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NATURAL RISKS AND SUSTAINABLE DEVELOPMENT IN THE MORPHOHYDROGRAPHIC GURGHIU BASIN

-PhD thesis-

(ABSTRACT)

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SUMMARY

Key – words: natural risks, sustainable development, morphohydrographic basin, Gurghiu, models, geographical space use, risk management.

The subject of the thesis "***Natural risks and sustainable development in the morphohydrographic Gurghiu basin***" was motivated by the future utility of such a study from the perspective of sustainable development on this territory.

The purpose of this thesis is a detailed analysis of existing or potential natural hazards that pose a threat directly or indirectly on the functionality and socio-economic development of the territorial system represented by the morphohydrographic Gurghiu basin and proposes solutions for sustainable development of the territory considered. Achieving this goal was accomplished by meeting certain objectives such as:

- Background in the field and deepen bibliographic notions and concepts that will operate during the research;
- An analysis of physical-geographical and anthropogenic factors that contribute to the onset of dangerous phenomena, with destructive effects on the socio-economic and environmental;
- Analysis of the types of natural hazards whose incidence has been reported in the morphohydrographic Gurghiu basin, identify the causes that generate them, the ongoing way and in the field location of risk processes and phenomena;
- An evaluation of the likelihood of occurring of a natural hazard and the mapping of susceptible areas, mapping of areas with high vulnerability to the analyzed hazards and risks;
- Analysis of the use of geographical space and how it affects the onset or development of certain phenomena of natural origin;
- Proposal for the control and mitigation of natural hazards induced and propose strategies in the context of sustainable development of the territorial system analyzed.

The research methodology followed on a side the identification and analysis of natural risks that are restrain factors generating failure of the analyzed territorial system, and on the other side to find solutions to problems imposed by the action of natural hazards on the social system. To achieve its purpose, the methodology starts from the analysis of existing data (in the archives of city halls, state forest districts in the archives at SGA Târgu-Mureş and Reghin, in electronic databases, Regional Meteorological Center South Transylvania), combining with field research (observing, measuring) were analyzed to produce similar patterns of events on which was performed a detailed analysis of existing situation and a forecast of future events associating risk in the Gurghiu basin.

The activities undertaken in this study were conducted in three main stages: the stage of documentation of the notions and concepts that will operate in this thesis, establishing the boundaries of the basin, collecting available data on the studied area and the issue addressed, field phase which provide support for the development study (supported by geomorphologic mapping, soil, land rating, soil quality evaluation and the land use); synthesis phase and logical ordering of ideas to develop the study (using statistical and mathematical methods of analysis and GIS analyses).

CHAPTER I.

NATURAL HAZARDS: CONCEPTS, PARADIGM AND RESEARCH METHODS

In the first chapter we consider the main definitions and meanings of Romanian and international literature on the concepts of hazard, vulnerability and risk, and some related concepts, such as susceptibility, exposure, resilience, perception, evaluation and risk management. This first chapter contains four parts, in each of which are shown schematically the main approaches to the concepts mentioned in the literature, both foreign and Romanian.

Risk in itself is an abstract, ambiguous and polysemantic notion. Numerous approaches are received in geography: the risk is defined as a system, measure, function, equation, condition, effect, etc. In most definitions, risk is defined and understood in terms of binomial hazard-vulnerability, often the product of two components. Many authors consider a third element as having a significant contribution in the calculation of risk: exposure – the state (individuals or goods that can be recovered economically) to be subjected to direct action of a natural phenomenon (figure 1), exposure degree being different and varying from one community to another, from one individual to another. The relationship between man and the risk can be seen from two angles. On the one hand, men are under direct threat (exposure) of certain natural phenomena, and on the other hand, through its activities, man, directly or indirectly, influence the onset or increase them.

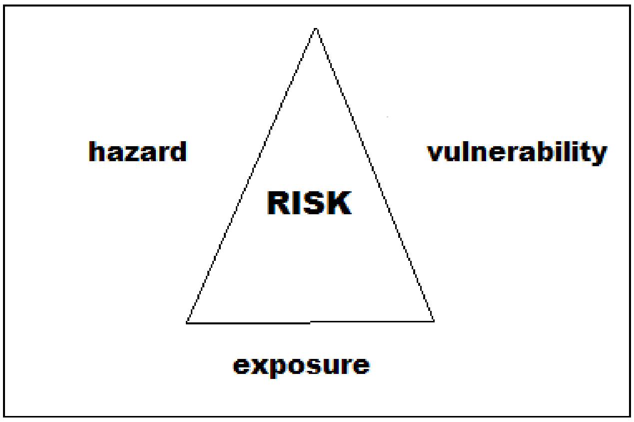

Figure 1. Risk triangle (after Crichton, 1999, cited by St. Schneiderbauer şi Daniele Ehrlich, 2006).

One of the key steps in natural hazards research is risk mapping, which combines both qualitative methods and quantitative research methods in the risk field. Zoning the areas exposed to various natural hazards is particularly important for territorial planning. Risk maps are a very efficient tool to restore the spatial distribution of hazards and risks. Risk mapping is requiring several essential steps (figure 2).

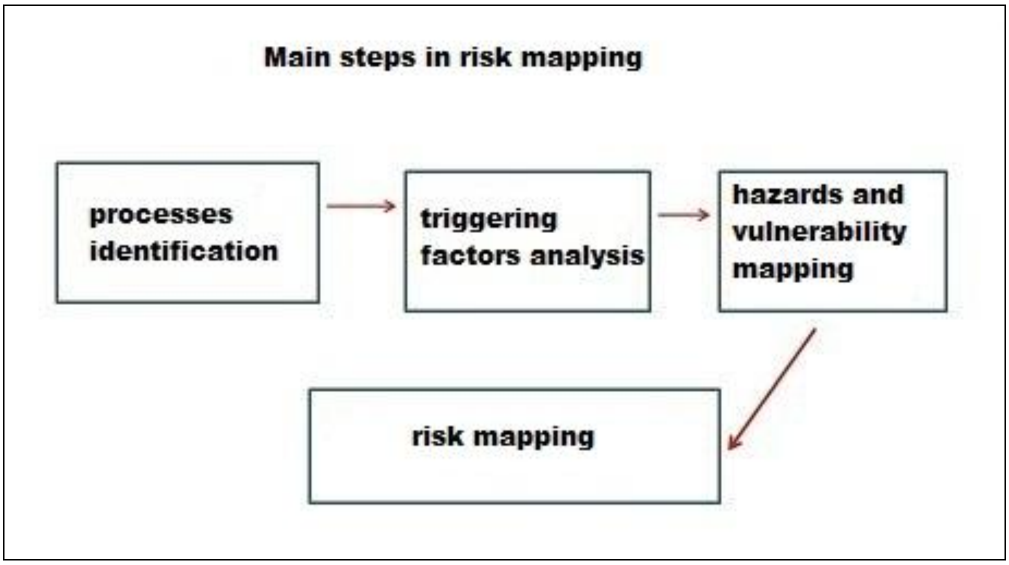

Figure 2. Main steps in risk mapping

CHAPTER II.
SUSTAINABLE DEVELOPMENT: TERMS AND MEANINGS IN FOREIGN AND ROMANIAN LITERATURE

The second chapter refers to the concept of sustainable development, being underlined the main objectives on European and national level, targeting its achievement. Although originally the concept of sustainable development arose in relation society-environment, now almost all fields are based in development policies including sustainable development to achieve this objective. In literature there are many definitions of the concept, each discipline or philosophy giving it a distinctive note. The connection between risk mitigation and sustainable development lies in the inclusion of the concept in foreign policy disaster management, between risk management and sustainable development is established a relation of interdependence.

The chapter is structured in four parts. In the first part is summarized the history of the concept of sustainable development, starting from the first definition in 1987 to present. Sustainable Development Strategy of European Union is presented in the second part. Also in this part, references are made to the way in which the concept is applied at European level and to the assessment of this process using sustainable development indicators. In our country, the process of sustainable development must take place according to the National Strategy for Sustainable Development, targeting the country`s economic growth and economic alignment with EU standards, while respecting the principles of sustainable development (equitable development without endanger the environment). Of course, achieving this goal of sustainable development in Europe and worldwide include a number of limiting issues (section 2.4), among which the differences of perception on the concept, global recession (limitation of financial resources for implementation of measures), discrepancies in national policies for implementing sustainable development strategies (caused by differences in economic, social, cultural, political, legal).

CHAPTER III.

NATURAL RISKS IN MORPHOHYDROGRAPHIC GURGHIU BASIN

Natural risk analysis in the morphohydrographic Gurghiu basin was done in several stages:

- Analysis of physical-geographical factors that may cause the occurrence of natural hazards;
- Analysis of anthropogenic factors that may influence the onset or development of natural processes;
- Qualitative and quantitative analysis of natural hazards in the studied area , based on identifying the types of dangerous phenomena occurred in the region, their location in space, event characteristics (based on historical landmarks recorded or retained in collective memory);
- Analyze the effects of natural hazards on people, in terms of its vulnerability;
- Evaluation of natural riks and establishing risk classes.

3.1. Physical-geographical factors generating natural hazards and risks

3.1.1. Geographic location and spatial relationships of the morphohydrographic Gurghiu basin with the neighboring units

The morphohydrographic Gurghiu basin is located in the eastern part of the Transylvanian Depression, overlapping volcanic area Gurghiu Mountains in the eastern part of the basin, and unity of the Reghin Sub-Carpathians hills and the Mureş terraced corridor.

From administrative point of view, the morphohydrographic Gurghiu basin is located in the eastern part of Mureş County (except a small strip in the eastern part, which belongs to Harghita county), the Center Development Region (figure 3).

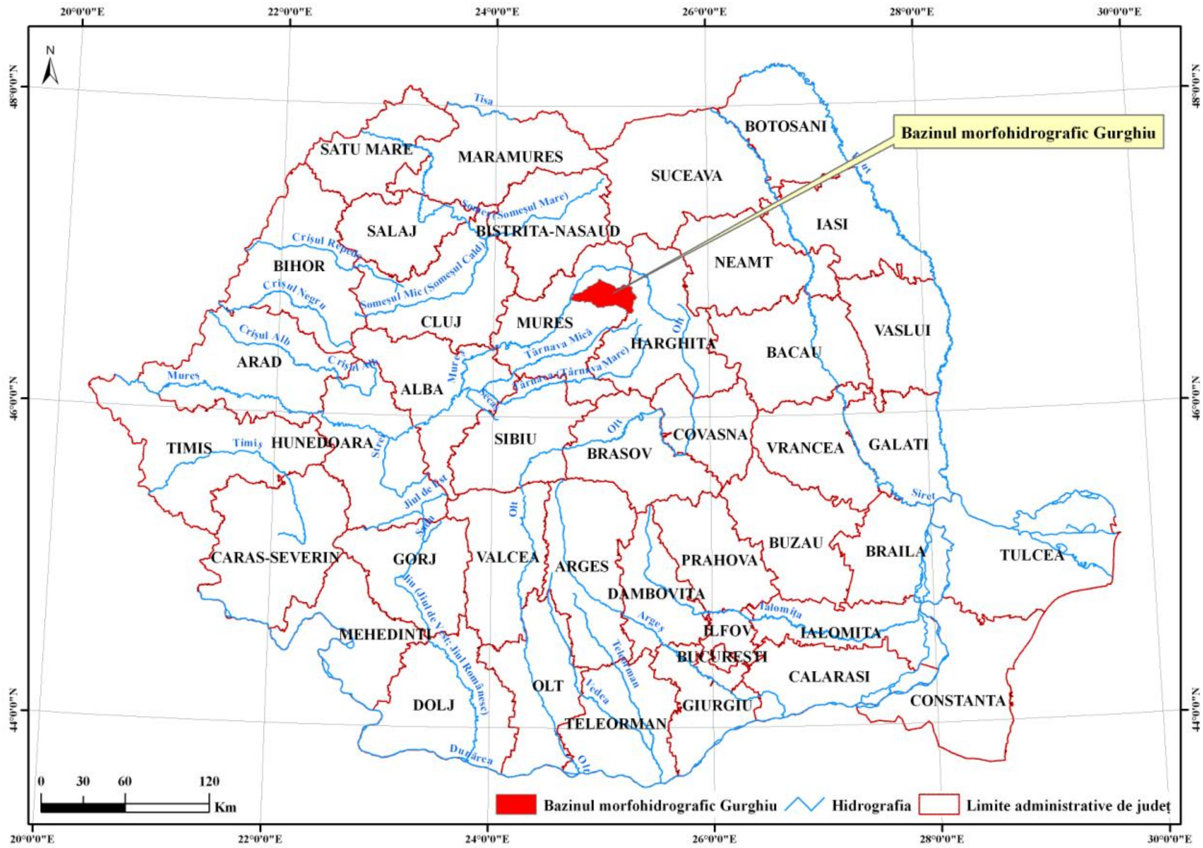

Figure 3. Location of the morphohydrographic Gurghiu basin in Romania

3.1.2. Lithology and tectonic

In terms of lithology, the morphohydrographic Gurghiu basin has to be analyzed taking into account three main levels of deposits: volcanic superstructure of Gurghiu Mountains, volcanic agglomerates and Quaternary sediments in the western part of the basin. Most of the basin surface is covered with volcanic features, resulted from volcanic eruptions and of course the deposits resulting from erosion made by exogenous factors.

In ***the Gurghiu Mountains*** the volcanic units of the superstructure are best preserved. They consist of a main caldera surrounded by volcanic cones with heights under those of the two others mountains of the East Transylvanian volcanic chain (between 1500-1700 m). At the bottom of the volcanic cones the lava plateaus (photo 1) stretch between 1200-1400 m, followed by volcanic agglomerates (850-1100 m).

a

b

Photo 1. a. Volcanic lava on the right side of the Tămăşoaia Dobârlii stream, June 2011; b. Volcanic lava with lapilli (Fâncel), July 2009.

In the central part of the basin, the pyroclastic breccias of Pleistocene age are dominant, and the andesites with amphibole and pyroxene are dominant on the high peaks. In the western part of the basin, in the depression area are prevailing the Neocene deposits, represented by clays, sand, gravel, tuffs, while Quaternary sand, gravel and clay are specific to the river`s meadow. The occurrence of salt in the western part complicates the morphology, salt being present at Orşova and Jabenița.

3.1.3. The Relief

From the geomorphologic point of view, the evolution of the Gurghiu morphohydrographic basin must be seen throughout three morphogenetic steps: the mountain step (Gurghiu mountains), the piedmont and hilly level (which consists of large depressions and high hills) and the valley step (represented by the Gurghiu valley, the asymmetric meadow and the terraces), located between 1776 m (the highest volcanic cone – Seaca Peak) and 377 m (the confluence with Mureş River, near the city Reghin).

The values of morphometrical features of the relief are influenced by lithological structure, arrangement stepped landforms, and also by the present geomorphologic process action. The fragmentation depth has values between 50 and 374 m, the highest values being characteristic to the eastern of the area dominated by mountain ridges. The fragmentation density has high values at the some confluences (Cracul Crucii, Isticeul), on some mountain ridges (Seaca Peak), the maximum being comprised between 4-6 and 5 km/km².

In the eastern part of the basin, the slopes with a convex profile are dominant, being steeper. There is high degree of coniferous vegetation cover. In the foothills, slopes are slowly downing in steps, with the long train of debris at their base. The slopes from the depression area have a profile rather concave, slightly sinuous.

As for the exposure of the slopes, dominant are the northern ones, followed by westerns and north-westerns. The slope degree values are higher in the mountain area, but usually dominate the slopes with values ranging from 2.1 -5° to 5.1 – 15°.

3.1.4. The climate

The stagger of the relief on steps is directly influencing the climate. The temperate continental climate has different nuances between the mountain and hlly areas, the average temperature ranging between 6-8° C. The annual average rainfall is between 800 and 950 mm (fig.4), maximum precipitation was reached at Fâncel: 1244.2mm / year. Maximum rainfall is in the spring, triggering some present geomorphologic processes. Combining the sudden warming during the early spring with the heavy rains cause high flow, this situation is often resulting in floods. Maximum precipitation is reached in July, both to Lăpuşna (815 m) and Ibăneşti (460 m) hydrometric station (figure 4). This is explained by the high occurrence of severe storms in the warm season, with large amounts of precipitation in a short time (sometimes less than 24 h).

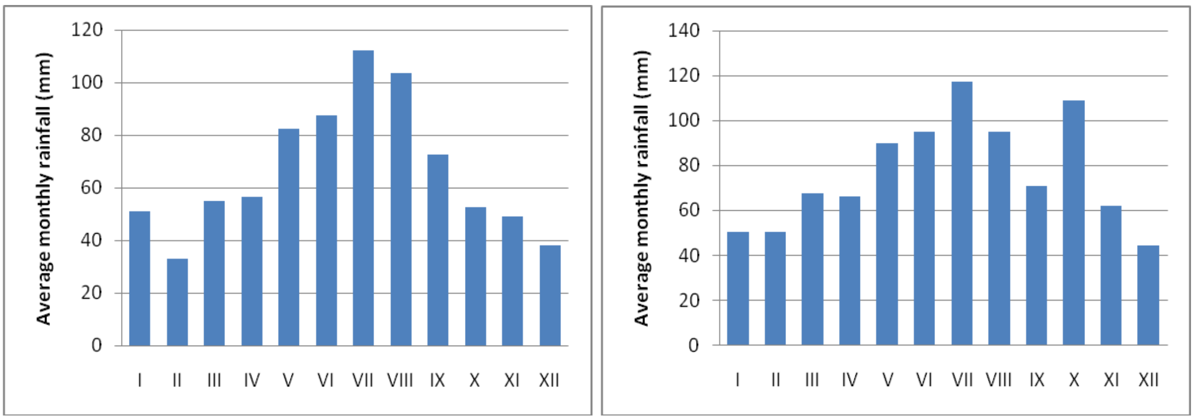

Figure 4. Average monthly rainfall between 2000-2011 (left – Lăpuşna hydrometric station, right – Ibăneşti hydrometric station).

3.1.5. Hydrography

The morphohydrographic Gurghiu basin is part of the upper Mureş basin, Gurghiu River being left tributary of the Mureş River . The basin shape is elongated, asymmetric, the left tributaries are shorter compared to the right ones. The length of the Gurghiu River is 55 km and basin area is about 585 km².

Highest flow rates are recorded in spring due to melting snow and spring rainfall (April - May). Flow rates are recorded in summer, due to convective rains. Quite exceptionally high flow rates are recorded in winter, due to a sudden warming of the weather, as happened on 27 December 1995. The highest measured flow of the river between 1986 – 2009 at Ibăneşti hydrometric station (460 m) were recorded in 1995 (199 mc/s), 2000 (182 mc/s) and 2006 (86.5 mc/s), the flood of 1995 has caused the most significant damages (figure 5).

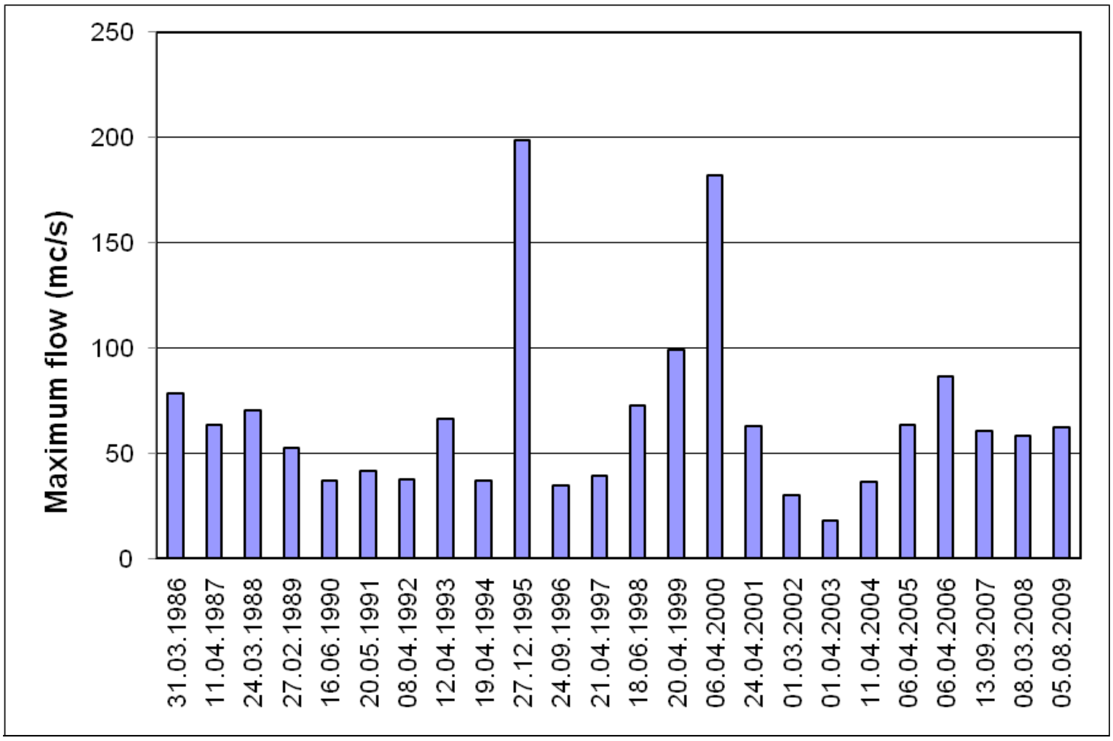

Figure 5. Maximum flow recorded between 1986-2009 at Ibăneşti hydrometric station (460 m).

3.1.6. Vegetation

In the morphohydrographic Gurghiu basin, vegetation is ordered by altitude, the forests of the basin occupying more than half of its surface, the degree of restocking is over 60%. Forests in this basin have ratios depending on the climate and altitude: up to 600 m height dominates leaved, between 600-1000 m resinous are mixed with broadleaf forests (the overstored – figure 6), while the resinous are dominant at the altitude above 1000 m. Dominant species are beech and spruce (figure 6).

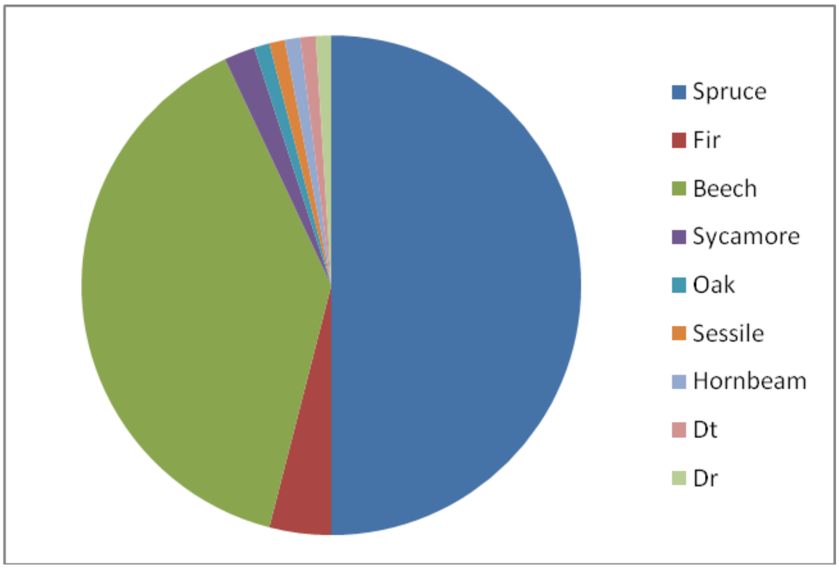

Figure 6. The share of woody species (after the forest planning of Gurghiu and Fâncel Forest Range, 2011).

In the morphohydrographic Gurghiu basin, due to large proportion of forested areas, many processes are weakened (such as floods or geomorphologic processes in mountain area, heavily forested). But deforestation that took place in order to extend the current grazing involved installing present geomorphic processes; surface erosion, gully erosion, torrents, landslides. This is expressed on field by a high rate of expansion of current geomorphic processes in the western basin (where dominated are pastures, grassland, crops), compared with the eastern part (where dominant are the woody slopes).

3.1.7. Fauna

Hunting Fund is characterized by diversity: deer, wild boars, rabbits and grouse. The wild animals have an indirect influence in triggering of natural hazards; in this matter the injuries produced by animals to trees reduce their resistance to the action of non-biotic factors such as wind.

3.1.8. Soils

Soils layer is composed of a variety of types, subtypes, varieties. Thus, throughout the basin have been identified six classes of soils, each comprising several soil types and subtypes. Dominant types of soils are belonging to andisols (AND) and cambisols (CAM), plus luvisols, protisols, antrisols and spodisols.

3.2. Anthropogenic factors involved in the generation of natural hazards

Anthropogenic factor, represented by the population and its activities is of great importance in the onset or increase of some effects of natural extreme phenomena. The continuous development of the society has determined the increase of the impact of the anthropogenic activities on the environment.

Thus, uncontrolled deforestation, undermining the base of slopes, overgrazing or irrational grazing, the inappropriate agro-technical usage, lack or insufficient number of works necessary to reduce the effects of natural processes and phenomena are just part of human actions that directly or indirectly influence the generation of natural hazards and induced risk. Man is also a main agent that interferes with work and improvement in natural hazards risk management techniques.

The influence of anthropogenic factors involved in the generation of natural hazards in the studied area was analyzed in terms of population density and number of inhabitants in common in terms of houses density, and finally the land use and resources exploit was analyzed (figure 7).

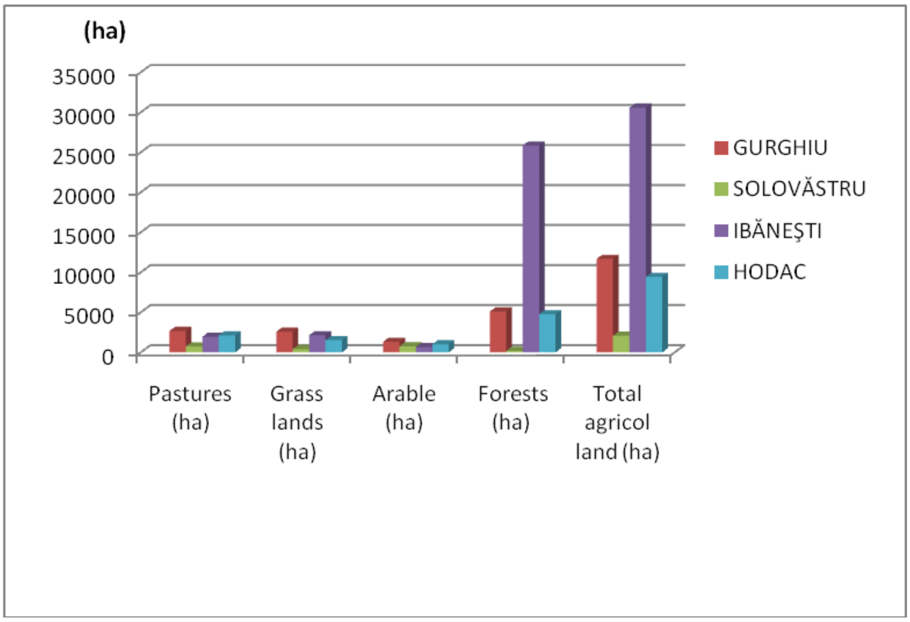

Figure 7. Land use in the Gurghiu morphohydrographic basin (according to Statistical Yearbook of Mureş County, 2009).

3.3. Hazards and natural risks in the Gurghiu morphohydrographic basin

The step which followed the identification of physical-geographical and anthropogenic factors involved in triggering of some natural hazards in the studied area was followed by the identification and the localization of the main natural phenomena which involve risk in the Gurghiu basin.

3.3.1. Types of natural hazards in the morphohydrographic Gurghiu basin

The studied area is affected frequently and with varying intensities by hazards caused by the occurrence of both natural and mixed origin, that can be grouped into four categories: geomorphic hazards, climatic hazards, hydrological hazards, biological and environmental hazards.

3.3.1.1. Geomorphologic hazards

The following geomorphologic hazards were identified in the morphohydrographic Gurghiu basin. Those are triggered by natural factors, but also by anthropogenic intervention:

landslides (partially stabilized and active landslides), crumbling, erosion (surface erosion, banks erosion), swamping. The occurrence of some natural phenomena, such as climatic hazards (windthrows) or hydrological (floods) can generate the emergence of geomorphologic processes.

Regarding the location of geomorphologic hazards, there was a greater expansion in the western part of the basin; this is influenced primarily by the high degree of forest which cover the eastern part. The following table shows the location of geomorphologic processes in the villages of the four townships of the Gurghiu basin (table 1).

Table 1

Location of geomorphologic processes in the four townships of the basin

Nr. Crt.	Type of process	Village
1.	Sheet erosion (surface erosion)	Ibăneşti, Gurghiu, Jabenița
2.	Gully erosion	Ibăneşti, Hodac, Jabenița, Solovăstru, Glăjărie, Gurghiu, Orşova
3.	Gullies	Ibăneşti
4.	Torrents	Ibăneşti, Orşova, Caşva
5.	Active landslide (photo 2)	Ibăneşti, Caşva, Solovăstru
6.	Stabilized landslide	Ibăneşti, Ibăneşti Pădure
7.	Crumbling	Păuloaia, Toaca, Ibăneşti
8.	Banks erosion	Orşova, Orşova Pădure
9.	Swamping	Outskirts of Gurghiu township (in Mociar Forest)

Photo 2. Landslide from Caşva (right side of Gurghiu River), April 2010.

3.3.1.2. Climatic hazards and risks

In the studied area, the climatic phenomena with the greater danger degree are those of short duration and high intensity (such as spring and summer storms, often associated with strong winds). Those of average duration and intensity are including earlier frost (causing damage to crops), or later frost. The long duration rainfalls are generating floods, and the heavy snow can determine damage to the trees, due to the layer of snow and its maintenance over a longer period. Strong wind is the most dangerous climatic hazard in this area, with direct consequences on forest ecosystems and indirect effects on economic activities (timber harvesting). Windthrows (term used especially in forestry) refers to damages induced to the stand due to wind action (I. Popa, 2007). The most affected are mountain forest ecosystems, and between them spruce stands are most vulnerable.

In the morphohydrographic Gurghiu basin, the catastrophic windthrows are rare, the most damaging ones were in 1975 and 2010. The most damaging windthrow was in November 1975, the total wood volume exploited being of 500000 m³ (after GurghiuValley Forest Range`s Chronicle 1968-2005). The most recent event occurred on the night of 14 and 15 June 2010, during a storm. The older stands (resinous and beech stands) and younger stands (including beech of 20-30 years old) over a total area of 5953 ha in PU II Isticeu (Fâncel Forest Range) and partially in PU I Glăjărie (same forest range). The total volume of damaged wood exceeded 200,000 m³.Trees damages was different: pulling the roots, tearing and bending of trunks, branches and broken tops (photo 3).

a  b 

Photo 3. a and b. Trees felled in June 2010, P.U. Isticeu.

3.3.1.3. Hydrological hazards

On the Gurghiu River, floods generally occur in March, April, August and October. They occur as a result of rainfall and a sudden warming of the weather that leads to snow melting. Due to the high degree of vegetation cover, the extent of flooding is reduced, especially in the upstream. Floods can occur on the Gurghiu tributaries, during heavy rainfalls caused by the storms of short duration, but significant amounts. The most significant floods which caused major damages occurred in May 1970 (photo 4 a, b), July 1975 and December 1995.


a


b

Photo 4 a and b. The effects of floods of 1970 at Lăpuşna (photos taken by engineer E. Negulescu).

3.3.1.4. Biological and environmental hazards

In the morphohydrographic Gurghiu basin, these types of hazards are determined by the invasions of insects attacking forest vegetation, causing major imbalances within these forest ecosystems. Among the pests that attack trees in this area, the most important are the bark beetles, especially *Ips typographus*, also known as the bark of spruce big beetle, those beetles attacking spruce stands in particular, more particularly affected being trees injured after windthrows. The impact of these invasions on the balance of forest ecosystems is very high; the damages determined by pests decrease the ecological and economic value of trees.

3.3.2. Analysis and evaluation of natural risks in the morphohydrographic Gurghiu basin

The analysis and risk evaluation focused on three categories of processes and natural phenomena that have a higher incidence in the territory: the present-day geomorphologic processes represented by mass movement processes (landslides and subsidence/caving) and sheet erosion, floods and windthrows. In the natural risks analysis the qualitative and quantitative analysis methods were combined, resulting in numerical values which were analyzed and processed using GIS techniques.

3.3.2.1. Land susceptibility to mass movement processes

The analysis of susceptibility to mass movement processes has proved to be necessary for the study of natural hazards in the morphohydrographic Gurghiu basin, given that these processes can have negative consequences on the functionality of natural and social systems. The methodology used in the analysis of susceptibility to mass movement processes based on numerical-cartographic method (M. C. Turrini and P. Visintainer, 1998), starting from rating the factors (parameters) that affect or may affect the initiation of processes, the reasoning being supported by field analysis, consulting the maps and the orthophotomaps, analysis of the manifestation of these processes and territorial specificity of the studied area. Rating method was combined with mapping method, by processing the values obtained using GIS techniques and obtaining susceptibility maps, according to each parameter analyzed and obtaining the global susceptibility map. The parameters considered for analysis of land susceptibility to mass movement processes in the morphohydrographic Gurghiu basin were: lithology, altitude, slope degree, fragmentation depth, fragmentation density, slope exposure, soil and land use. For each parameter was made a reclassification of numerical value classes, each class being rating from 1 to 5, depending on its importance in triggering or increasing mass movement processes - landslides and crumbling (table 2).

Table 2

Classes of Susceptibility according to susceptibility index (SI)

Susceptibility (SI)	**Susceptibility class**
1	Very low susceptibility
2	Low susceptibility
3	Medium susceptibility
4	High susceptibility
5	Very high susceptibility

Following reclassification operations of thematic maps based on evidence obtained, their transformation in raster system and adding using GIS tools (Raster Calculator), the total susceptibility to mass movement processes map was obtained (figure 8). Total susceptibility was obtained by applying the formula:

TS = [(**Lithology***25) + (**Soils***20) + (**Slope Degree***10) + (**Altitude***10) + (**Slope Exposure***15) + (**Land use***10) + (**Fragmentation Depth** *5) + (**Fragmentation density** *5)] / 100,

Where:

TS – Total Susceptibility

5, 20, 25....etc. - the percentage value of each parameter.

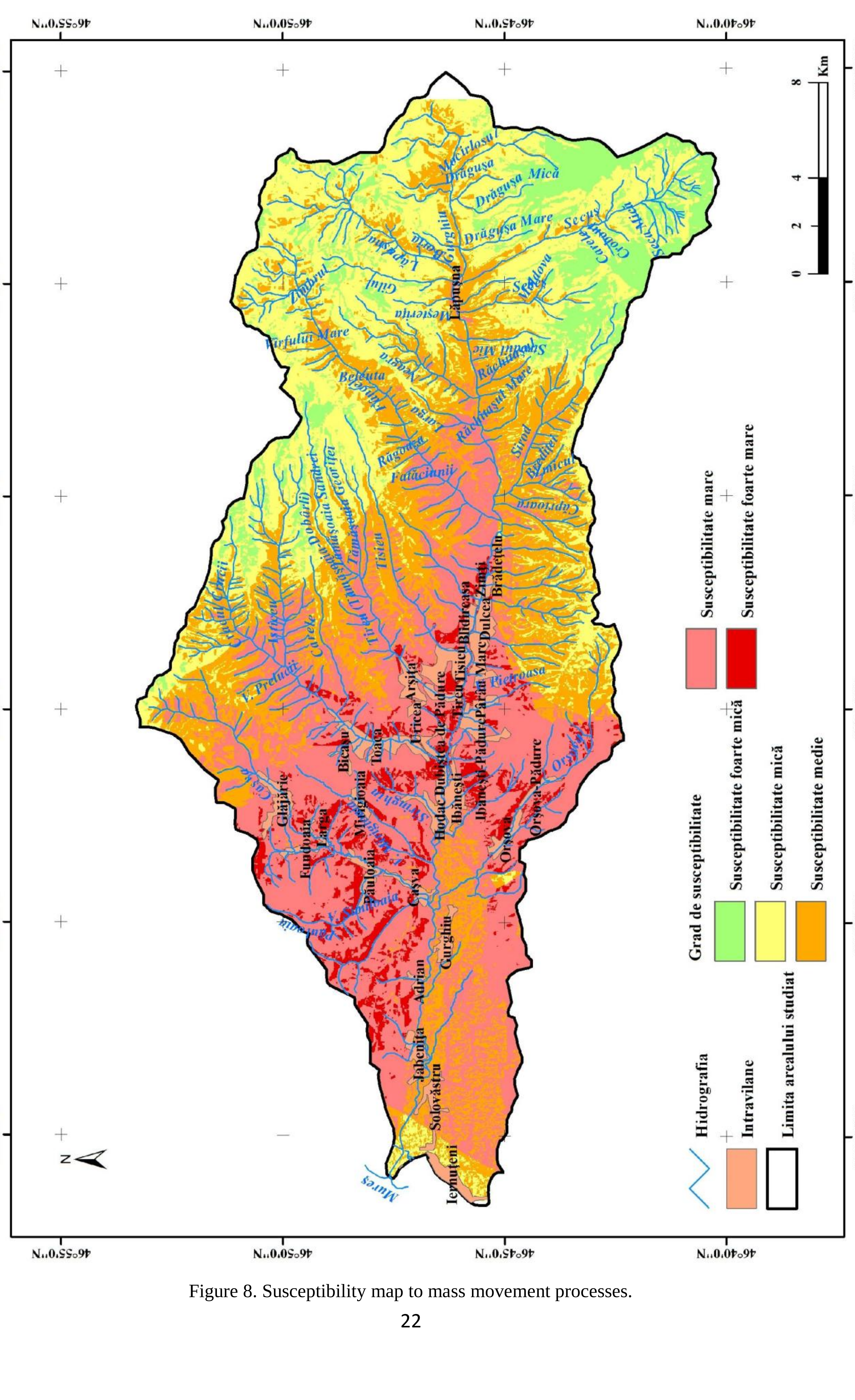

Figure 8. Susceptibility map to mass movement processes.

The analysis of susceptibility to mass movement processes map has relieved that the land characterized by high and very high susceptibility to mass movement processes are located in the western part of the basin, while areas located in the mountains and foothills have average susceptibility and low or very low susceptibility to such processes.

3.3.2.2. Susceptibility of land to surface erosion

To analyze the susceptibility of land to surface erosion, U.S.L.E. Universal Soil Loss Equation) model was used, according to the formula below:

E = K * S * C * Ls * Cs, where:

E – Average annual surface erosion rate in tons/ha/year;

K – Correction coefficient for climate agressivity;

LS – Slope length (m) and slope degree;

S- Correction coefficient for soil erodability;

C – Correction coefficient for cover-management factor and vegetation characteristics;

Cs – Correction coefficient for soil conservation.

The annual average erosion rate for the analyzed basin was calculated using the formula obove, using GIS techniques (the Raster Calculator function of the Spatial Amalyst module), the obtained values ranging between 0.1 and 1 t / ha / year (the surface erosion map). The highest values of surface erosion are characteristic for the western part of the basin, values above 1 ton / ha / year average rate of erosion being characteristic for the agricultural lands of the four townships (figure 9). Classes of susceptibility to surface erosion were established according to the classes of annual erosion rate (tons/ha/year), as follows:

Table 3
Susceptibility to surface erosion

Eroziune (tone/ha/an)	Susceptibility
0 – 0,1	Very low susceptibility
0,1 – 0,2	Low susceptibility
0,2 – 0,5	Average susceptibility
0,5 - 1	High susceptibility
>1	Very high susceptibility

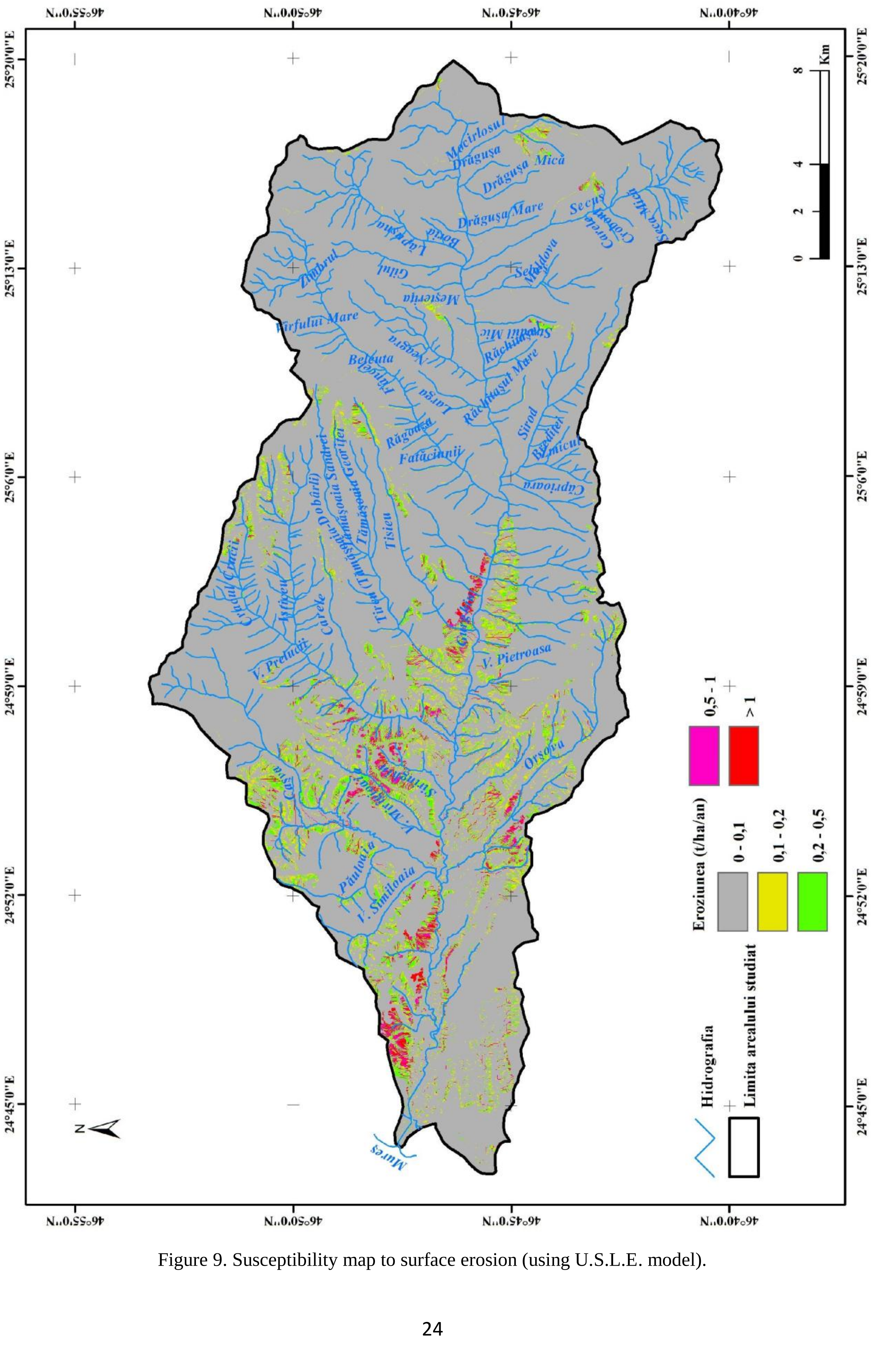

Figure 9. Susceptibility map to surface erosion (using U.S.L.E. model).

To validate the model, a comparison was made between map and field observations (photo5).

a 

b 

Photo 5. Soil erosion a. Township of Ibănești, May 2009, b.Township of Gurghiu, May 2009.

3.3.2.3. Population`s vulnerability to geomorphologic hazards

Lack of consistency of existing data on the damages caused by geomorphologic processes that occured in the past in the studied area which could alow a statistical analysis of vulnerability, imposed a spatial analysis of vulnerability, elements at risk being considered human settlements (the 30 localities form the Gurghiu basin). Thus, to achieve vulnerability map to present geomorphologic processes the IDW method (Inverse Distance Weighting), function of Spatial Analyst Module of ArcGis 9.3 software was used, based on current geomorphic processes prior location (present geomorphic processes map). Establishment of classes of vulnerability was based on the rating method, depending on the economic importance of potencial damage determined by the geomorphic processes. Thus, according to it the geomorphic processes were rated form 1 to 5, their reclassification being necessary to facilitate the analysis. Thus, very high vulnerability is characteristic to the south-east of the Gurghiu Village, Orşova and Orşova Pădure villages, Ibăneşți village, to the left side of the Păuloaia Valley and to the left side of the Pietroasa Valley. The most part of the territory is characterized by high and average vulnerability to present-day geomorphologic processes, meanwhile the mountain and piedmountain area are characterized by low and very low vulnerability, due to the concentration of human settlements in the western part of the basin, between the confluence of Gurghiu River with Fâncel stream (in the east) and with Mureş River (in the west).

3.3.2.4. Population vulnerability to floods

According to S.G.A. Mureş, flooded area taken into account as protection plan against the flood at the level of Gurghiu basin is represented by the the meadow of Gurghiu between Zminti (township of Ibăneşti) and the confluence with the river Mureş, plus a small village area Lăpuşna. For this area was considered a 1% probability a flood to happen. The flood vulnerability map of morphohydrographic Gurghiu basin was done after plan site no. 7 in which is mapped the flood area for the Gurghiu River.

Exposed elements include 189 households, and over 200 households' annexes. Most houses and household annexes exposed to the flood are located on the Gurghiu meadow, near Solovăstru (over 70). The land area that might be affected by flooding is of 466.45 ha (mainly grassland and arable land). To these are added 22 culverts (of which one of concrete), county and municipal roads in floodplains continuity in township of Solovăstru (Solovăstru and Jabenița villages) the total length of road network being exposed 4.9 km plus 0.3 km from DJ 154 E. The cultural objectives exposed are the community centre from Dulcea, and kindergarden located in the same building. Vulnerability increases with the growth of anthropogenic impact, the constructions in the flooded area, the lack of cleaning works in the river`s bed and its tributaries.

3.3.2.5. Forests vulnerability of the morphohydrographic Gurghiu basin to windthrows

High vulnerability to wind throws for area studied is characteristic stands in UP I and II of O.S. Fâncel and U.P. VIII O.S. Gurghiu Valley, dominated resinous, and the average age is about 85 years, indicating a high degree of instability of trees to wind action. Consistency is the average of 0.5 trees and in the production class dominates class II and class III production. A special situation can be seen in high mountain areas, where even if the ruling stands of spruce, the vulnerability is very low because of high altitude, which explains the short duration of the period vegetation of spruce, and thus an index of less slender. Also in the same area, much smaller stands of trees` age (young plantation) and a low degree of human impact (Seaca protected area) has to be considered.

Very low vulnerability to windthrows is characteristic to areas dominated by mixed stands (predominantly beech), more resistant to strong winds. These phenomena does not affect man directly, they are not threatening the life or health of the humans, but indirect losses are significant because the wind throw is a disruptive factor on the ecological and economic point of view - of forest bio production.

3.3.2.6. The total population vulnerability to natural hazards in the morphohydrographic Gurghiu basin

Population vulnerability to natural hazards in the studied area can be considered from two perspectives: direct vulnerability (direct threat) and indirect vulnerability (threat is reflected on the inhabitants' activities: timber harvesting, agriculture, rural tourism). Total vulnerability was calculated using GIS techniques, as the sum of all natural hazards analyzed vulnerabilities likely to occur in the studied area, with the following formula:

$$\mathbf{V_t = V_i + V_d + V_g}$$

Where:

V_t - total vulnerability;

V_i - vulnerability to flooding;

V_d – vulnerability to windthrows;

V_g – vulnerability to present geomorphic processes.

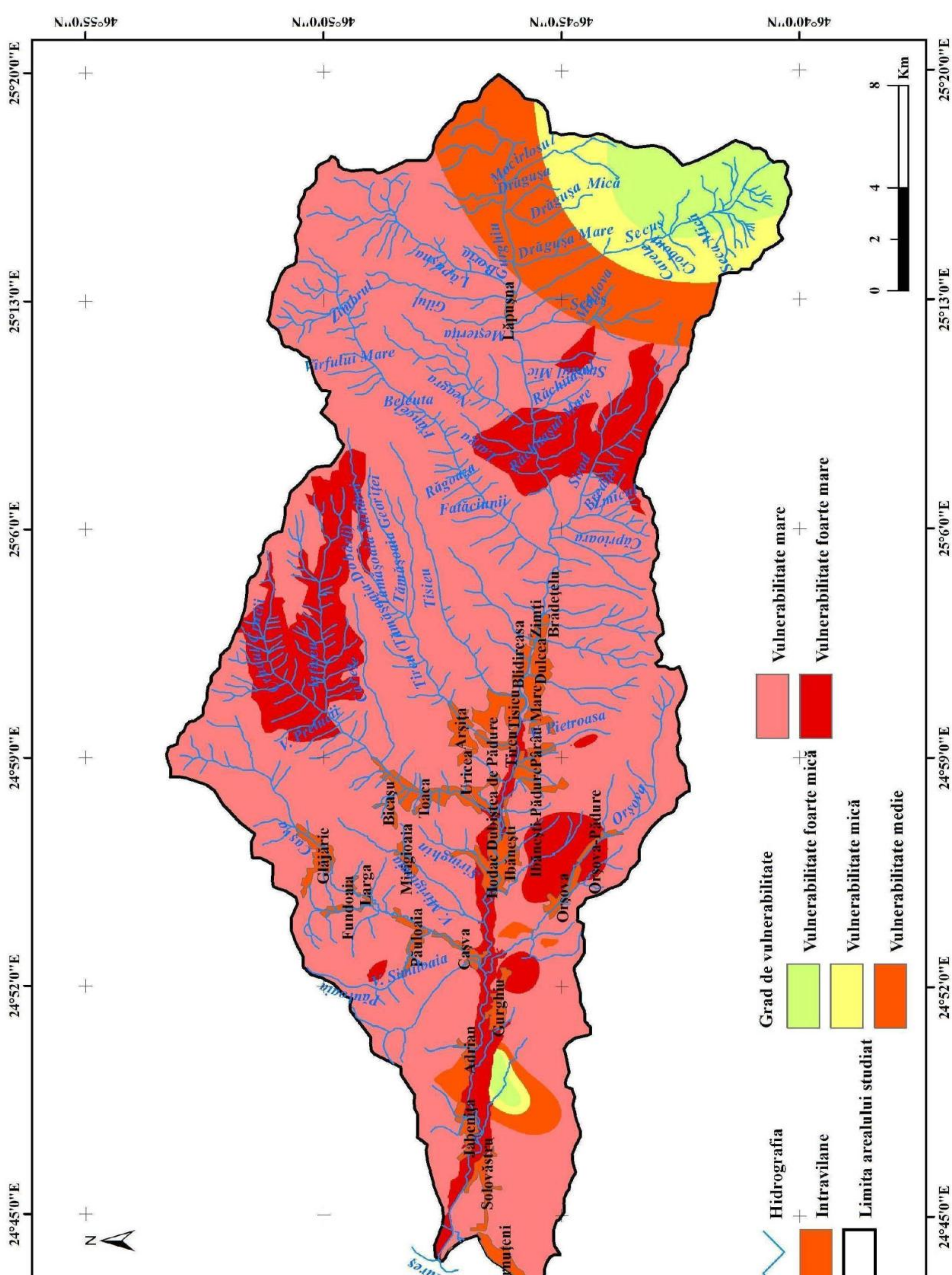

Figure 10. Total vulnerability map.

3.3.2.7. Natural hazards risk evaluation in the morphohydrographic Gurghiu basin

In this study, two types of evaluation (qualitative and quantitative) were used, with the aid of GIS, risk calculation formula is:

$$R = (S_t + S_{er}) * V_t,$$

where:

R – natural hazards risk ;

S_t – susceptibility to mass movement processes;

S_{er} –susceptibility to surface eosion;

V_t – total vulnerability, calculated as sum of vulnerability to mass movement, vulnerability to flods, vulnerability to windthrows.

There is a high percentage of areas characterized by high risk and very high natural hazards (over 70% of the total area of habitat), while low risk areas characterized by very small and is only 14% (table 4, figure 11).

Table 4

Share of risk degrees in the studied area

Risk degrees	Surface (km^2)	% from surface
Very low risk	11.4	2
Low risk	67.8	11,8
Average risk	79.3	13,5
High risk	226.4	38,7
Very high risk	198.2	34
Total	**583,3**	**100**

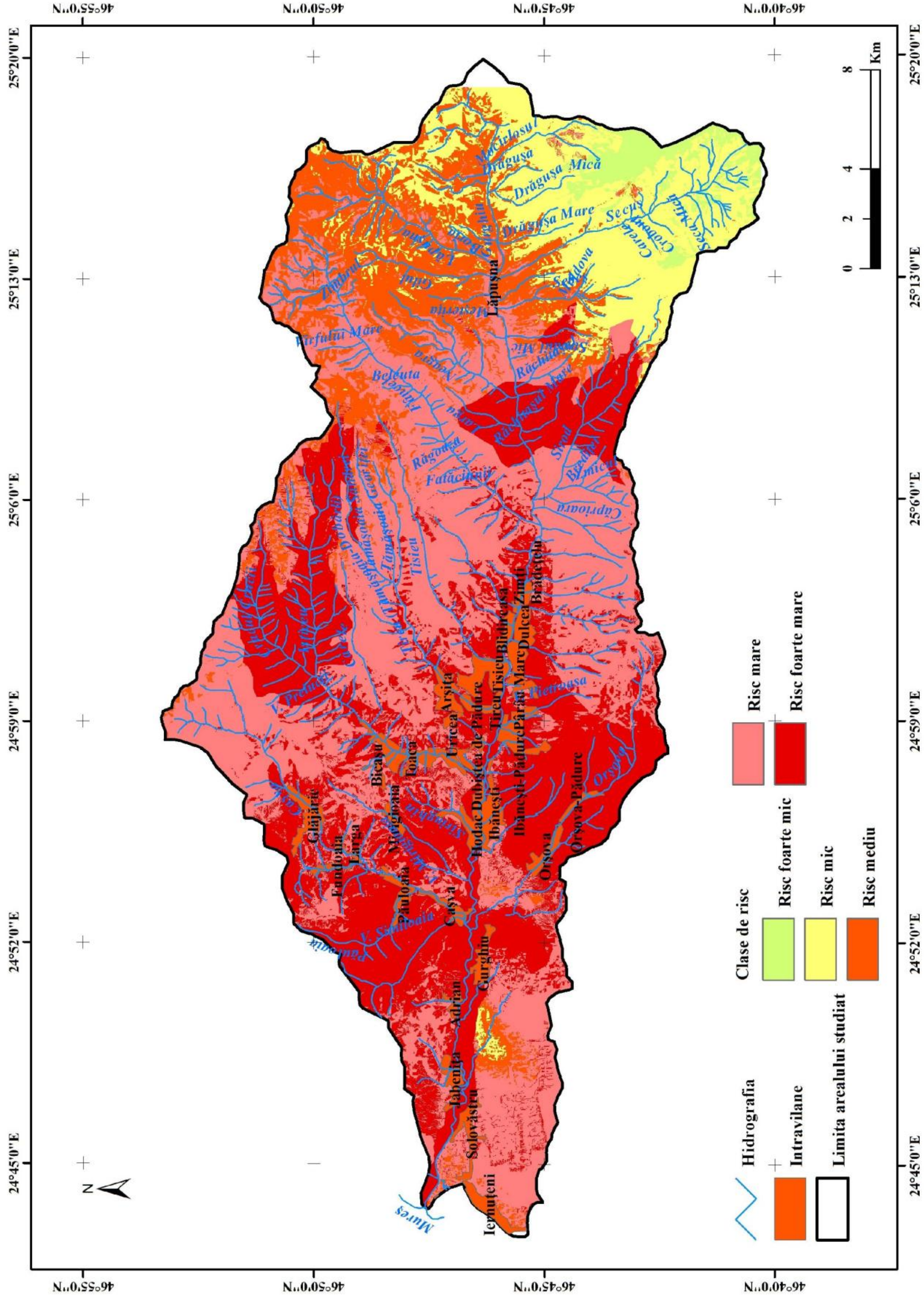

Figure 11. Natural hazards risk map in the morphohydrographic Gurghiu basin.

CHAPTER IV.
SUSTAINABLE DEVELOPMENT AND GEOGRAPHICAL SPACE USE IN THE MORPHOHYDROGRAPHIC GURGHIU BASIN

The way in which the Gurghiu basin`s inhabitants have set up the geographical space and have used the natural resources (soil`s and subsoil`s resources) is defining the fundamental characteristics which are expressing today the basin`s identity. Geographical space use, which mean the use of natural resources, changes on the geographical subsystems, anthropogenic interventions on the geographical space`s geo-components and inducing a state of imbalance in the natural systems` functionality represent a consequence of anthropogenic intervention to transform and set up space. To this is added the imbalances caused by natural hazards, which constitute risk factors in the territories evolution and development.

The criteria taken into account in the analysis of space use in the morphohydrographic Gurghiu basin were the geomorphologic, biotic and anthropogenic criteria. Considering the three criteria for the geographical space use there were three types of models: the anthropological – rural model, the forest model and the pastures and grassland model. The morphohydrographic Gurghiu basin represents a rural space, in which the inhabitants` main occupational activities are timber harvesting, agriculture. This rural space tends to a continue modernization while at the same time a large part of traditional values are being kept.

4.3.1. The anthropological – rural model

In terms of administrative-territorial the morphohydrographic Gurghiu basin includes four townships, consisting of 30 villages, most villages belonging to Ibănești – 10, Gurghiu - 10, and the less to Solovăstru - 2. The four townships are stretching along the Gurghiu River, in the western part of the basin, where the relief was favorable for establish settlements. Tradition is fusing with modernity. Thus, especially after 1989, the elements generally found in urban areas began to exist in the Gurghiu Valley villages, in order improve the peasants' life. The preservation of some traditional elements (such as icon as beside the bed) gives a note of specificity. In terms of population activities, dominate commercial, agricultural and forestry.

The rural system of Gurghiu basin represent one of the largest rural systems of the Reghin micro-region (Andreea Man, 2009, PhD thesis), both in terms of large inhabitants' number and expansion. This region is distinguished by its ethnographical traditions, those representing one of the reasons which contributed to the decision of foundating the Gurghiu Valley Community, in 2006.

4.3.2. Forest model

Wood was and is the main resource available in the Gurghiu basin, the forest found being at over 40000 ha in 2009 (table 5).

Table 5

Forest found in the Gurghiu basin (2009)

The Gurghiu Forest Range		**The Fancel Forest Range**		**Ghindari Private Range**	
State forestry	15065 ha	State forestry	12243 ha		
Private forestry	4368 ha	Private forestry	7704 ha	Private forestry (the property of Ghindari county)	600 ha
Recent plantations	45,7 ha	Recent plantations	19,4 ha		

Large area occupied by forests led to exploitation of this resource since early 19^{th} century. Spruce and beech are exploited, the exploited trees generating from accidental products (resulting from windthrows), from forest hygiene (sear trees) and the main sources (included in the forest range's decimal plans). The strict monitoring of the activities taking place in the Gurghiu Valley woods is assigned to the Forestry Directorate, throughout the forest ranges.

Wood is a raw material for the musical instruments industry, Reghin being one of the largest centers of this industry in Europe. Here there are produced a wide variety of musical instruments: violins, guitars, wind instruments. At Hodac and Gurghiu the production of whistles had a long tradition. Also, wood is used in producing of handicraft work, the decoration of the traditional symbols with specific usage to the Gurghiu Valley area.

4.3.3. The pastures and grassland model

From the total farmland area, pastures represent only 13% (which is 7386 ha) and grassland 12% (6631 ha), the rest being occupied by arable land (with a much smaller area) and forests. In addition to natural grasslands, pastures are created by man through clearing bushes vegetation. Given that much of the basin surface is covered with forest vegetation, pedologic conditions and limiting climatic factors for growing plants, the dominant is livestock (figure 12), pasture and hay constitute support for the development of this branch of agriculture (second occupation for residents after timber harvesting).

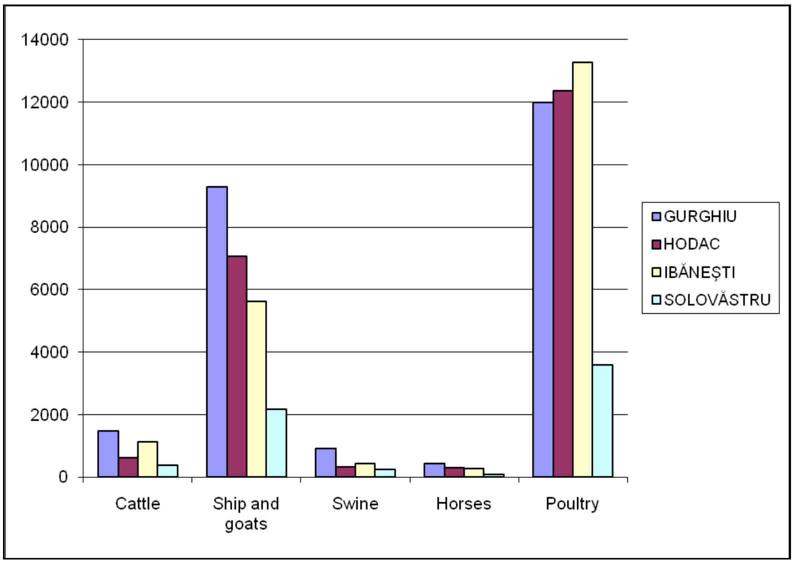

Figure 12. Livestock from Gurghiu basin for 2010 (from P.A.A.R. of Mureş county).

Of the four townships, the largest agricultural area belongs to the township of Ibăneşti: 30 590 ha. But most of it is occupied by forests: over 25 800 ha. This was why the village was declared disadvantaged mountainous area, according to Order no. 335 from 10.05.2007. Currently there is an encouraging resumption and revival of agriculture, both at nationally and local level. The absorption of European funds and investment in agriculture could mean a revival of local economy. Establishment of associations of breeders of animals

(Ibăşteanca, Tocarul) at local level is a first step towards encouraging the development of this economy branch.

CHAPTER V.
NATURAL RISK MANAGEMENT AND SUSTAINABLE DEVELOPMENT OF THE MORPHOHYDROGRAPHIC GURGHIU BASIN

In this chapter in the first stage were addressed the measures of control and mitigation of analyzed natural hazards, whose application is subject to material and human resources available to the territorial system. In the second stage of the chapter were analyzed the resources available in the event of natural disasters (floods and landslides) as well as who are the actors and their responsibilities in the scheme of management of natural risks. In the end of the chapter were proposed a number of objectives to be achieved in sustainable development of the analyzed basin.

5.1. Measures to mitigate and prevent the effects induced by natural hazards in the morphohydrographic Gurghiu basin

Applying a set of measures should be based on the dynamics of the phenomena which have to be blurred or eliminated, and depending on the triggering factors of the process or phenomenon.

5.1.1. Measures envisaged for preventing and mitigating the effects of geomorphic hazards

In this set of measures were proposed: measures to eliminate or stabilize landslides (among which hydro based improvements and agro-pedological works, hydrographic works, stabilization or grassing land in orchards, avoiding excavation works on the slopes, etc..), measures to reduce the effects of subsidence and collapse processes (strengthening slopes of forest roads, the use of nets), measures that lead to the elimination of the causes underlying generation of gully erosion process (improvement of the water drainage on slopes, avoiding overgrazing, etc.) banks erosion mitigation measures (desalting of river beds, making dams to correct water drainage channel).

a  b 

Photo 6 a and b. Torrent correction works in the Tireu basin (June 2011).

5.1.2. Measures to prevent the effects of floods

Flood protection works have been performed up to date including works to strengthen banks (by gabions) and regularization, especially in the localities Ibăneşti (photo 7), Hodac, Gurghiu and Solovăstru.

Photo 7. Work to strengthen the Gurghiu river banks and regularization, township of Ibăneşti (June 2011).

5.1.3. Measures to prevent the effects of climate hazards

Management measures of stands affected by destabilizing factors (wind or snow) are included in forest planning of the two forest districts. These include a set of management and protection measures aimed at increasing the resistance on the part of individual endangered trees and on the other hand ensuring greater stability of the entire forest. In order to improve the implementation of management measures of affected trees should be an inventory of all areas affected over time, the causes underlying their production, followed by a classification of these areas depending on the degree of damage and their mapping. The measures set out in forest planning include: restocking the goals (selvedges) resulting from the extraction of felled trees, completion of the care and proper hygiene, adoption of treatment or training to ensure maintenance of trees with increased resistance to the action of wind, making a stand composition close to the natural (also called composition-goal), etc.

5.1.4. Measures to prevent the effects of pests' invasions

Currently used methods for detection and pest control are pheromones traps, or the tubular type or the barrier type, the last ones proving to be most efficient. Of the latter, are used the triangular traps, funnel traps (photo 8), glass or Teysson traps.

Photo 8. Pheromone traps against pests *Ips typographus* in UPVII Secuieu, OS Gurghiu, September 2010.

5.2. Prevention of natural hazards in the morphohydrographic Gurghiu basin

Protection of vulnerable natural sites is currently the most important preventive measures taken in the studied area. In the morphohydrographic Gurghiu basin there are four protected areas: Seaca natural Reservation, the Resonance Spruce from Lăpuşna, Mociar Forest protected natural area and the Daffodils Glade protected natural area.

5.3. Natural risk management in the morphohydrographic Gurghiu basin

In addition to the set of measures needed to prevent or reduce the effects of natural hazards on territorial system of the morphohydrographic Gurghiu basin, it is imperative to make an inventory of community resources available to achieve the crisis management actions generated by a specific phenomenon but also to develop a scheme of action in case of a disaster.

Actors involved in the management of natural hazards in the morphohydrographic Gurghiu basin are (figure 13):

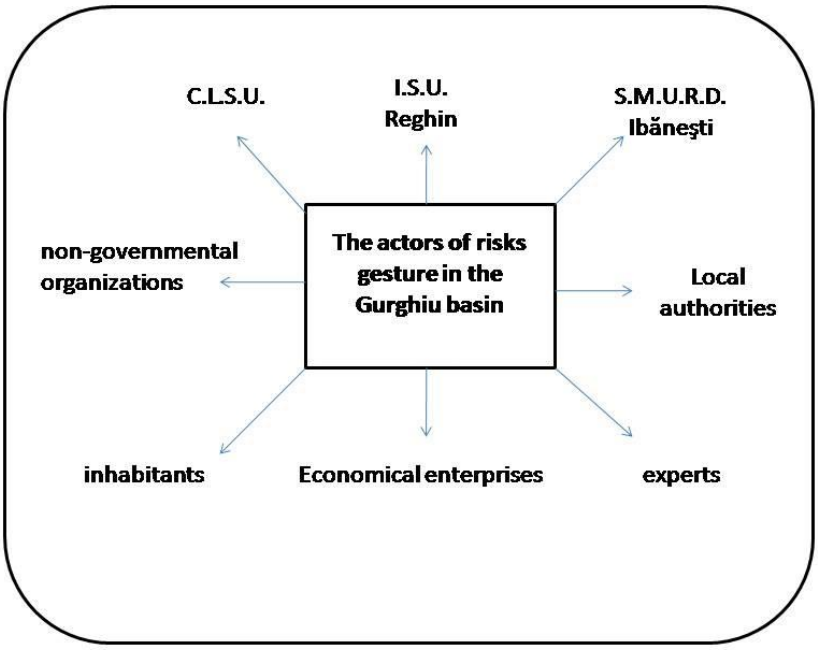

Figure 13. The main actors of gesture of risks in the Gurghiu basin.

5.4. Natural risks and sustainable development in the morphohydrographic Gurghiu basin

Socio-economic development reflects the readiness of people to confront and overcome the crisis installed with the occurrence of a natural phenomenon, human and material resources available to a particular territory, also indicating the degree of resilience of the population and socio-economic systems affected. Socio-economic development of the territory considered, including agricultural recovery (particularly of livestock) and forestry (using increasingly more environmentally friendly exploiting techniques, which refers to cutting off compensation with the forestation) also capitalization of touristic natural and anthropogenic potential, is closely related to the possibility of applicability of measures included in the management of natural hazards. Thus, resilience is directly proportional to the territorial economical growth of the system analyzed.

In order to have sustainable development of the basin analyzed a series of objectives have to be achieved, including: sustainable exploitation of natural resources, rehabilitation and reconstruction of road infrastructure, attracting foreign investments, development of economic partnerships between administrative-territorial units of the region, human resource development and employment, securing risk exposed areas, increase population resilience to natural disasters.

The analysis of risks generated by natural hazards in the morphohydrographic Gurghiu basin revealed that they are in true syncope malfunctioning generators at both geo-systems and social systems. Reducing these failures is a step without which sustainable development objectives would be unnecessary. Failure to risk management measures could restrict shaping any development strategy. For example, failures to adopt measures to prevent and mitigate the effects induced by geomorphic risks are futile efforts for authorities to invest and attract external funds for development of zoo-techniques.

CONCLUSIONS

The need for a study on natural hazards that associates risk in the morphohydrographic Gurghiu basin was proven by the lack of information on local community intervention measures for manifestation of extreme geographical phenomena. This thesis has highlighted some issues: over 70% of the basin is subject to high and very high risk, the occurrence of dangerous natural processes and phenomena induce the failure of natural and anthropogenic systems, irrational exploitation of natural resources led to acceleration processes, the need to include risk management in the sustainable development strategies of territorial system represented by the morphohydrographic Gurghiu basin, the importance cartographic materials as a spatial express of risk and the need of using them in risk reduction strategies.

In conclusion, this thesis has proved itself necessary and useful in terms of possible inclusion in regional studies. Also, the future requires a careful approach to natural hazards and risks, both locally and regionally. Equally, precision and accuracy studies are needed in order to reduce risk of discrepancies between risk management and sustainable development of territories.

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