100$$

The increase of the adult population share and the decline of young population share due to lower birth rates show a slight

decrease in the average values of this index for the studied area, from 83.6% in 2002 to 80.9% in 2011. As an expression of the degree of aging, high dependency ratio values are determined by the high degree of aging.

2.2. Human settlements

In the relatively small space of Reghin Hills there are located 74 rural settlements, organized into 18 administrative units totally or partially overlapping the analyzed area, respectively Reghin municipality.

Demographic size of settlements. The changes that have occurred in the last century in the population dynamics were reflected in the evolution of settlements' number and in their demographic size.

Thus, if in 1966 medium villages had the highest number (39), in the census of 2011 their number had decreased to 19, and the number of settlements under 500 inhabitants increased from 15 to 41 (Figure 6).

For large villages should be considered also the population migration from smaller villages to the village centers.

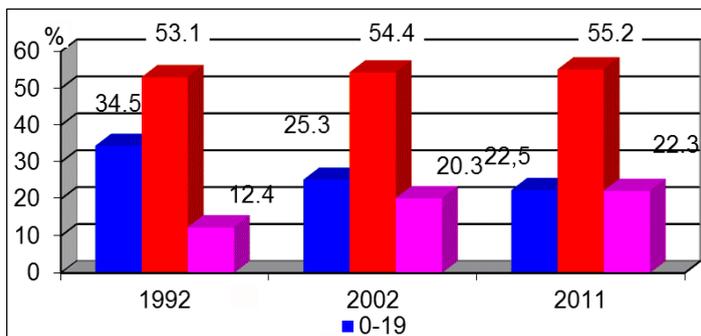


Fig. 6. Demographical size of rural settlements

Depending on the demographic potential, the settlements in the studied area are grouped into the following categories:

a. Very small villages (under 200 inhabitants) comprise 13 settlements, ie 17.6% of all rural settlements. Most of these settlements are scattered in the foothill area of the Gurghiu Mountains, in places with difficult access (Căcuciu, Fundoiaia, Larga, Orșova de Pădure, Ar i a, Bicașu, Larga, Uricea), with households grouped by the site' properties or the recovery manner of local resources. In their totality these are "young" places, declared as self-reliant settlement in 1956.

b. Small villages (201-500 inhabitants) include 28 settlements, representing a share of 37.8% from the total rural settlements. The settlements in this category are located predominantly in secondary valleys that fragment the Sub-Carpathian area in contact with the mountain (Beica de Sus, Chiheru de Sus, Comori, Dubiște de Pădure, Șerbeni) and from the depression basins of Teleacul Hill (Pădureni, Hodos, Isla, Iara de Mures) and Bato (Săcalu de Pădure).

In the current conditions of population dynamics, very small and small villages present a very high vulnerability, being characterized by a high aging degree, some of which are at risk of depopulation. With the highest degree of vulnerability to this phenomenon are the localities Ilioara, Ihod, Mura Mică (37 inhabitants), Mura Mare (36 inhabitants), Mirigioaia (30 inhabitants)

Uricea (55 inhabitants) and Ar i a (79 inhabitants).

c. Medium villages (501-1500 inhabitants) represent 25.7% of the total, ie 19 settlements, of which 4 have the demographic potential that includes 100-1500 inhabitants (Bistra Mure ului, Jabeni a, Ru ii Mun i, and Vălenii de Mure). The settlements in this category are old settlements, with further development, located in easily accessible places, positioned on the Mure Corridor (Ideciu de Jos, Ideciu de Sus, Lunca Mure ului), on the lower terraces (Luieriu) and in depression basins of the main valleys that fragment the Sub-Carpathian area (Beica de Jos, Urisiu de Sus – Beica Valley, Gorenii – Lu Valley, Orșova – Gurghiu Valley), where the topography allowed their spatial expansion and optimal exploitation of local resources.

d. Large villages (1500-4000 inhabitants) include 14 settlements and have a share of 18.9% from the total rural settlements and concentrate half of the rural population (49.59%). Excepting the localities Toaca and Glăjărie that are situated in the main sub-mountainous area, all other localities are located in the valleys of the main rivers, which drain the Sub-Carpathian area: Deda, Aluniș, Brâncovenești, Suseni, Petelea, Gornești, Dumbrăvioara - Mure Valley; Ibănești, Hodac, Gurghiu, Solovăstru - Gurghiu Valley; Dedrad – Lu Valley. The largest demographic potential belongs to three localities: Glăjărie (in 2672

inhabitants) Ibănești (2162 inhabitants) and Aluniș (2015 inhabitants).

Density of settlements is the ratio between the number of settlements and unit area and expresses the number of localities that belong to an area of 100 km². Thus, to an area of 931.8 km² from the analyzed area, belongs 75 settlements, resulting in an average density of 8.1 settlements/100 km², with large differences for each administrative-territorial unit.

The grouping of settlements in territory was strongly influenced by landscape features, place's natural and economic potential and accessibility. Thus, in territorial profile, there can be outlined two areas with high densities of settlements, concentrated on the Mureș and Gurghiu valleys, areas that concentrate the largest settlements.

At the level of administrative-territorial units, high density values of settlements are recorded in the central sector, for the localities Beica de Jos (12.9 villages/100 km²), Gornești (10.5 villages/100 km²), Hodoa (10.1 villages/100 km²), Aluniș (7.4 villages/100 km²), Idecu de Jos (7 villages/100 km²).

With the lowest values of settlements density are part of the municipalities in the eastern sector: Vătava (1.7 villages/100 km²), Ibănești (3.2 villages/100 km²), Chiheru de Jos (3.4 villages/100 km²) and Petelea (4.5 villages/100 km²).

These large differences in the value of settlements density between the two sectors is due to the discrepancies that exist between the municipalities' surfaces and the number of settlements assigned, meaning that there are localities that have small areas and a large number of settlements and population (Beica de Jos: 46,2 km², 6 settlements, 2243 inhabitants; Gornești 2243: 85 km², 9 settlements, 5885 inhabitants), and the opposite are the municipalities in the eastern sector, with large areas, but with few settlements and population (Chiheru de Jos: 115 km², 4 settlements, 1744 inhabitants;

Vătava: 169 km², 3 settlements, 2100 inhabitants).

The areality coefficient is the ratio between the area and the number of settlements, expressing the land surface that lies to a settlement. The mean value of areality coefficient for Reghin Hills is 12.4 km²/settlement. At the level of administrative units, the coefficient ranges generally between 13 - 15 km²/settlement, values close to the national average (18.3 km²/settlement).

With the highest values of this index are the communes situated in the sub-mountainous area, whose administrative area extends far beyond the studied area in the mountainous area (Vătava - 56.4 km²/settlement, Ibănești - 31.3 km²/settlement, Chiheru de Jos - 28.8 km²/settlement) and municipalities which have large areas but they are made up of a small number of villages (Petelea - 21.8 km²/settlement).

Dispersion index reflects the arrangement of the houses in the territory. Dispersion of settlements is influenced by natural factors (physical landscape, river network), demographic factors, socioeconomic factors (type of ownership, usage and degree of land use) and organizational factors.

Depending on the value of this index, the municipalities in the study area can be grouped into the following categories:

a. Municipalities with very low dispersion index (0 to 1.0) are made up of a single village (without the village centre): Suseni, Solovăstru, Petelea;

b. Municipalities with small dispersion index (1.1 to 2.0) located in the sub-mountain area, some overlapping the piedmont sector and are composed of 3-4 generally small villages: Deda, Rușii Munți, Vătava;

c. Municipalities with average dispersion index (2.1 to 4.0) overlap the main valleys that fragment the Sub-Carpathian area and comprise between

4 and 6 villages: Brâncovenești, Beica de Jos, Hodac, Chiheru de Jos;

d. Municipalities with high dispersion index (4.1 - 6.0), consist of a large number (9-10) of generally small villages (some very small), but with village centers of high demographic potential (over 2000 inhabitants): Gornești, Gurghiu.

2.3. Transport network

The development of a territorial system is influenced by a number of factors among which the most important are the land's geographical potential, the position of polarization centers at national level, and the configuration and degree of development of communication and transport network (accessibility). Accessibility is the direct expression of mobility, both in terms of population mobility and exchange of goods, natural resources and information, necessary conditions for economic, demographic, social and cultural development of a territory.

The road network of Reghin Hills, represented by national, county, village and local roads, has a total length of 292.2 kilometers. Compared to the total area, the road network has an average density of 0.31 km/km², close to the country average value 0.36 km/km² (2013).

From the total length of road network, national roads, fully upgraded, it sums 59.2 km, representing a share of 20.27%. The main axis of communication is the road linking Transylvania and Moldova (Turda - Bacău) DN 15, which in the sector between Reghin and Toplița belong to the European coding system E 578 (Sără el - Reghin (DN 15A) – Toplița – Gheorgheni - Miercurea Ciuc - Sfântu Gheorghe - Chinchiș) , a secondary axis which links the roads E 60 and E 58. The relation between east and west is maintained by DN 16 (Apahida-Reghin), which crosses the Transylvanian Plain, connecting the roads E 576 and E 578.

County roads, with a share of 40.16%

(117.4 km) of the total length of the road network, drawn from DN 15 and conect Reghin and the main villages. The most of them overlap sectors belonging to the main tributaries of Mure Valley (Gurghiu - DJ 153C, Beica, Chiheru - DJ 153, Lu - DJ 154), which make them particularly vulnerable both to river bed and also slope processes.

Village roads are part of roads with local importance, generally the valleys overlapping secondary valleys and river divedis, linking the residences and villages. From the total length of 115.6 km (39.5%), only 43.55% are covered with asphalt, and the remaining 56.45% are paved or dirt roads.

The rail network is represented by the secondary railroad Războieni - Deda which makes the connection between the main rail lines: 400 - Bra ov - Satu Mare; 300 - Bucharest - Bra ov - Oradea that runs through the northern sector of the analyzed area.

2.4. Land usage

Reghin Hills by their geographical location, topography dominated by hills with an average altitude and moderate climate provides optimal conditions for a versatile land usage. The analysis of land structure in territorial profile highlights the high share of agricultural land, 51.9% of the total surface, which shows the agricultural characteristic of the area. Surfaces covered with forests hold 42.5% of the total, with the highest degree of afforestation detaching the administrative units whose surfaces excede the Sub-Carpathian area, partially overlapping mountain area. Areas with other destinations have a small share, 5.6% of the total.

Regarding the land use by administrative -territorial unit, some differences occur, some certain category of land having land use categories based on the total area of land administrative-territorial units and the

overlapped landscape characteristics.

Agricultural land. Pedo-climatic and morphometric characteristics of relief allow practicing all forms of agriculture - crop production, fruit production, viticulture, livestock. At the level of the examined area, the total agricultural land, the highest share belongs to arable land 35.5%, followed by surfaces covered with natural pastures and hayfields with a share of 29.5% and 32.1% of agricultural land.

Arable land represent the highest surfaces in the administrative-territorial areas overlapping totally or partially the sector of the Mure Corridor, where they meet most favorable conditions for crops growing. With shares above 50% of the agricultural area are the municipalities Suseni - 63.7%, Hodo a - 63.5%, Petelea - 59.2%, Gornești - 57.5%, Beica de Jos - 51.7%. The lowest share of arable land belongs to municipalities whose administrative area overlap mountainous area where topography and climatic conditions constitute limiting factors in practicing crop culture: Gurghiu - 20.1% Deda - 14.2%, Ibănești - 14.0%, Vătava - 9.8%.

Natural pastures and hayfields represent the second category of land use and the high percentage of these categories of land, 61.6% from the agricultural land, reflects the potential of the area for animal growth. At the level of administrative units, these land categories hold the largest share in the municipalities whose area largely overlaps the foothill space of Gurghiu and Căliman Mountains. From the total agricultural area, the area occupied by pastures represents 24328 ha (29.5%), the the most extensive areas belonging to the municipalities Brâncovenești - 2720 ha (44.0%), Gurghiu - 2679ha (40.7%), Chiheru de Jos -1972 ha (42.8%), Ibănești - 1947 ha (41.0%), Deda - 1930 ha (37.2%), Vătava - 1908 ha (39.0%), Hodac - 1777 ha (41.1%), Gornești - 1612 ha (25.6%).

Natural hayfields have a higher share, 26

606 ha, which represents 32.1% of the agricultural area. The largest share of this land category belongs to the municipalities Vătava - 4624 ha (44.3%), Deda -2524 ha (48.6%), Gurghiu - 2575 ha (39.2%), Ibănești - 2133 ha (45.0%).

Orchards and vineyards occupy the lower surfaces, 2.7% and 0.2% of total agricultural area. After the restitution of lands, based on the Law No.1/1990, the areas occupied by orchards and vineyards have been reduced considerably, on the one hand due to high maintenance costs, on the other hand, many of these lands were sold and the destination of the land was changed. Thus, only in the municipality of Reghin, between 1992 and 2011, the areas occupied by orchards were reduced from 859.57 ha to 778 ha, while those occupied by vineyards has reduced from 47 ha to 39 ha.

The areas with forests represent 42% of the total surface, well above the national average of 26%. With high forest cover are the municipalities Ideciu de Jos - 1256 ha (29%), Solovăstru - 864 ha (28%), Brâncovenești 2193 ha (25%), Petelea 1127ha (25.8%), Beica de Jos 823 ha (17.8%), Hodo a 710 ha (17.9%).

Road surfaces occupy by 2131 ha, which represents 23.7% of the total land surface. Territorially, the most significant area occupied by roads is recorded in the municipalities Brâncovenești - 143 ha, Deda - 101 ha, Gornești - 199 ha, located in Mures Corridor; Gurghiu - 169 ha, Ibănești - 127 ha, Gurghiu Valley; Batoș - 138 ha, on Lu Valley. Reghin municipality has road surface of 326 ha, which is 5.8% of the administrative area.

Civil engineering - courtyards and buildings - occupies an area of 2766 ha which represents 30.7% of the total land surface and 1.7% of the total surface of the area analyzed. The size of construction surfaces show differences by size of population and economic development of administrative-territorial units, so the largest areas with over 150 hectares occupied by

these categories of land, have generally big municipalitie s: Gornești - (326 ha), Ideciu de Jos - 182 ha, Ibănești - 174 ha, Beica de Jos - 156 ha, Hodac - 154 ha. The built surface of Reghin is 330 ha, which represents 5.9% of the administrative area.

3. Vulnerability analysis

Considering that the vulnerable elements group mainly people, goods and activities, in evaluating the population's vulnerability to geomorphological hazards were considered as indicators related to population (femininity index and dependency ratio by age at the level of settlements), and the vulnerability transport network and the land usage (Figure 7).

To highlight the vulnerability of the population according to the percentage of the female population was calculated the femininity index for each settlements and based on extreme values were established five classes of vulnerability, as follows: very low vulnerability $FI \leq 90\%$; low vulnerability $FI = 90.1-100\%$; average vulnerability $FI = 100.1-110\%$; high vulnerability $FI = 110.1-120\%$; very high vulnerability $FI > 120\%$.

According to this index, from the total of 75 settlements that overlap the analyzed area, 34 settlements present a reduced vulnerability, of which 4 cases have femininity index values below 90% (Ilioara - 69.2%, Comori - 79.3%, Păuloaia - 86.6%, and Săcalu de Pădure - 88.1%) and in 30

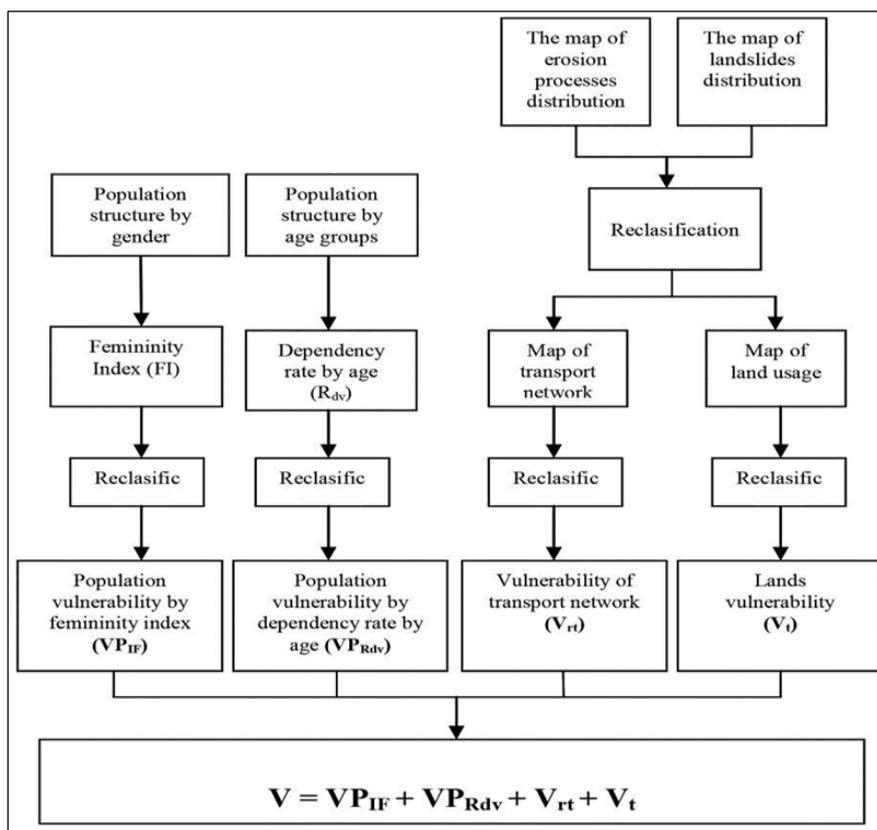


Fig. 7. Scheme of analysis of population vulnerability to current geomorphological processes.

cases the values are between 90.1 to 100%.

With high vulnerability are 14 settlements (18.4%), predominantly widespread in sub-mountainous area with high degree of aging population. In this class fall the localities: Căcuciu - 118.7%, Sâmbriaș - 117.9%, Mura Mică - 117.6%, Habic - 116.1%, Nadă a - 115.1%, Chiheru de Jos - 114.1%, Uricea - 111.5%, Larga - 110.9%, and Aluniș - 110.9%, Mirigioaia - 130.7%, Larga - 131.2%. The highest values of femininity index (FI > 120%), are recorded in the localities Larga (131.2%), Mirigioaia (130.7%) and Brâncovenești (124.6%).

In order to assess the population vulnerability based on extreme values of dependence index by age were established the following classes of vulnerability: very low vulnerability ($\leq 80\%$); low vulnerability (80.1 to 90%); average vulnerability (90.1 to 100%); high vulnerability (100.1 to 110%); very high vulnerability ($> 110.1\%$).

Depending on the value of age dependence index, 31 settlements (40.8%) have a reduced vulnerability, of which 19 settlements have an index value of less than 80%, and in the case of 12 settlement, the values range between 80.1 and 90%. In an average vulnerability fall 11 settlements, which represents a 38.6% of total settlements.

Demographic aging index highlights the high vulnerability for 34 settlements which represent a share of 44.7% of all settlements in which 9 settlements (11.8%) have high vulnerability and 25 settlements (32.9%) a very high vulnerability.

The vulnerability of communications network and lands to geomorphological processes is associated with processes magnitude they are exposed and affected by. Lack of data on damage caused by geomorphological processes determined a spatial analysis of vulnerability that has considered the land usage, classification of roads, processes type and the distance of risk elements to source area.

To assess the degree of vulnerability to geomorphological processes of roads and land, in a first phase, using the system of evaluation was made a classification of geomorphological processes and land based on the economic importance of potential damages on a scale of 1 to 5; after that, it has established a threshold distance of 50 m from the source area, so the vulnerability degree decreases from very high to very low from 50 to 50 m, at over 250 m the impact is considered negligible.

General population vulnerability map to geomorphological processes using GIS was obtained by the method of overlapping thematic layers in raster format, according to the indicators analyzed (Figure 8).

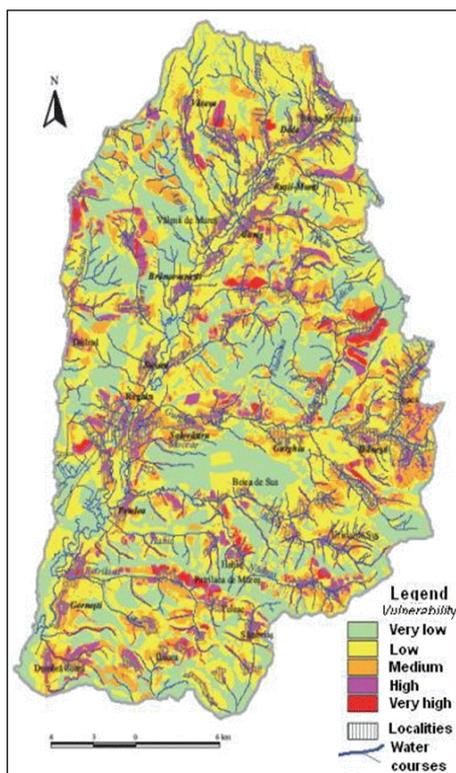


Fig. 8. Population vulnerability to actual geomorphological processes

After analyzing the map, it can be observed that compared with actual geomorphological processes, in the class of

high and very high vulnerability are the settlements superimposed on the valleys that fragment the Sub-Carpathian area, contact aprons and slopes with a high morphodynamic potential, being highly susceptible to landslides and linear erosion processes where sheet flow systems installed

gutters and trenches, active throughout the year.

An average vulnerability to geomorphological processes presents the areas located close to the slopes less inclined affected by stabilizing or stabilized landslides but with potential reactivation.

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