“BABES-BOLYAI” UNIVERSITY

FACULTY OF GEOGRAPHY

PHYSICAL AND TECHNICAL GEOGRAPHY DEPARTMENT

RELIEF, A DECISIVE FACTOR IN TERRITORIAL PLANNING. STUDY CASE: UPPER AND MIDDLE SECTORS OF STREI VALLEY.

Ph.D. THESIS

-summary-

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Key words: *territorial planning, restrictivity, favourability, morphology, morphometry, present day geomorphological processes, morphodynamic units, geomorphological map sketch, upper and middle sectors of Strei valley;*

CHAPTER I

Lately, politicians, economists, territorial planners, pedologists, foresters or geographers are more and more preoccupied by increasing the territorial cohesion by reducing and eliminating socio-economic disparities. All these are done in planning studies. For this, we must conduct a comprehensive analysis of the natural and man-made landscape to point out their failures.

In this study, the role of relief in territorial planning was emphasised, providing a perspective of its comprehensive analysis, which should take place in development studies. We must admit this is a bold theme, which betrays a certain amount of bias and draws criticism from other specialists involved in planning, who will hasten to emphasize their domain as a priority. Under these circumstances, we should be as objective as possible and admit that: **the relief** *is support for development; is a factor restricting or favouring development works through morphology, morphometry and morphodynamics; is the landscape element according to which decisions are taken and which is modified when acting on other elements*; **the geomorphologist** *is the first professional consulted on areas suitable for a particular use, the processes which affect landforms or which can be triggered by conditions of misuse or abuse of resources; the measures to be taken to stop the geomorphological processes to reintegrate in the agricultural or forestry circuit the areas etc.*;

The above issues have been dealt with in the upper and middle sectors of the Strei valley. From the geomorphological point of view, this is a well individualised and complex unit, with an area of approximately 1.559sq.km. (Fig.1).

In general, planning and development strategies are made and implemented at the administrative-territorial unit level to avoid problems that arise concerning the target funds. Under these circumstances, many will say that the analysis will have to cover an administrative unit. But, they overlook the fact that the administrative boundaries do not coincide with the physical-geographical ones and thus the approach would have been useless. Therefore, we have taken into account when building the database and calculating indices, only the administrative-territorial units fully incorporated into the study area (Baru, Pui, Salasu de Sus, Santamarie-Orlea, Sarmizegetusa, Totesti, Densus, Rachitova, G-ral Berthelot and Hateg). The comprehensive database that was developed can be used in the future development strategies of these units.

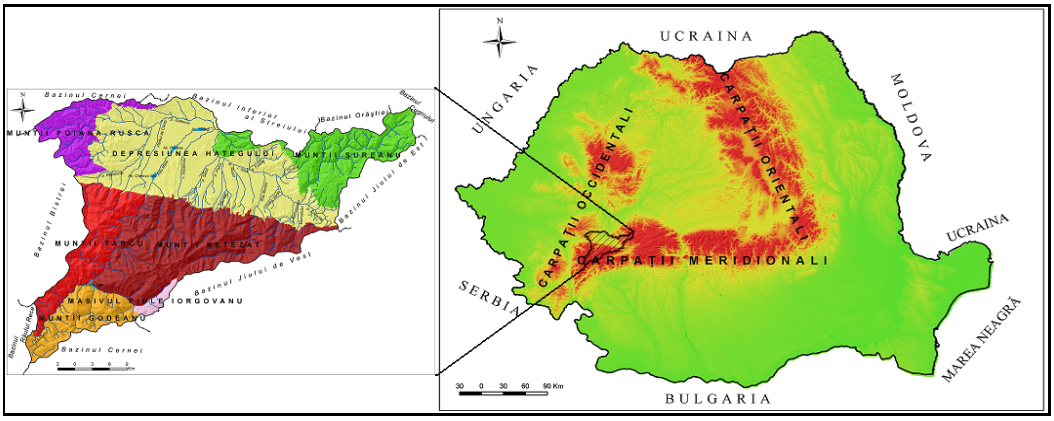

Fig. 1. Location of the upper and middle sectors of the Strei valley

For this study, we suggested a series of objectives, from which we selected the following:

⇒ restrictivity and suitability relief assessment in territorial planning;

⇒ establishing an proper investigation methodology of relief role in territorial planning;

⇒ building a database of cartographic materials from different periods to illustrate land use change dynamics and human impact on landforms;

⇒ analysis of the other components of the natural and anthropogenic landscape in relation to topography;

⇒ suggesting development work to improve or halt processes that unstructure landforms, for better land management;

⇒ identification and spatial analysis of land use changes and human impact on landforms;

⇒ identifying geomorphological consequences of human interventions and ameliorative measures taken up to date or to be taken in the future;

⇒ dividing the territory into morphodynamic units and their relationship to the land use;

⇒ elaboration of a geomorphological sketch map for the study area using GIS techniques;

⇒ analysis and elaboration of hazard maps;

CHAPTER II. HISTORICAL RESEARCH

To know *what must be done*, *where*, *why* and *how* and, mainly, to have a clear picture of the study area, it was necessary to consult several scientific studies from geology, paleogeography (***Maxim, 1957, Orghidan, 1969, Cotet, 1973***), geomorphology (***de Martonne, 1907, Niculescu, 1965, Grumazescu, 1975, Ilinca, 1976, Urdea, 2000, Dragut, 2003, Ardelean, 2010,*** etc.), hydrology (***Ujvari, 1959, 1972, Diaconu, 1971***), climatology (***Atlasul climatologic, 1966***), biogeography (***Geanana, 1992-2000, forestry plans, Directia Silvica, Deva***), geoecology (***Duma, 1998***), tourism (***Floca, 1957, Trufas C-ta and Trufas, 1986, Krautner, 1984***), history (***Daicoviciu et al., 1989***), demography (***Popa, 1999, 2000***) etc.

CHAPTER III. CONCEPTUAL AND METHODOLOGICAL FRAMEORK

From the very beginning of this study, we had into consideration the fact we had to answer the following question: "Why < *relief, a decisive factor in territorial planning*>, and not <*relief, a decisive factor in territorial/geographical space organization/ territorial planning/plannification*>?" We have to admit the fact that the activity in this sense is not an easy one, but on the contrary, many common definitions, the confusions that are made, unrest you. Therefore, we considered it necessary to follow a legal framework, not only in terms of defining concepts, but especially for developing the methodology for planning studies.

Given the theme of the study, an proper methodology of investigation was established (Fig.2). It is true, this methodology covers one component which interests in planning, but the activities to be undertaken in development planning studies, largely coincide with those provided in the methodology of development planning studies.

In the **documentation stage**, various sources of information have been used (digital photos, satellite images, cartographic materials form various areas and periods, reports and studies etc.) to get information on how the land use, hydrography, climate, soil, biogeography, infrastructure, geomorphology, human impact on landforms etc.). The forms of anthropogenic intervention in the territory were also taken into account as well as the triggered geomorphic processes and the resulting landforms.

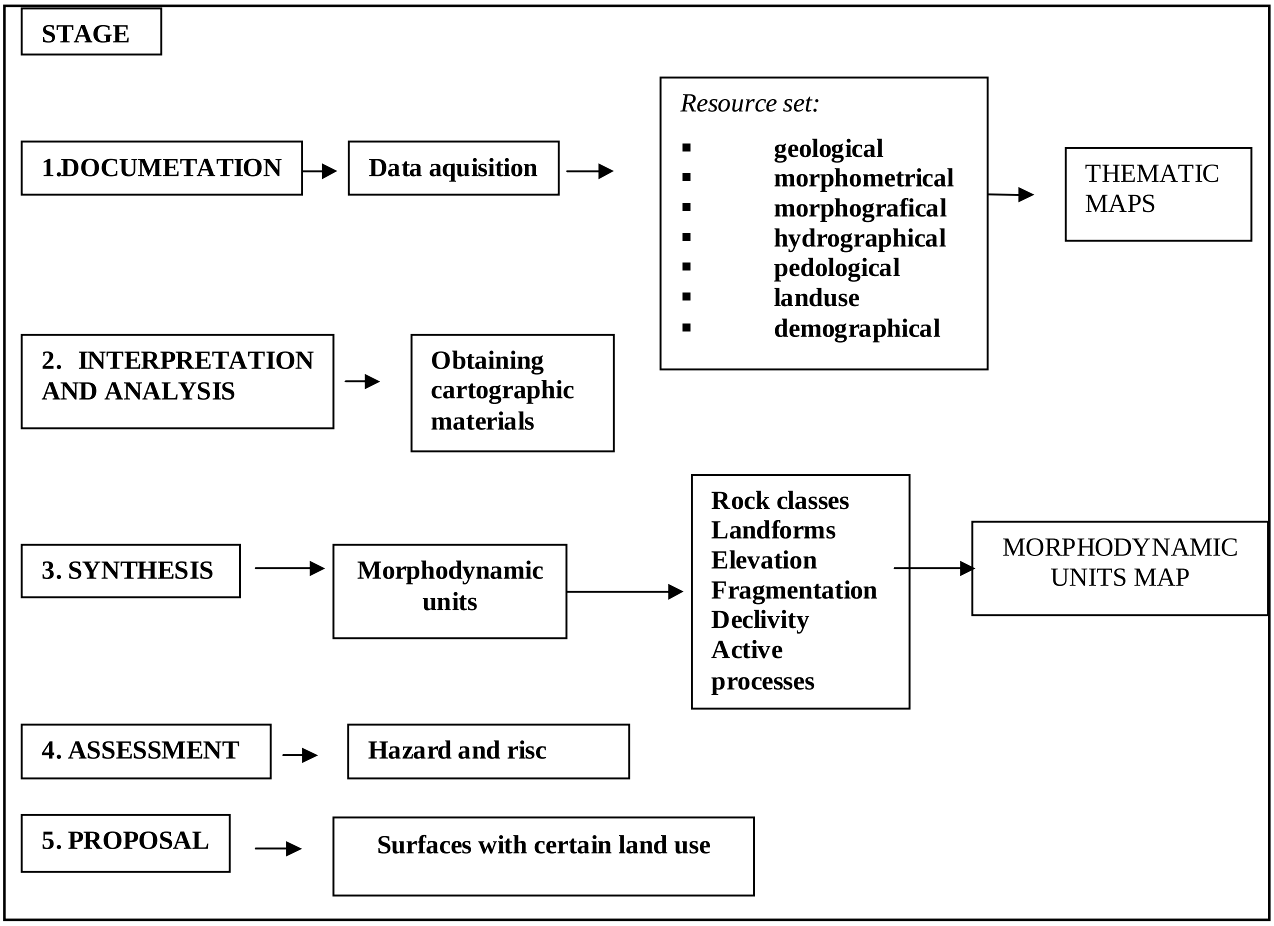

Fig. 2. General used methodology

In the **interpretation and analysis stage**, the thematic maps regarding the morphology, morphometry, land use, soil classes, rock classes, hydrography etc. were obtained. A geomorphological sketch map was elaborated, using GIS technique, which includes only the landforms and processes that interest in planning. They were represented as 38 layers in vector format, plus information in raster format on slope and shading (Fig. 13). In planning studies, a zoning based functional, structural and management criteria, was made following five areas, such as: agriculture, forestry, industry, tourism and services to increase territorial cohesion by reducing socio-economic disparities. To identify the potential of an area, for a more efficient and rational management of geomorphological processes and present geomorphological processes, in the **synthesis stage**, the territory was divided into three morphodynamic units based on four criteria: lithology, morphometry, morphology and dynamics, on the methodology proposed by ***Bergonzoni et al., 1995***.

The evaluation stage is part of the planning process. To be objective, the evaluation followed clearly defined procedures by the legislation in force. This was done in order to obtain hazard maps.

The proposal stage involves actions to be taken to enhance, improve an existing situation, thus helping to safeguard the natural heritage. Also, changes to be made regarding the use of land were suggested.

CHAPTER IV. RELIEF AND OTHER LANDSCAPE COMPONENTS

In a planning study to all components of the landscape are to be analyzed and the failures recorded are to be highlighted. In this study, the relief was linked with other parts of the environment (soil, agriculture, forestry and wildlife) that directly affect them. Their use, exploitation and development works depend on morphology, morphometry and the present geomorphological processes.

At the end of this analysis, we reached the following conclusions:

- the soil resources are varied and layered according to altitude, prevailing cambisoils (52.6%) and spodisoils (24.4%) specific to mountainous areas (Fig.3);
- the structure of agricultural land varies from one community to another depending on the morphological and morphometrical aspects of the relief; over 70% of the agricultural land consists of pastures and meadows, followed by arable land;
- human interventions on forests (the change of the upper and lower limit of the forest, forest road building, applied exploitation and treatments, the extension of land with another destination) and on the agricultural land (farm road construction, inadequate agricultural techniques, non-maintenance of the orchards with antierosion role etc.) have consequences on geomorphological plan (e.g. reactivation of the denudation processes);
- after recreating the land use for nearly 200 years, the conversions were identified on stages by calculating the rate of change and we reached the following conclusions: artificial surfaces, agricultural and aquatic areas had an ascending trend as opposed to wooded ones

which decreased in each stage; the land around settlements has been used in agriculture and that from mountainous and sub-mountainous areas were covered by forests (Fig. 4);

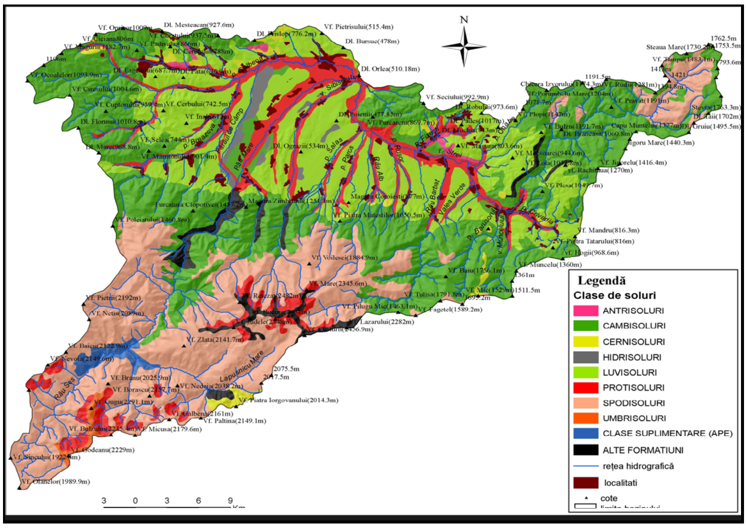

Fig. 3. Upper and middle sectors of the Strei Valley. Soil map.

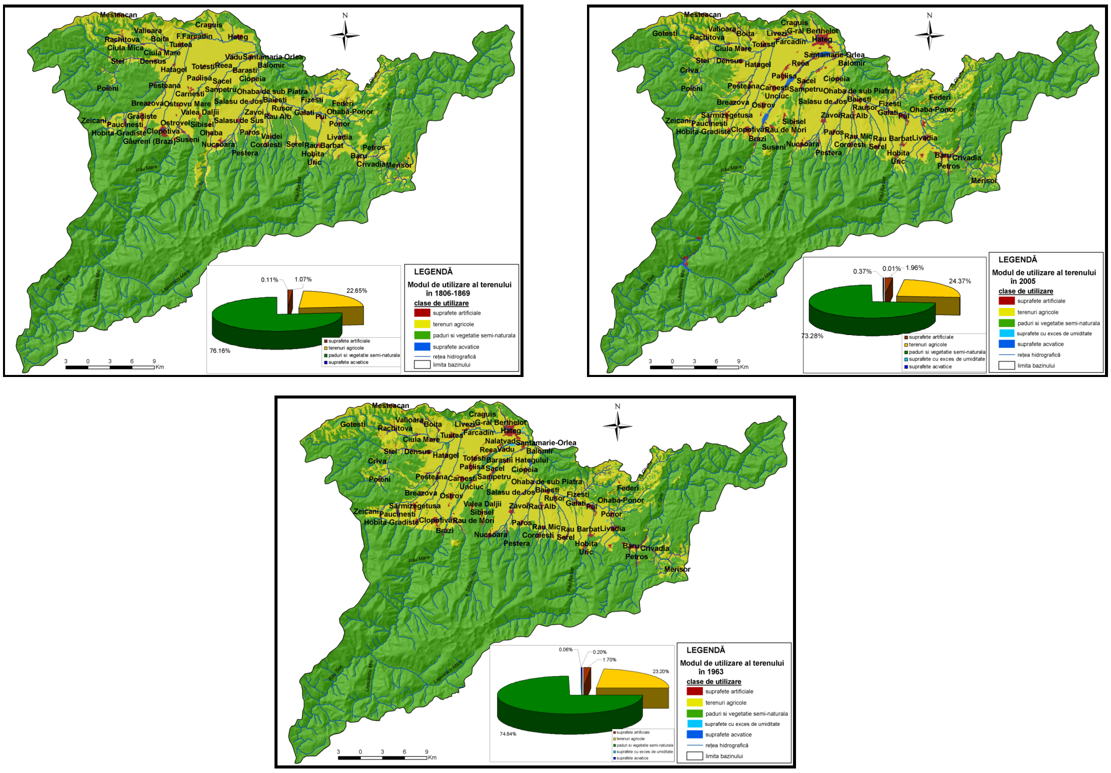

Fig. 4. Upper and middle sectors of the Strei valley. Land use dynamics (1806-2005)

CHAPTER V. RELIEF. RESTRICTIVITY AND FAVOURABILITY IN TERRITORIAL PLANNING.

Relief matters in landscape planning in terms of favourability or restrictivity given by morphological, morphometric and current geomorphological processes aspects.

Morphographic aspects.

The valleys shape is determined by the paleogeographical evolution of the territory, the lithology and tectonics, the characteristics of the rivers that were formed, by the climatic factor etc.

- *The valleys developed on crystalline rocks* are deep and narrow, with sectors that have gorge aspect; have a typical "V"-shaped profile; the slopes are steep with undercuttings created by lateral erosion (e.g. Strei, Rau Barbat, Rau Alb, Paros, Sibisel etc.).
- *The valleys developed on granite and gneiss* have a wide open "V"-shaped profile and convex slopes (e.g. Rau Mare and its tributaries on the left, on the Gura Apei-Brazi section).
- *In the category of valleys developed on limestone,* we distinguished *blind valleys* (Lunca Hobenilor Valley, Ohaba-Ponor Valley, Lola Valley, Sipot), which end downstream, at the foot of a steep slope (antithetical step), then continue underground, and *gorges* (Crivadiei, Jgheabului).
- *The glacial valleys* from Retezat, Godeanu and Tarcu Mountains have a “U”-shaped profile.
- *The valleys located along faults* are characterized by stability because the course is maintained on the same direction, creating a concave longitudinal profile and a long river basin (ex. Crivadia, Ohaba, Fizeşti, Baiestilor valley).

The slopes are conditioned by lithology, structure and the evolution in time of the denudation processes. On *crystalline schists*, complex slopes have been developed with a convex sector in the upper part and the lower one concave, separated by a rectilinear sector, which corresponds to a knickpoint where the transit takes place. The valleys that cross the *limestone areas* have vertical wall-like slopes with lateral undercuttings, needles, towers etc. (Photo 1) (Jgheabului and Crivadiei gorges). These can be used for climbing.

Photo 1. Vertical walls (upper sectors on the Streiului valley, upstream Petros, Baru commune)

Interfluves aspect depends on the rocks on which they develop. In general, the interfluves preserve very well the traces of relief evolution and belong, either to denudation surfaces, or to some glacial and periglacial forms.

✓ *The interfluves developed on granites and granitoides* on the left side of the Rau Mare are narrow, bordered by slopes with high declivity and they are wooded. In the case of the *granodiorites* from the Retezat Mountains, in the area affected by Quaternary glaciation, by the withdrawal of neighbouring glacial slopes, sharp peaks emerged called custura.

✓ The *interfluves developed on the crystalline* of the Şureanu, Retezat, Tarcu and Godeanu Mountains appear as heavy ridges, elongated and smooth, with low gradients (0.1 ° - 2 °), which generated bogs. If on the interfluves appear monadnocks and the interfluves are short, the shift towards the valley sectors is made through straight slopes, with undercuttings.

✓ The *interfluves developed on limestone* are smooth, with positive (limestone pavement, needles) or negative forms (sinkholes, uvalas). The connection with the valley areas is made by means of vertical walls (Photo 1).

✓ The *interfluves developed on sedimentary rocks*, with varying degrees of resistance to erosion from the NW, W and E of the basin, appear in the form of elongated ridges with longitudinal stepped profile.

✓ The *interfluves consisting exclusively of unconsolidated sedimentary deposits* (sand, gravel, boulders) (e.g. the piedmont of Rau Barbat), are smooth and have low gradients and degree of fragmentation, thus they can be used as agricultural land.

After analyzing the aspect, the following conclusions were drawn: the shaded and semi-shaded slopes (59.9%) prevail which restrict the spread of housing and land use; public buildings and street network are adapted to the aspect; aspect conditions the land use (the shaded or semi-shaded slopes are covered by forests, and the sunny and semi-sunny are used for crops, fruit growing and viticulture).

Morphometric aspects to be considered in planning are: elevation, slope, drainage density and relief energy.

To determine the **hypsometric steps,** we took into consideration the upper limit of permanent settlements and of the human activities. The two staps (285-900m and 901-2466m) have favourable and restrictive aspects for house spreading, living and economic activities. All permanent settlements and the main economic activities are carried out between 285-900m.

The slope classes were established according to the critical slope for the initiation of certain geomorphological processes and anthropogenic activities suggested by ***Ichim and Bordeianu, 1970, Ungureanu, 1978, Grigore, 1979, Goudie, 1990, Surdeanu, 1998 and Irimuş et al., 2005***. The predominance of areas with slopes of 6.1°-17° and 17.1°-35° indicates that most of the land is restricted for construction and infrastructure location (Fig.5).

On the areas with gradients of 0.1°-2° the settlements are located (Hateg, Paclisa, Totesti, Unciuc, Nalativad, Vadu, Carnesti, Reea, Ostov, Ostrovel, Hatagel, Sibisel, Barastii Hategului etc.), as well as roads and rails even if they are subject to floods. The areas with gradients of 2.1°-6°, overlapping glacis and debris, do not impose restrictions to the location of buildings (Zeicani, Paucinesti, Sarmizegetusa, Clopotiva, Rau de Mori, Nucsoara, Malaiesti, Salasu de Sus, Salasu de Jos, Coroiesti, Rau Alb, Uric, Petros, Ciula Mare, Farcadin etc.).

The number of permanent settlements located in the areas with gradients of 6.1°-17° is small because the slope of 17° is the threshold slope for building (Fizesti, Federi, Rachitova).

The drainage density is a parameter that gives a good picture of the degree fragmentation of the landscape and, therefore, it must be considered in planning activities. We obtained a wide range of values from <3km/sq.km. to >9km/sq.km. High (6,1-9km/sq.km) and very high (>9km/sq.km) values were identified in the junction basins which are "*collecting water markets*" (e.g. Paraul Cald- Paraul Rovinelor; Strei-Sasu valley; Strei- Jigureasa valley; Crivadia- Rachitei valley; Strei-Barusor; Rau Barbat-Murgusa; Varatecului valley- Dreptului valley etc.).

In these confluence basins, Baru, Fizesti etc. are located. The other villages are located on areas with fragmentation of <3km/sq.km (Hateg, Nalativad, Vadu, Reea, Totesti, Paclisa, Carnesti, Ostrov, Hatagel, Rau Barbat, Rau Alb, partially Pui etc.), of 6,1-9km/sq.km (Sibisel, Sampetru, Sacel, Rau de Mori, Suseni, Clopotiva, Rachitova, Densus, Fizesti, Ohaba-Ponor, Crivadia, Merisor etc.) (Fig.6). High fragmentation levels are reflected in the gathered or scattered structure of the settlements.

Together with the drainage density and declivity, the **relief energy** reflects the degree of evolution of the landscape and proves through its values how near or far the local erosion bases are, how intense the linear erosion was, which the proportion of the slopes height is and where possible equilibrium breaks are in the basin morphology. Values between 0-50m/sq.km characterise the piedmont interfluves. Declivity and drainage density are low. This allowed the placement and extension of the following settlements: Salasu de Sus, Salasu de Jos, Ohaba de sub Piatra, Zavoi, Ostrov, Ostrovu Mic, Unciuc, Carnesti, Paclisa, Totesti, Reea, Barastii Hategului, Vadu, Santamarie-Orlea, Hateg, Hatagel, Rau Barbat and Ponor. Other settlements such as: Baru, Petros, Livadia, Pui, Galati, Rusor, Rau Alb, Rau Mic, Coroiesti, Paros, Pestera, Ohaba-Sibisel, Sacel, Sampetru, Valea Lupului, Tustea etc. lie on surfaces with energy relief of 50,1-100m/sq.km. The buildings are placed along the river network in the floodplain on the river terraces.

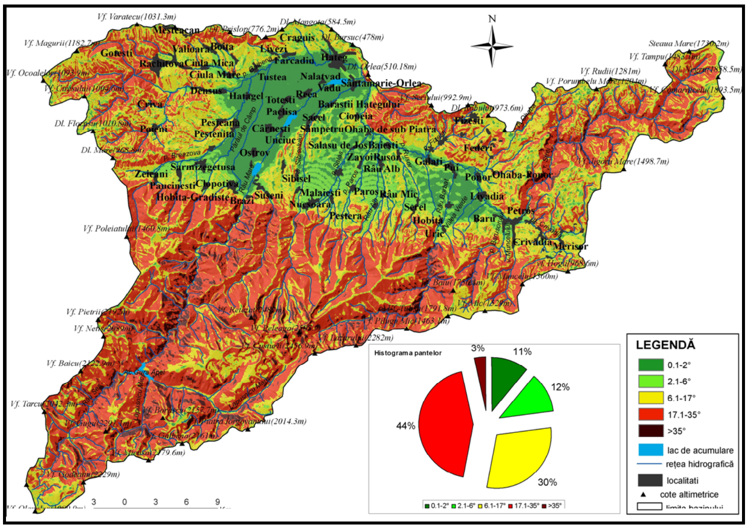

Fig. 5. Upper and middle sectors of the Strei valley. Declivity.

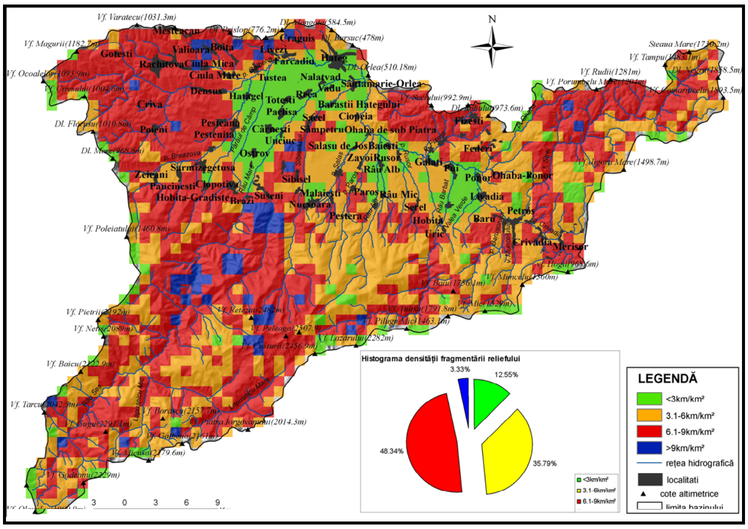

Fig. 6. Upper and middle sectors of the Strei valley. Drainage density.

The landforms are the result of natural and anthropogenic intrinsic and extrinsic factors.

Taking into consideration the fact that in the upper and middle sectors of the Strei valley there is a lithological variety, we classified the rocks according to their physical-mechanical characteristics, the behaviour to water and the technical properties starting from the classification made by ***Teodorescu, 1984***. The compact hard rocks (igneous and metamorphic) have the largest expansion, forming the mountainous area foundation (61.7%). The transition from compact hard rocks to non-consolidated ones is made by semi-hard packs alternating with soft and unconsolidated rocks. The non-consolidated rocks packages represent 18.6% of the territory and are found in the flood plains, piedmonts and the terraces that border them (Fig. 8). These resulted from the weathering of hard and semi-hard rocks from mountainous areas.

To analyse **the climatic factor**, we used the data from ***Atlasul climatologic (1966)*** and from Gura Apei, Rau de Mori, Pui, Fizesti and Hateg pluviometric stations, and we reached the following conclusions:

- all in all, the climate of the upper and middle sectors of the Strei valley is Carpathian;
- the large difference in elevation (over 2200m) resulted into a considerable vertically variation of climatic elements;
- the annual amount of precipitation has an uneven distribution (Fig.9);

- the monthly quantities are reduces in the cold season, when the masses of air have a reduced content of vapours and the thermic convection is low; most of the precipitation falls between April-September, which intensifies the slope processes;

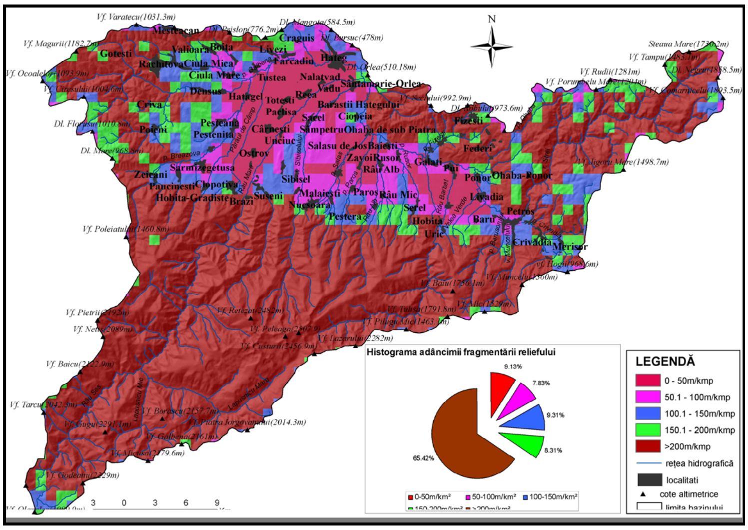

Fig. 7. Upper and middle sectors of the Strei valley. Relief energy.

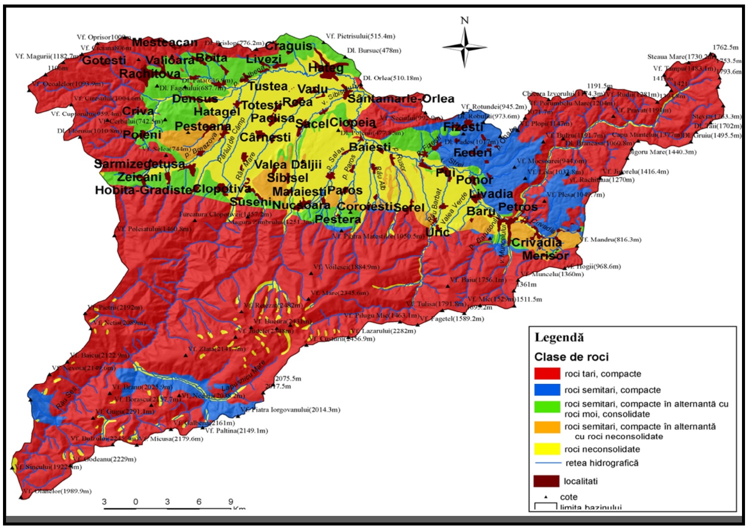

Fig. 8. Upper and middle sectors of the Strei valley. Rock classes.

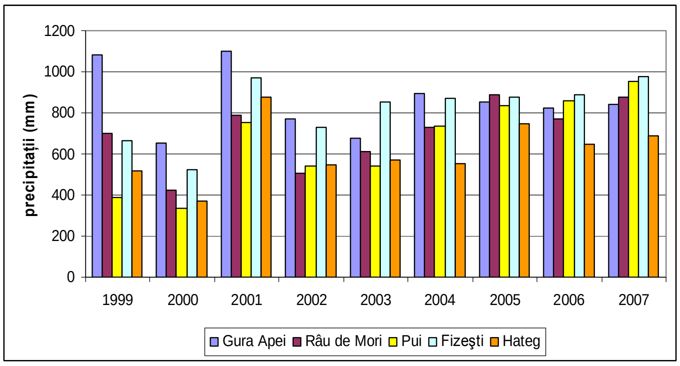

Fig. 9. Annual amount of precipitation (1999-2007)

The **hydrologic factor** does not only model the landforms, but it also directs the territorial planning. Analysing the hydrological aspects, we reached the following conclusions:

- the floods are frequent not only in the spring (April) and summer (July, August) months, but also in the autumn ones (October) and have pluvial origins;
- the minimum discharge values were recorded between September-April (in autumn and winter months) due to the decreasing of the precipitation amounts and of the underground reserves;
- on most rivers, the volume of the average flow characterizes the spring months (March-April-May), when the snow melting in the upland areas together with the precipitation which ensure an abundant alimentation (Fig.10);

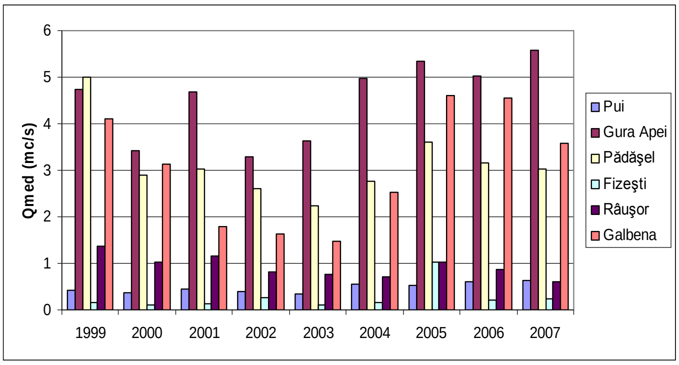

Fig.10.The annual discharges at the gauges from the upper and middle sectors of Strei Valley (1999-2007)

Through his actions, **man** has proved to be an active morphogenetic agent, who, on the one hand, has corrected the geomorphological processes, has implemented constructions to improve his life conditions, and on the other hand, has intensified the processes and triggered disequilibrium. For a correct assessment, we have to evaluate the anthropogenic interventions from historical, geomorphological, socio-economic and planning perspectives. Over time, land reclamation works were carried out (Photo 2 and 3), river regulation and embankment (Photo 4), hydro-energetic works, infrastructure building and expansion (Photo 5), mineral workings and riverbed aggregates exploitation (Photo 6 and 7) etc. (Fig.11).

Photo 2. Irrigation system at Ostrovu Mare (Rau de Mori commune) (August, 2009)

Photo 3. Anti-erosion works on the left side of Rau Barbat (Hobita, village, Pui commune), affected by landslides, dep and surface erosion (September, 2010)

Photo 4. Embarkment works of the Sibisel, upstream Sampetru (Santamarie-Orlea commune)(August 2009)

Photo 5. Right slope of the Crivadia valley, consolidated due to road widening at Crivadia (Banita commune) (June, 2010)

Photo 6. Clay quarry exploitation at Galati, Pui commune(Sept. 2009)

Photo 7. Bauxite quarry, Comarnic Hill, Federi village, Pui commune (August 2009)

But man is an active factor, with decision role in territorial planning, who must be consulted and informed about the stage of the territorial planning process because **planning is made for and by people**. Also, he is a pressure factor, fact pointed out after calculating artificialization indices. The higher the value of the indices is, the more profound the interventions on the landforms were. For the analysed period, the trend is descendent in all cases. The anthropogenic pressure is higher in the case of the administrative units where there are industrial activities (Hateg) or agro-industrial ones (Baru) and for the agricultural or forestry areas the percentage is low. Most of the time, this pressure is reflected in the landscape.

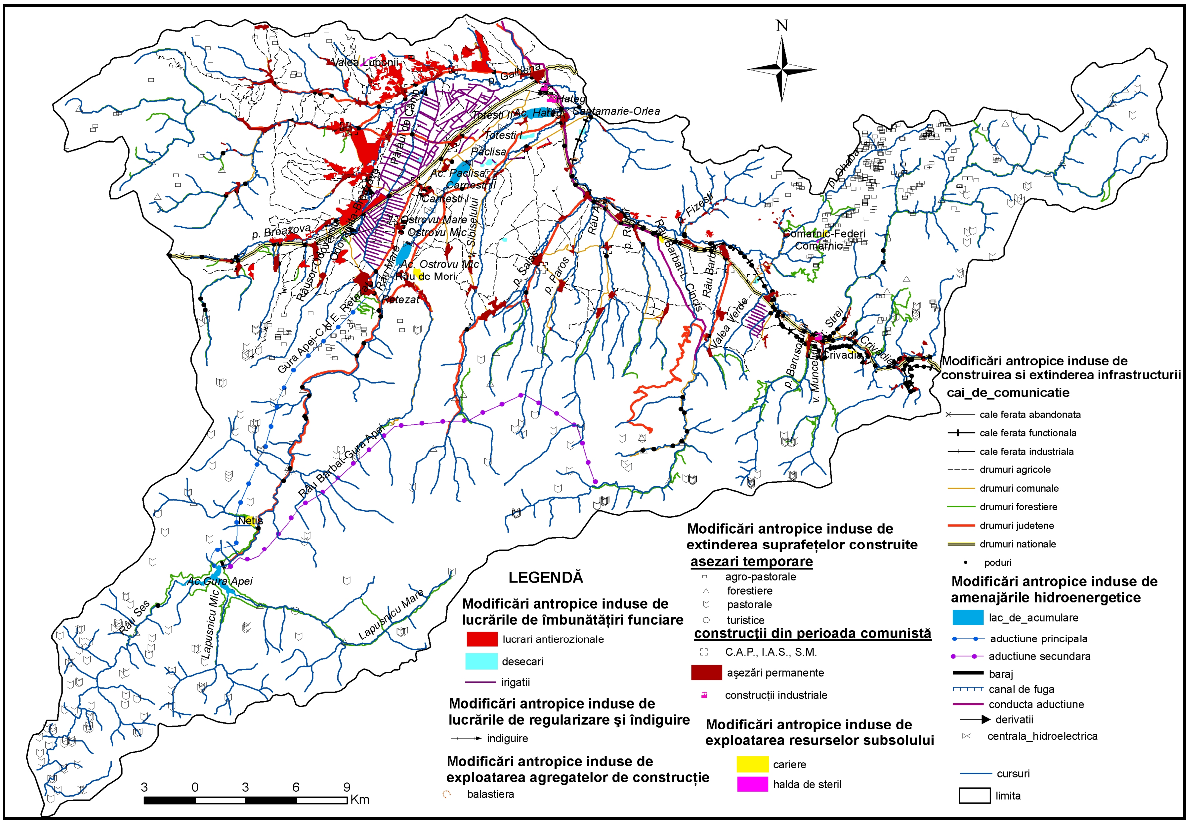

Fig.11. Upper and middle sectors of Strei Valley. Anthropogenic changes reflected in the present geomorphological landscape.

Genetic relief types

- **Structural and lithological relief**

The landforms on discordant structures, that make the geomorphological landscape spectacular, are the *epigenetic valleys*. The courses with springs in the crystalline area of the

Sureanu Mts. (ex. Jgheabului valley, Sipot), buried in the Jurassic limestones placed over the crystalline schists, creating gorges sectors. Along the Strei valley, there have been identified some epigenetic sectors, both in the upper (between the junction with Apa Rea and the entrance in the Hategului Depression, upstream Petros, Baru commune) and middle sectors (between Ohaba de sub Piatra and Ciopeia).

The landforms on folded structures (anticlines, synclines, hanging synclines, anticline valleys) are reflected in the geomorphological landscape of the study area.

The landforms on faulted structures are represented by steep slopes and tectonic valleys.

From the **lithological** point of view, in territorial planning we take into consideration the landforms resistant to erosion that convey stability. Most of the landforms can be included in the touristic circuit due to their spectacular generated by lithological variety.

<u>The relief developed on granites and granitoides</u> on the left side on the Rau Mare basin, downstream Gura Apei reservoir up to Brazi, is characterised by narrow interfluves surrounded by deep valley with steep slopes. The one on granodiorites (the right side of the Rau Mare), presents the following characteristics:

⇒ in the sector affected by the Quaternary glaciation, the interfluves were reduced to narrow and very narrow crests (custura), due to ice mass oscillations; the valleys have a typical cross profile of troughs;

⇒ outside the glacial sector, the interfluves are rounded, prolonged, massive, less fragmented by the river network; the valley have a typical open “V” shape, bordered by convex slopes;

<u>The landforms developed on crystallin schists</u> are present in the upper basins of the Muncel, Barusor, Rau Barbat, Sibisel, Strei, the northern and central parts of the Godeanu Mts., in Tarcu Mts., upper basin of the Breazova, partially Rusor, Rau Alb, Paros and Salas. The interfluves are slightly rounded or narrow, separated by deep valleys bordered by steep slopes. In the Sureanu Mts., the interfluves are massive, smooth and preserve the denudation surfaces.

<u>The karst relief</u> introduces a discordant note in the landscape through the created spectacular. From the simplest (clints, sinkholes, uvala, vertical walls, caves etc.) to the most complex forms (karstoplains, caves), the karst landforms are well represented at both surface

and underground. The vertical walls, limestone ridges, pillars, towers and needles are eye-catching, from Cioclovina-Crivadia area. In the karst area, the river network with springs in the non-limestone rocks area, creates transverse epigenetic valleys (Ohaba-Ponor, Jgheabului, Strei) and blind valleys sectors (Ohaba-Ponorului valley upstream Fundatura Ponorului and Lunca Hobenilor in Fundatura Hobenilor).

The sculptural relief is represented by denudation surfaces and piedmonts, which are grouped into two categories: of accumulation and erosion.

The erosion piedmonts are situated at the contact with the mountainous area and present a heterogeneous lithology (crystallin schists, micaschists, paragneiss, Daniene, Paleogene, Miocene and Pliocene sedimentary deposits). They appear as interfluves with stepped longitudinal profile, which correspond to erosion surfaces. They are elongated or short and narrow, highly fragmented, dominated by monadnocks, or smooth, flattened (western, north-western and northern part of the basin, those between Rau Alb and Serel), which preserve erosion surfaces. Those between the Sibisel and Rachitei valleys (left tributary to Crivadia valley), due to the lithological structure (crystalline rocks, Pliocene and Cretaceous sedimentary rocks), are highly inclined, appearing as buttresses, dominated by monadnocks.

The accumulation piedmonts were built by the rivers descending from the Retezat and Tarcu Mts., and are represented by the piedmont plain, Holocene dejection cones and terraces. They appear as uniform surfaces, sloping from south to north, fragmented by torrential bodies, consisting of gravel, sand and boulders.

The fluvio-denudational relief. After analysing the current geomorphological processes, some measures must be adoped in the planning activities to stop them.

Sheet erosion develops both in the mountainous area and in the depression one when the favourable triggering and developing conditions are fulfilled (lithology, slope, aspect, precipitation, anthropogenic interventions etc.) (Photo 10). This process precedes that of **gully erosion**. Therefore, the causes underlying their initiation and evolution are similar. However, the anthropogenic factor is noted as being the most aggressive (animal paths, overgrazing, unpaved roads, decommissioning of anti-erosion works). The rills formed during heavy rains, can develop outlining gullies and ravines.

The rills were identified in the areas devoid of vegetation from the exploitation perimeter areas (quarries, heaps from Boita and Comarnic), arable plots perpendicular to the contour (Boita, Baru etc.), along the unpaved roads, on the slopes from where the woody vegetation was exploited (the upper basins of Strei and Barusor).

Much more obvious on the slopes are the *gullies*. Stabilized, semi-active and active gullies were identified on the slopes surrounding Livezi, Boita (Foto 11), Ciula Mare, Ciula Mica, Valioara, Rachitova, Densus, Rau de Mori, Valea Daljii, Sampetru, Sacel, Malaiesti, Paros, Coroiesti, Hobita, Livadia, Ohaba-Ponor etc., on the left side of the Strei river between Ponor and Pui etc., as well as along unpaved roads. The stabilized ones are either grassed, or fixed with bushes. The semi-active ones have the lower part grassed or wooded, and the upper one is active, the gully advancing regressively through erosion. The active ones are not protected by grass and evolve in ravines. Their lengths vary between 5-80m.

The ravines develop on the slopes and reach up to 500m length, widths of 3-40m and depths of 2-20m. There were identified stabilized (downstream Malaiesti), active (the right slope of the Strei at Livadia, the slopes around Ciula Mare, Ciula Mica etc.), continuous (the slopes around Rachitova, Ciula Mare, Ciula Mica etc.) and discontinuous (the right slope of the Strei at Livadia etc.).

The most advanced deep erosion forms are *the debris flows*. The debris flows from the upper sector of the Strei and Rau Mare were corrected. To reduce the slope, thresholds and dams have been completed and the confluences were routed. Their intensive activity is reflected in the morphology of the drainage channel, paralysed by silt and floats of different sizes. The transit, being intense, determined the ascension of the drainage channel and the clogging of the loopholes, and the materials have been evacuated over the weir and deposited on the road.

The selective erosion affects the landforms that consist of packages of rocks with different degrees of resistance to erosion. The process has been identified on the right slope of the Strei river between Livadia and Baiesti (Photo 12), often associated with corrasion; on the slopes of Gomodin and Ciurila Hills, upstream Sampetru; the left slope of Valea Baltii, upstream Ciopeia etc.

The landslides pose most of the problems because considerable agricultural and forestry areas are impracticable, and the prevention measures, in addition to being costly, prove to be ineffective when the triggering factors are not removed. Areas with landslides have been identified in the eastern part of the basin, between Baru and Merisor; the left slope of Galbena, between Rachitova and Hateg; the right slope of the Sibisel; the slopes of the Valceaua valley (Sacel) (Photo 13); the slopes of Glameia Hill, Livadia; the right slope of the Strei river, between Ponor and Pui; in the Fizesti catchment; in the upper sector of the Strei etc. Most landslides occurred in the Hateg Depression, due to the dominant lithology and the morphologic and morphometric aspects of the relief.

Shallow landslides, fixed, very old and old were identified in the north of Livezi village and on the slopes from Galbena catchment, and active, with escarpments that reach heights of 2-10m (Livadia, the right slope of the Strei river between Ponor and Pui; Fizesti, Sacel, Sampetru, Ciula Mica, Ciula Mare, Livezi, Boita, Tustea, Hateg, the right slope of the Strei at Baiesti etc.). The old stabilized landslides have been reactivated after undermining the slope foot by waterways or by building roads, due to the destruction of orchards created to stabilize the slopes, the practice of overgrazing, building roads etc.

Photo 10. Effects of overgrazing on the right slope of the Valceaua valley, upstream Sacel, Santamarie-Orlea commune (Oct., 2010)

Photo 11. Gullies, right slope of the Ponii Valley (Boita village, Rachitova commune) (Aug., 2009)

Photo 12. Selective erosion (Livadia, Baru commune) (June, 2010)

Photo 14. Landslides on the left slope of the Valceaua Valley, Sacel, Santamarie-Orlea commune (Oct., 2010)

To determine the relationship between the landslides occurrence and preparatory, triggering factors and those that support them, we used the frequency rate method (***Lee and Pradhan, 2006***). Based on these results, we deduce the following:

- most of the landslides affect shaded and semi-shaded slopes;
- the landslides occurrence probability on slopes with gradients of 2.1°-6° and 6.1°-17° is high and very high;
- the areas with high drainage density (>9km/sq.km) has a very high susceptibility to landslides occurrence;
- the landslides occurrence probability is high and very high in the case of surfaces with relief energy of 50.1-100km/sq.km and 100.1-150km/sq.km;
- most landslides occur on landforms consisting of a sequence of semi-hard, compact rocks with soft, sedimentary rocks, around the following settlements: G-ral Berthelot, Farcadin, Tustea, Ciula Mare, Ciula Mica, Breazova, Livadia, Merisor etc.;
- modified areas after resources exploitation, orchards, pastures and grasslands are the most susceptible to landslides;

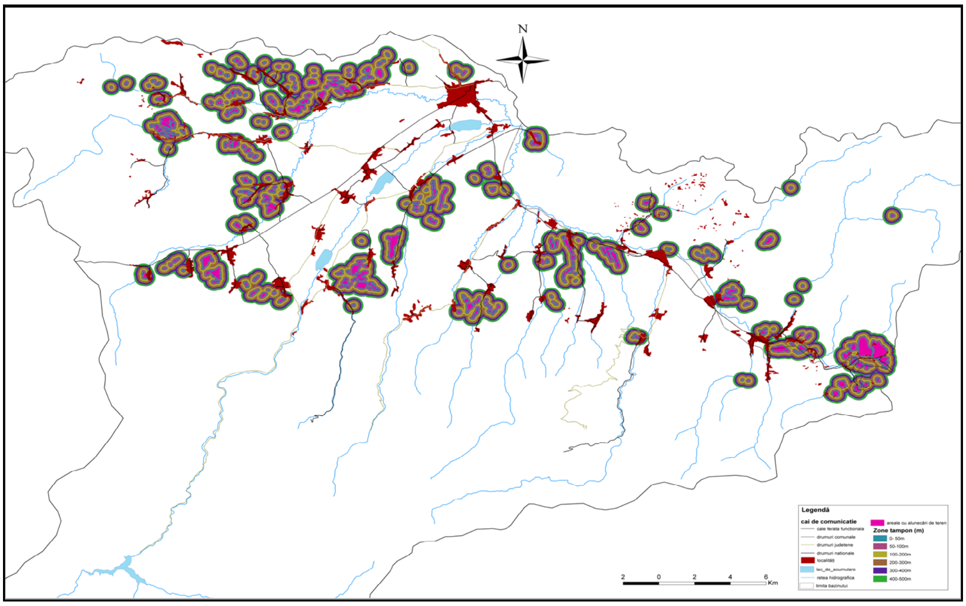

Fig. 12. Upper and middle sectors of the Strei Valley. Vulnerability to landslides.

We determined the distance between the area affected by landslides and the anthropogenic elements (settlements, transport infrastructure) and it was found out that settlements such as: G-ral Berthelot, Farcadin, Tustea, Ciula Mare, Ciula Mica, Livezi, Livadia, Crivadia, Merisor etc. and the road and railway in Baru-Marisor sector (Fig.12) are most vulnerable to landslides occurrence.

In planning activities, **the fluvial processes** as well as the resulting landforms should be considered to know what works must be performed, where and why. Among river processes, the erosion always attracts planners attention, through their intensity. These processes have a high intensity in the spring-early summer months, when high discharges are recorded as a result of snow melting combined with rainfall.

Particular attention must be given to lateral erosion when it comes to courses buried in unconsolidated rocks, which form concave banks affected by collapses. These banks reach heights of over 3m, for instance the Strei river at Baiesti or Rusor.

The glacial and periglacial landforms in the study area are characterised by highly attractivity, allowing their exploitation in tourism activities. But, not only the landforms that give spectacular to the landscape must be considered (pyramidal peaks, glacial valleys, glacial cirques etc.), but also those unstable from the dynamical point of view, such as debris, mobile rocks and avalanche corridors.

The analysed genetic relief types are illustrated in this **geomorphological map sketch** (Fig.13). This has a general character, taking into consideration the study area and the aim of the study, but when a planning work is made, the cartographic material should be detailed. This must illustrate the landforms that will be used in planning and is the basis for planning, the changes that occurred as a result of human intervention and the geomorphological processes that must be stopped.

The morphodynamic units of the upper and middle sectors of the Strei valley are heterogeneous areas from lithological, morphometric and morphodynamic points of view, which are suitable for certain uses. They are the basis for the human activities, for the morphodynamic processes occurrence, for the extension of the other environmental components.

Floodplains morphodynamic units. In terms of lithology, it is characterized by heterogeneity, but the unconsolidated deposits predominate. The processes that occur are in the category of fluvial gravitational (bank collapses), overmoistering and floods. Under these circumstances, draining, regulation and embankments works are necessary. After 1975, extensive conservative and changing channel works were performed (Raul Mare, Strei, Sibisel, Rau Barbat etc.) to stabilize them and to fight floods.

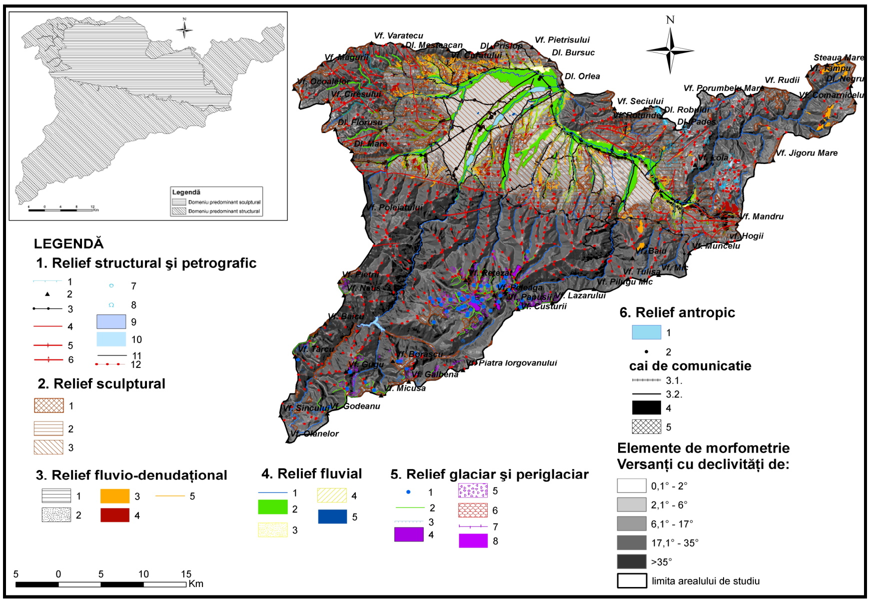

Fig. 13. Upper and middle sectors of the Strei Valley. General geomorphological map.

Piedmont morphodynamic unit includes areas resulting from erosion and accumulation. It is characterized by high lithological, morphometric and morphodynamic diversity. Their composition includes rocks with diverse physico-mechanical characteristics and degrees of resistance to erosion, ranging from hard, compact to soft and non-compact. The denudation processes are widespread, in particular, in the erosion piedmonts, which consist of packages of rocks with different degrees of resistance to erosion and characterized by high gradients and fragmentation.

The morphodynamic unit of the interfluves and slopes from the mountainous area modelled by glacial and periglacial processes is characterised by lithological homogeneity. The landforms have high slopes >2.1°, high fragmentation and relief energy of >100m/sq. km, which proves the existence of highly deepened erosion basis and mature courses. Apart from the intense periglacial processes that model the landforms (interfluves and slopes), selective erosion and mass-movement processes occur (rolls, avalanches, landslides, collapses). The slopes are covered by forest vegetation with protective role. Those with gradients higher than 35° or up to 35° are protected by woods whose exploitation takes place in accordance with the rules of the planning studies. On the interfluves there are pastures used during summer for grazing.

CHAPTER VI. HAZARDS AND RISKS

Any planning study must contain a risk analysis, identifying the areas prone to or affected by them (floods, landslides, earthquakes). Natural hazards assessment must be objective, worldwide accepted that is why we followed clearly established procedures by the legislation in force.

Earthquake hazard assessment.

No maps were elaborated for the study area, but we used the seismic maps, legislation and regulations in force for the whole country, because the upper and middle sectors of the Strei valley is in a low seismicity area (www.cutremur.net).

Landslide hazard assessment.

To assess the landslide hazard we used the methodology from *H.G. no. 447/2003*, that must be followed in any planning study. The results validation was made by laying the landslide layer over the hazard map. Over 81% of the landslides were identified on areas with high susceptilibity to landslides (Fig.14).

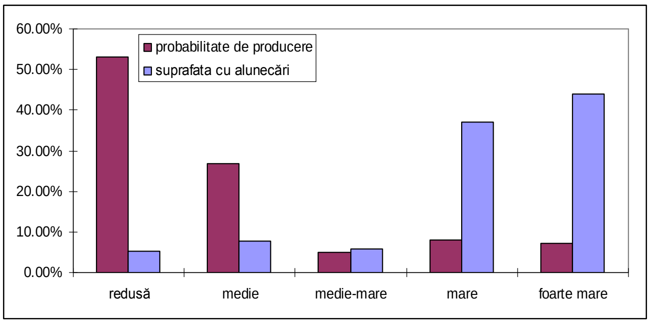

Fig. 14. Results validation

Areas with low landslides occurrence have the highest percentage and overlay the accumulation piedmonts and the interfluves from the mountainous area protected by vegetation. From the lithological point of view, we identify a great homogeneity, consisting of unconsolidated rocks (accumulation piedmonts) or hard compact rocks. These represent 53.2% of the whole area.

Areas with medium landslide occurrence represent 31.6% of the area and are characterised from the lithological point of view by high homogeneity, consisting of hard compact, altered or cracked rocks. They are covered by unconsolidated deposits. The landslides affect these deposits, fixed with forest vegetation, which is no longer a protective factor, but a triggering one through its weight.

Areas with high landslides occurrence represent 15.1% of the catchment area and appear on the erosion piedmonts consisting of semi-hard compact rocks in combination with soft or unconsolidated rocks. The slopes have gradients of 6.1°-35°, highly fragmented by debris flows. The landslides recorded are shallow, new, active arising from the development of linear forms of erosion. We also identified old landslides reactivated as a result of an inefficient management (anti-erosion works destruction, overgrazing, conversion of pastures and orchards into arable lands). To these triggering factors we add: loading slopes with constructions, undermining the slope foot by building roads or by the rivers through lateral erosion etc. (Fig. 15).

Of the 11 administrative units, only in Totesti commune, the conditions for landslides occurrence are not met. In all the others, the erosion and accumulation piedmonts consisting of packages of rocks with different degrees of resistance to erosion, gradients of 2.1°-6° and 6.1°-17° and modelled by the anthropogenic agent, the susceptibility to landslides occurrence is medium and high (Table I).

Tabel I. Landslides probability ocucurrence at administrative level

Communes	***Landslide probability occurrence***				
	low (%)	***medium (%)***	***medium-high(%)***	***high (%)***	***very high(%)***
BANITA	*44,7*	*18,7*	*5,7*	*0,7*	*30,3*
BARU	*36,0*	*50,2*	*4,5*	*3,6*	*6,0*
DENSUS	*68,1*	*4,5*	*5,2*	*11,1*	*11,1*
G-RAL BERTHELOT	*48,8*	*1,0*	*9,2*	*29,5*	*11,5*
HATEG	*58,1*	*0,2*	*0,5*	*17,4*	*23,9*
PUI	*32,4*	*34,4*	*6,0*	*16,0*	*11,3*
RACHITOVA	*33,6*	*26,4*	*10,8*	*25,7*	*3,5*
RAU DE MORI	*69,6*	*22,6*	*3,2*	*0,8*	*3,8*
SARMIZEGETUSA	*52,6*	*21,5*	*9,1*	*10,1*	*6,7*
SALASU DE SUS	*57,7*	*18,8*	*6,1*	*11,8*	*5,6*

SANTAMARIE-ORLEA	*40,2*	*36,4*	*4,0*	*7,8*	*11,6*
TOTESTI	-	-	-	-	-

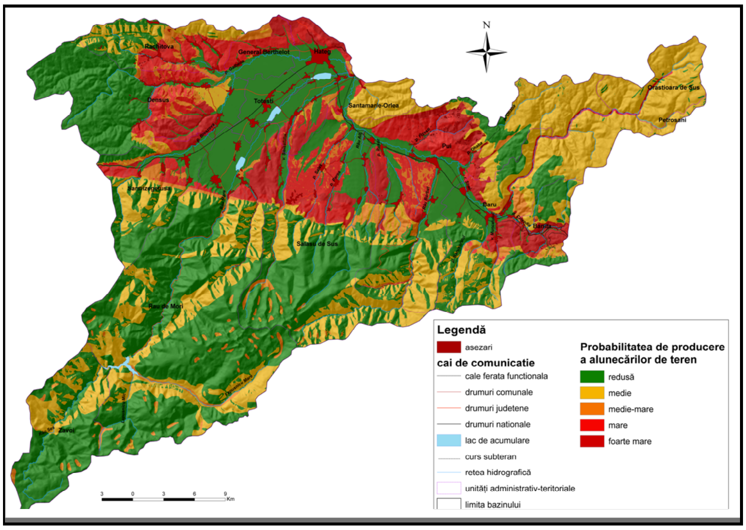

Fig. 15. Upper and middle sectors of the Strei valley. Landslides probability occurrence map.

Flood hazard assessment.

The floods were caused undergound water level increasing (Totesti), caused by rivers (Strei, Sibisel, Fizesti) (Baru, Pui, Santamarie-Orlea) or by debris flows (Baru, Pui, Salasu de Sus, Santamarie-Orlea, Densus, Rachitova) (Fig. 16). From now on, these communes are susceptible to floods caused by the above mentioned factors.

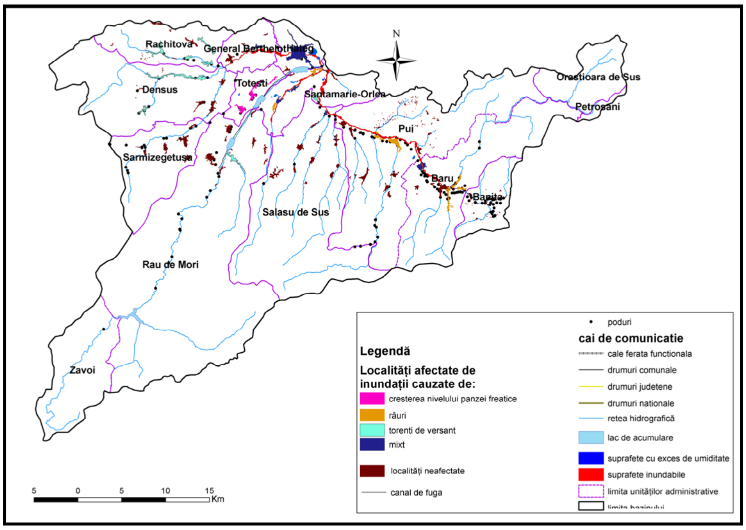

Fig. 16. Upper and middle sectors of the Stri valley. Flood hazard map.

CHAPTER VII. SUGGETIONS TO IMPROVE THE PRESENT SITUATION

In this activity, we started from the premise that the relief is the support of development. We operate on the relief to make it useful in a certain or several directions, to improve an existing situation.

Because the study area is very large (over 1.559sq.km), the proposed works are general. In the future, in case development studies are elaborated at administrative unit, following detailed analysis, specific works are to be suggested. Starting from the morphodynamic units established in Chapter V, we will suggest works strictly connected to relief to eliminate malfunctions and to use its potential. All these works have long term effects and are in line with sustainable development (Fig.17).

For the floodplains morphodynamic unit we suggest (Fig.17):

⇒ carrying out drainage works in the areas with excess of moisture to include them in the agricultural circuit (Hateg, Totesti, Santamarie-Orlea, Pui, Baru);

⇒ grassing and landscaping area to limit precipitation water infiltration because the groundwater level is less than 2m deep (Hateg, Totesti, Paclisa, Totesti, Carnesti);

⇒ transverse section calibration by cutting meander loops and removing secondary arms (on the Strei between Baru and its confluence with Rau Mare, at Subcetate);

⇒ making conservative works (protective dikes) along the banks affected by collapses and with big heights (in the vicinity of Rusor and Baiesti, the bank of Strei reaches heights over 3m) and inside the settlements where such works are, their maintenance is required (Baru, on the Strei, the Crivadia, the Muncel, the Baruşor; Pui, on the Rau Barbat, the Fizesti);

⇒ protecting infrastructure by building dikes (Petros, on the Strei and Crivadia; Pui on the Strei; Rusor, on the Rusor);

⇒ greening the areas where there were or still are gravel pits and sorting stations after they have completed their activity (Baru, Livadia, Ponor, Baiesti, Ohaba de sub Piatra, Ciopeia);

⇒ no storage platforms will be built;

For the accumulation piedmonts morphodynamic unit, we suggest:

- ❖ removing excess moisture by making draining works on the area of the following communes: Baru, Pui, Salasu de Sus, Santamarie-Orlea, Totesti etc.;
- ❖ there is the possibility of settlement expansion (Rau de Mori, Santamarie-Orlea, Pui);
- ❖ stabilizing the landforms affected by landslides and erosion by applying agro-technical and forestry measures (the interfluve between the Rau Alb and Rusor; right slope of the Sibisel around Sacel and Sampetru);
- ❖ hydro and agro-technical works to collect rain water and to reduce gully erosion (the slopes around Sacel, Sampetru, Livadia);
- ❖ vegetation cover compactization after is was removed as a result of excessive grazing by reseeding with grass species mentioned in section 4.3. to stop the erosion processes (the communal pastures around Petros, Baru, Livadia, Ponor, Hobita, Baiesti, Fizesti, Ohaba-Ponor, Rusor, G-ral Berthelot, Farcadin, Boita, Ciula Mare, Ciula Mica, Rachitova, Densus etc.);
- ❖ plowing practices along contours and not long the gradients slopes (Baru, Rachitova, Sarmizegetusa, Densus, Pui communes etc.);
- ❖ greening resources perimeters exploitation (Galati, Pui commune);

For <u>the erosion piedmonts morphodynamic unit</u>, we suggest:

- ✓ anti-erosion works in the areas affected by sheet, selective or gully erosion; these are recommended not to be used as arable or pastures (the slopes around G-ral Berthelot, Tustea, Craguis, Boita, Ciula Mare, Ciula Mica, Rachitova, Stei, Densus, Breazova, Sarmizegetusa, Malaiesti, Uric etc.; the interflue between Rau Mare and Sibisel etc.);
- ✓ carry out works to eliminate the causes of landslides by making drains in the forefront sliding, drainage wells and building walls to take the pressure of the body mass sliding (between Baru and Merisor; Crivadia quarry as a torrent can be formed that can flow on the rail); in some cases such works have been made (between Baru and Merisor) but they must be maintained, given the fact that the processes are very active;
- ✓ modifying the natural drainage through hydro and agro-pedo-ameliorative works (leveling, shaping, agro-terraces) (Rachitova, G-ral Berthelot, Densus, Pui communes);
- ✓ rehabilitation of the fruit areas (left slope of the Galbena, right slope of the Breazova etc.) which were abandoned or distroyed, and which stopped the geomorphological processes;

- ✓ land use conversion of the areas affected by denudation processes: arable land/grassland→ orchards/forest areas (e.g. G-ral Berthelot, Densus, Sarmizegetusa, Rau de Mori, Santamarie-Orlea, Pui, Baru, Banita communes etc.);
- ✓ planting the areas affected by landslides with forest vegetation (privet, common pine, black pine, dogwood, alder etc.) or grass to stabilize them and to ensure, through evapo-transpiration, excess moisture removal;
- ✓ debris flow correction by building dams and anti-erosion thresholds as well as the rehabilitation of the existing ones (Densus, Rachitova, Rau de Mori, Santamarie-Orlea communes etc.);
- ✓ greening resources exploitation perimeters (e.g. quarries and heaps) (Crivadia, Banita commune; Arsuri, Baru commune; Comarnic, Pui commune; Rau de Mori);

For <u>the morphodynamic unit of the slopes and interfluves from the mountain area</u>, we suggest:

- ➢ debris flow correction by making dams and anti-erosion thresholds because they destroy transport infrastructure (in the upper Strei catchment, Rau Barbat, Rau Mare etc.);
- ➢ afforestation of the reception torrent basins in the upper sector of the Strei and Barusor with spruce;
- ➢ greening the granite and granodiorite quarry on the Netis valley and the areas from where the vegetation was removed when the hydropower development works on the Rau Mare were conducted;
- ➢ avoiding the execution of cuts at the slopes base for forest roads or by resizing the existent ones when in their composition there are rocks with different degrees of resistance to erosion;
- ➢ river embankment to stop lateral erosion which leads to the undermining of the slope base and to protect roads (the upper sector of the Strei);
- ➢ slopes protection characterized by high gradients (>35°), with woods;
- ➢ tourist facilities: tourist exploitation of the karst (Sureanu Mts.), glacial and periglacial (Retezat, Godeanu, Tarcu Mts.) and anthropogenic landforms (Gura Apei reservoir);
- ➢ rafting practice at spring-summer discharges on the upper sector of the Strei; the Rau Barbat could also be included, but we must take into account the fact that its flow is man-controlled;

- ➢ ski slopes building on the shaded slopes of the Retezat Mts. in Baru, Pui, Salasu de Sus communes;
- ➢ special landscape aspects allow trekking practice;

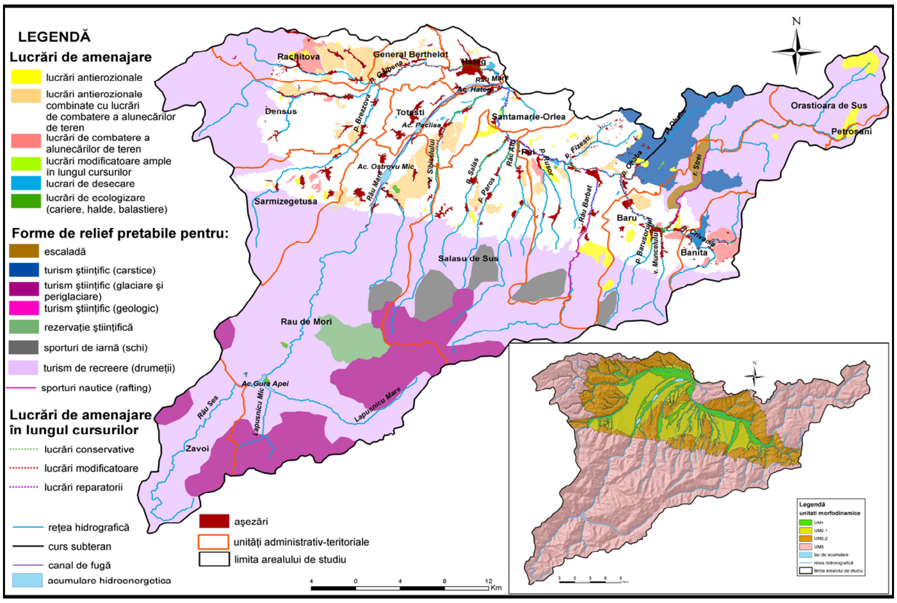

Fig.17. Upper and middle sectors of the Strei valley. Suggestions.

CONCLUSIONS

The present study offers a comprehensive analysis perspective of the relief in territorial planning. For this, we built a diverse data base, regarding lithological, soil, bio-geographical, geomorphological, demographic, artificial landscape, anthropogenic changes, natural hazards, etc., which can be used in future studies of the administrative-territorial planning, as it obeys the laws in force.

The study area was divided on the basis of complex criteria into units which we called 'morphodynamic' for a better management of the existing resources and geomorphological processes. Each unit has certain features that make it or not favourable to facilities and use.

- ➢ **The floodplain morphodynamic unit** is suitable for agricultural use (field crops, gardens, pastures, meadows depending on soil), except that you need to make some fitting (hydro-ameliorative, conservative, modifying, ecology).

- **The accumulation morphodynamic unit** is characterized by morphological and morphometric aspects that allow the extension of settlements. On these areas the agricultural use must be maintained (livestock, crop production (cereals, potatoes), fruit trees, pastures) because they do not have restrictions regarding access to agricultural machinery. However, we must take into account the high anthropogenic pressure that triggers intense erosion processes, which evolve into mass movement processes, and the fact that there are areas that can not be used only after some hydro and erosion works.
- **The erosion piemonts morphodynamic unit** dynamically unstable presents a high degree of restrictiveness. The first measures to be taken are designed to improve and to bring stability to the relief affected by erosion and landslides. It requires maintaining the agro-forestry use (pastures, meadows, wooded areas), except that grazing should be restricted to the low productive pastures. Forested areas are not required to undergo operational work as it serves as protection forest.
- **The morphodynamic unit area of the mountain slopes and interfluves** is also characterized by a high degree of restrictiveness, which does not allow various uses (e.g. location of buildings, roads). Activities that may take place are in the category of agro-pastoral, forestry and tourism (hiking, climbing, skiing, rafting, scientific tourism). Since these forms are included within parks, resource management and other human interventions are restricted.

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