“BABEŞ-BOLYAI” UNIVERSITY OF CLUJ-NAPOCA
FACULTY OF GEOGRAPHY
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Morphology, dynamics and spatial development and planning in Târgu-Mureş city

SUMMARY of the PHD THESIS

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Urban spatial planning is the foundation for the territorial development of the city as an individual entity (in this case Târgu-Mureș city), but also for the surrounding settlements with which the city develops relations of interconnection and interdependency. Therefore, city development strategy is the basic tool employed in analyzing favorable and restrictive development aspects, scientifically well-argued, for each specific field. These aspects will then be integrated into a "space-time matrix showing projected interventions and approaches" (Cocean, 2011) which will subsequently have an important role in the

organization, planning and development of the area under study.

The study on the morphology and dynamics of Târgu-Mureş city will highlight the city development stages in relation with socio-economic contexts and, last but not least, the restraints imposed by the natural factors: geomorphologic (land morphology, altitude, slopes, fragmentation density, slope direction etc.), hydrological (water courses, flooding), climate (temperature, precipitation, drought, etc.), soil (soil type, texture, physical and chemical characteristics).

The attention will be focused on the role and influence of topography on the development and planning of the territory within the administrative borders of Târgu-Mureş city.

With a population of 144,806 inhabitants, Târgu-Mureş is a mid-sized city, part of the Central Development Region of Romania, representing the county seat of Mureş County, geographically located in the Transylvanian Depression, on the middle course of Mureş River (Fig. 1).

Due to its geographic position and economic level of development, it is the main polarizing center in the Transylvanian Plain, holding the position of a second-rank urban center in the regional system (General Urban Plan; Ro: PUG, Târgu-Mureş, 2012). This central role provides Târgu-Mureş with the advantage of polarizing the surrounding areas, which subsequently triggers high development potential and creates premises for increasing its influence on the adjacent space.

In order to identify the development potential of Târgu-Mureş city, we first highlighted the current socioeconomic development status, the restrictive and favorable natural and anthropogenic factors (technical infrastructures, environment conditions, development level of various economic activities), these factors eventually becoming vectors for the potential development of the city. Another objective of the present study is to identify territorial dysfunctions mainly caused by land morphology, and their possible effects on other environmental components, fact that will help identify the strategic concepts needed for such an extensive study.

The relief will be analyzed from all perspectives: qualitatively, quantitatively, functionally and strategically. Most of the features will be identified using GIS analysis, aiming to identify any correlations between them, mainly in relation with the human component.

This study will be a fundamentally useful tool in making decisions on the practical measures that can be implemented to reduce the identified dysfunctions in the territory, but also in revealing possible development directions in the area under study.

The study entitled “Morphology, dynamics and spatial planning in Târgu-Mureş city” consists of a detailed analysis on the territory where all activities specific to the urban area of Târgu-Mureş are carried out, with emphasis on the relief and the influence of environmental factors on city sprawl.

Previous geographic studies on the Transylvanian Depression, Mureș County and predominantly on Târgu-Mureș city represent the theoretical basis of the present study. They all helped to create the synthetic image on the relation between the geographical reality and the projection of Târgu-Mureş city image over time.

In order to study the morphology of the city and its influence area, we used old cartographic resources (Topographic Maps 1:50,000; Topographic Plans 1:5,000; Geological Map 1:200,000; and Soil Map 1:100,000) but also recent satellite images (Google, 2018; Landsat satellite imagery, 2018). They represented the informational basis for the following detailed analysis and were afterwards modeled in specialized software for integrated individual analysis but also in relation to data on climate, water and soil, etc.

Statistical data analysis on population indices, on climatic and hydrological data series as well as on morphometric indices and quantitative indicators of distribution of buildings by land use classes, by altitude classes or slopes, showed the quantitative traits of the territorial subunits analyzed at the micro- and macro-scale.

The SWOT analysis on Târgu-Mureş city was performed to emphasize the main development opportunities of the city the main strengths and weaknesses, along with the dysfunctions showed by analysis results.

Spatial planning takes into account the stability of landforms, their dynamics potential and, last but not least, the likelihood of occurrence of negative processes and phenomena that could impact population, infrastructure and other facilities. This explains the high density of buildings and the construction of the main communication routes along Mureș River valley (meadow and terraces). Particular attention must therefore be paid to areas characterized by a high degree of flood risk.

Thus, the main land morphometry and morphology features that can determine certain degrees of favorability for the development of housing and transport infrastructure

within the administrative borders of Târgu-Mureş city were analyzed.

Since a spatial choremathic model implies a certain level of abstraction and generalization of all the characteristics of the territory under study, the choremathic analysis was also carried out. This allows for the elaboration of development trends and directions in accordance with the development potential. Thus, through the proposed choremathic model, the natural pattern of the administrative territory of Tîrgu Mureş city, the main development nuclei and the main development axes and directions were highlighted, so that it should benefit from as many advantages as possible in its future development.

Among the current geomorphologic processes that have usually occurred and have been active within the administrative territory of Târgu-Mureş, landslides are recorded. Soil erosion is very low, most of the territory being protected by rehabilitation and maintenance works, extension of the built-up area and green areas; flooding is also extremely reduced due to regularization works along Mureş river, measures that were taken to diminish the negative effects caused by previous floods.

A particularly important aspect to be pursued in spatial planning is to identify the degree of geomorphologic vulnerability of the urban territory. In recent years, the built-up area of Târgu-Mureş city has spread out. However, these actions were performed independently of the restrictions that should be imposed in order to avoid the authorization of construction in areas recording a high probability of landslide occurrence.

Therefore, we employed GIS software to reveal the classes of built-up area of Târgu-Mureş considering the probability of landslide occurrence, as mentioned in the provisions of the Government Decision 447/2003. Geomorphologic mapping that highlights active geomorphic processes on slopes was also used as a validation method for the previously obtained results.

In order to systemically identify the characteristics of the city, a double approach was used: on the one hand, the specific characteristics at the county level were identified, their role and the relations they develop with settlements in the city's area of influence and, on the other hand, the same characteristics were analyzed at microscale at the level of the mapped geomorphologic units.

The analysis of the physical-geographic features of the territory within the administrative borders of Târgu-Mureş city, and also the identification of risks associated with the geomorphic processes that occur spatially, can both contribute to the elaboration of

General Urban Plans, Zonal Urban Plans and other strategic documentations. The current strategic documents show the morphological configuration of the city built-up area to date.

Remodeling the geographic space within the administrative borders of Târgu-Mureş city implies a new design of the urban planning aspects in direct relation to land morphology of the urban built-up area and the associated risks determined by the contemporary geomorphic processes.

In chapter 2 the historical-geographic features of the urban development of Târgu-Mureş city were identified. Due to the favorable position in the country and especially in Transylvanian Depression, archaeological evidence about Târgu-Mureş was found ever since the Neolithic to the Feudal period (9^{th} -14^{th} centuries). The first records are found in the Franciscan Annals (1316), where we learn about one of the four monasteries existing in Transylvania at that time, "Forum Sicorum", followed by the Pope's Payments Registry since 1332 that mention the new location of the fair of the Székelys ("Novum Forum Siculorum") as being a larger settlement than the neighboring ones.

From the written and cartographic evidence of this period we found the following details: the district of Pocloş is remembered as consisting of the most valuable buildings; the district of St. Nicholas is remembered as consisting of quite modest buildings; we found about the development tendency of the city towards Gh. Doja and Liviu Rebreanu streets, but also towards Belşugul and Libertăţii Streets, to Pocloş creek, December 22, 1989 and December 1, 1918 streets, until the bridge over the stream; all these details reveal the presence of agricultural activities of the region.

According to historical records in 1800, the built-up area of the city reached a size of 210 hectares.

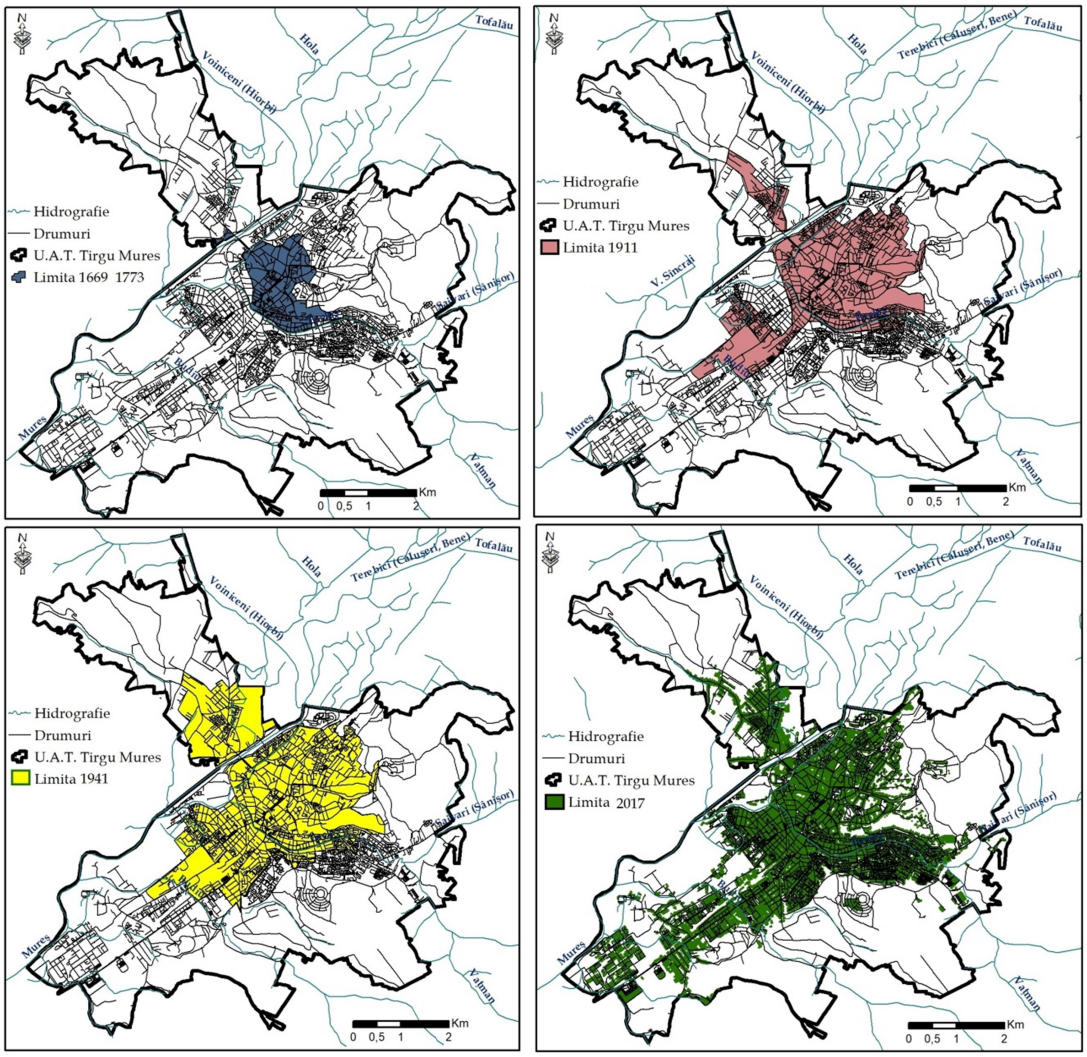

Fig. 1. Spatial evolution of the built-up area of Tîrgu Mureş city from 1773 to 2017

Other cartographic resources that helped identify the spatial evolution of this city are represented by the map of Captain Theumen in 1750, topographic surveys carried out in 1872, the city map of Pompery Elemer in 1898, the map of the publisher Reves Bela in 1914, the engravings of Morelli Gustav from 1860 and others.

After 1850, the rapid development of the modern city begins with the increase in the number of inhabitants and constructions. During this period regularization works along Mureş River and the first development works were carried out. City modernization was supported by the development of food industry, construction materials industry, or wood processing.

The increase in the number of buildings and in the number of streets within the

boundaries of the built-up area of Târgu-Mureş city is of more than 2,900 constructions, during the period 1892-1900. Multi-storey buildings were constructed on the streets of Gheorghe Doja, Libertăţii, Dorobanţi, but also on the right bank of Mureş River.

The construction of the railroad from Războieni to Gara Mare was completed in 1871, and the construction of Gara de Nord (North Station) in 1883. These works also included the construction of bridges and new streets.

Chapter 3 focused on land morphology and typology of the urban space. From the analysis on the density of constructions in the districts of Târgu-Mureş city, the central district stands out recording the highest concentration of buildings (about 2536 constructions) on a relatively small area of 153.9 hectares, with an average density of 15.9 constructions per hectare.

Regarding the altitudinal distribution of the territory within the administrative borders of Târgu-Mureş city, we find predominantly the level of terraces and terraced slopes (310.1-350 m altitude) and the level of low hills (elevation of 350.1 - 450 m), which represent 27.45% and 26.91% of the city.

Slopes vary in the range of 0 - 23.85 degrees. Slopes of 0-2 degrees are extensively present in the Mureş river meadow, on about 38% of the territory (18.95 km^2).

There are some districts, namely Gheorghe Marinescu and Belvedere, located in areas with high values of the average slope, with values of 8.34 and 7 degrees. Low values of the amplitudes of slope are mostly characteristic to the areas where the following districts are located: Libertății (3.48 degrees), cartierului Rovinari (3.43 degrees) and Podeni (5.43 degrees).

All this morphometric data provide an initial picture of the geomorphic processes that may occur in this territory and will represent databases to be used in the next chapters to identify the geomorphologic potential and the relief-related risk classes within the administrative borders of Târgu-Mureş city.

To depict the particular aspects of land geomorphology, the geomorphologic map of the territory under study was made. Thus, it was observed that the meadow area of Mureş River, which, due to specific morphography and morphology, offers a favorable conditions for the development of the city. Here, we also noted some abandoned meanders as formerly active components (Fig. 3).

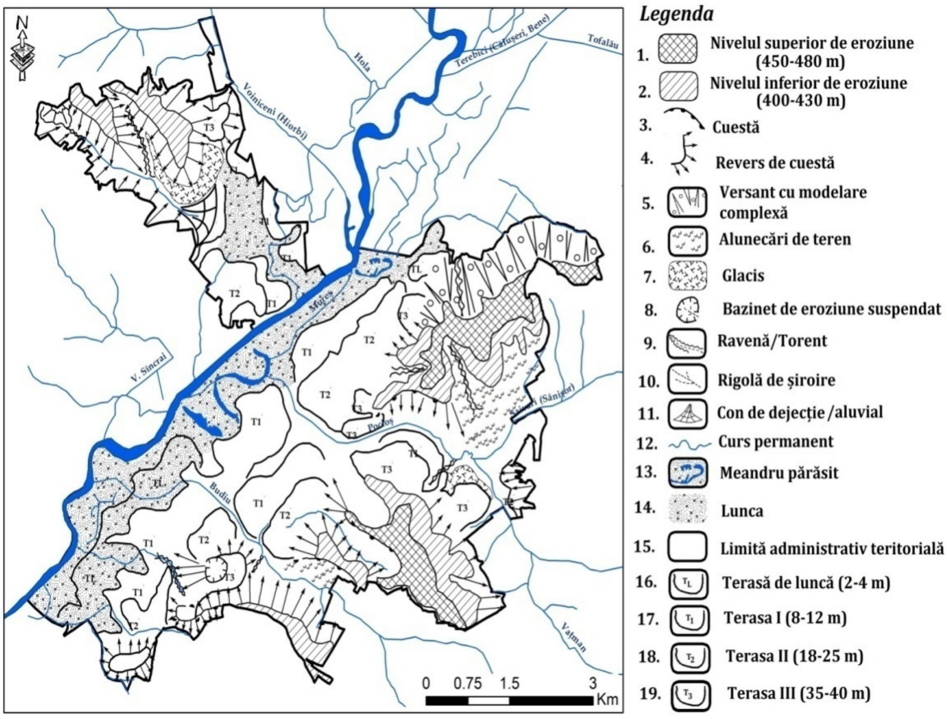

Fig. 2. Geomorphologic map of Târgu-Mureș city

Slopes also represent a significant part of the analyzed area (25.6 km^2) and landslides were noticed to develop in the areas with high slopes and with susceptible geological substrate. These processes restrain the urbanization phenomenon by limiting the expansion of the built-up area.

Using the map that shows the probability of flood occurrence by exceeding the 1% probability flows, which is available for the population on the website of Târgu-Mureş City Hall, we digitized the limit of the flooding area for this flow.

According to measurements on this flooding area belt, it was calculated that in the event of a 1% occurrence probability, a surface of 1.98 km^2 within the administrative border of Târgu-Mureş city presents flood risk, if this flow is reached (4.01% of the territory under study).

According to official data, the population of Târgu-Mureş city is of 143,939 inhabitants, a slight increase being recorded lately (for example, the number of newborns in 2009 was of 1,583, the number of deceased was of 1,390, resulting in a natural increase of 193 persons (at a rate of 1.33 $_0/^{00}$).

The economic activities found in Târgu-Mureş administrative area are mainly related to: chemical industry, particularly represented by S.C. AZOMUREŞ S.A. for the production of basic chemical and inorganic products; drug industry represented by S.C. SANDOZ SRL, S.C. BIOEEL S.R.L., S.C. GEDEON RICHTER ROMANIA S.A. etc., food industry, plastic processing industry, textile industry. All these trigger a potential environmental risk due to the likelihood of producing high level of emissions.

Chapter 4 focused on the analysis of morphometric aspects in the distribution of urban built-up area, the distribution of residential quarters on morphogenetic levels, zoning of urban morphodynamics in relation to slopes, fragmentation and relief energy, the distribution of land use classes and landscape functions in relation to the slope direction.

The distribution of morphodynamics in relation to the depth of relief fragmentation by classes in the period 1669-1941 indicated an extension of the built-up area on increasingly higher depth fragmentation classes compared to the average values of 40.4 km/km^2 recorded in the period 1669-1773. Thus, we learned that about 30% of the studied territory is represented by discontinuous urban and rural space, and about 24.72% of the territory is covered by deciduous forests. These wooded areas are located outside the built-up area, with a surface of about 12.2 km^2 afferent to the e residential districts of 22 Decembrie, Gheorghe Marinescu, Belvedere, Mureşeni and Unirii.

Current morphological dynamics and subsequent restrictiveness in relation with urban space planning were also analyzed. Following the analysis of topographic maps and satellite imagery, a number of areas affected by superficial and deep landslides were identified; these territories were marked on the geomorphologic map, also being subject of field research.

Using GIS mapping and spatial analysis techniques, maps of hazard coefficients induced by landslides were obtained (reflecting soil, geomorphology, structural, hydrology, climate, hydrogeology, seismicity, forestry and anthropogenic coefficients).

Buildings and transportation network were mapped employing recent satellite imagery (using the Google Earth software) to identify the elements of the built-up area that are prone to landslides. About 17,389 construction sites and 518 km of roads were identified (including all road categories within the administrative borders of Târgu-Mureș city), elements that were subsequently used to obtain the anthropogenic coefficient map (Kh).

Results showed areas with medium and large probability of landslide occurrence,

extensively located in Unirii residential district (mostly used as orchards and agricultural land), and in other residential districts, namely Gheorghe Marinescu, Tudor Vladimirescu and Belvedere, but also Mureşeni and Dâmbu Rotund.

Overall, 21.2 km^2, representing 43.4% of the whole studied area, can be assigned to medium probability class (with an average risk factor in the range of 0.10-0.30, but about 41% of the territory (17.6 km^2) can be included in the category of medium-high probability (0.3<Km<0.5). High probability (0.5<Km<0.68) was recorded in the case of 2.4 km^2 of the entire city area.

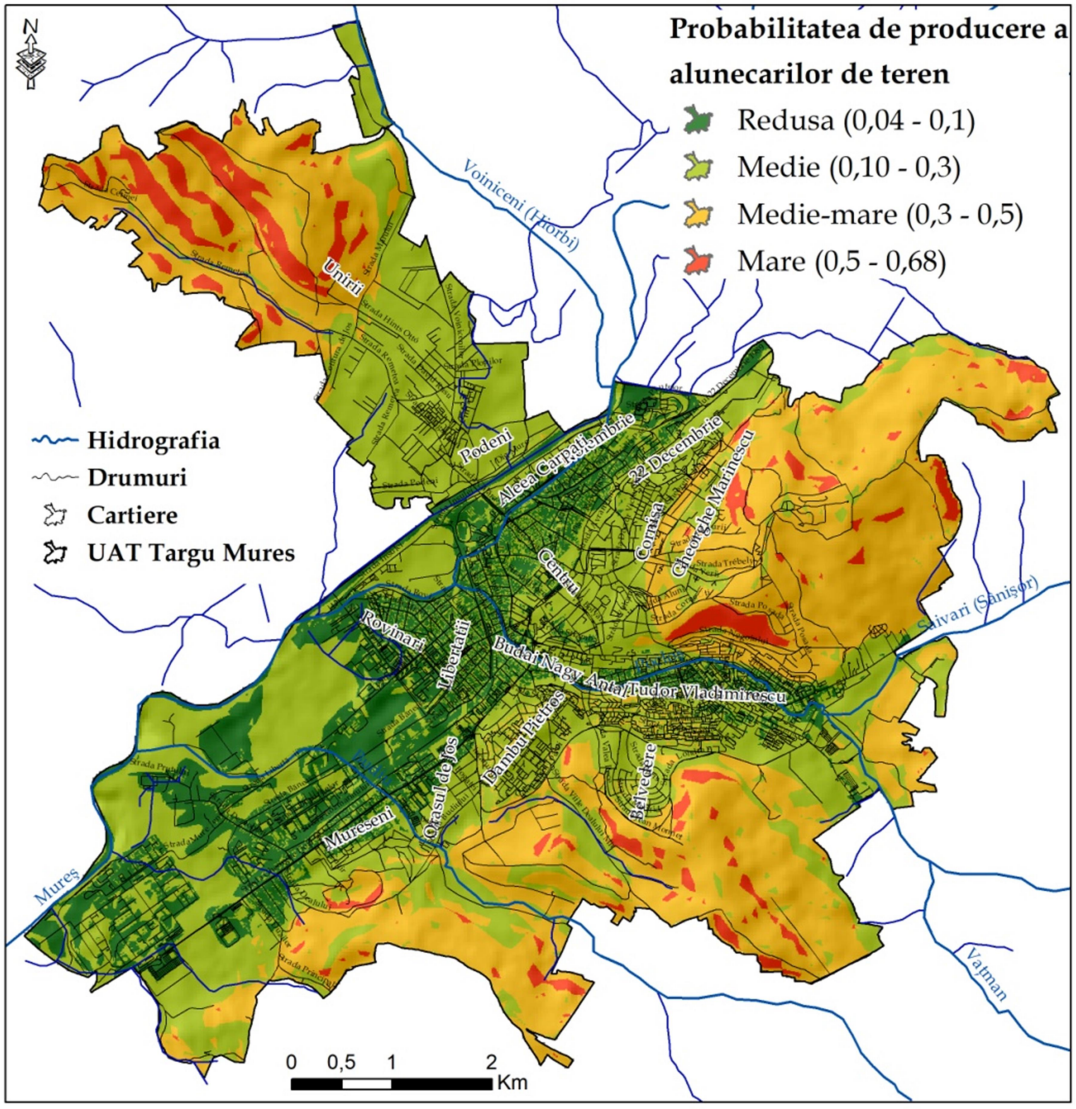

Fig. 3. Map of probability of landslide occurrence

Table 1: Classification of housing and transport infrastructure into classes of landslide risk

Elements at risk	Risk of landslide occurrence			
	Practically none	Small	Medium	High
Constructions (no.)	9,746	17,885	2,752	37
Roads (km)	170	267	73.4	0.3
Railroads (km)	7.6	2.8	-	-

It was identified that 7.32% of the number of constructions in Târgu-Mureş city are located within the flood risk area. Besides these, we add 20.7 km of roads (3.9% of the total 518 km) and 0.28 km (2.64%) of the 10.57 km of railways connecting the city with neighboring regions.

Chapter 5 focused on the city and its role in spatial development and planning.

The functional zoning of Târgu-Mureş city for 2015 shows, to a certain degree, a general picture revealing the concentration of economic, industrial activities and the main land use categories. Thus, the functional areas of Târgu-Mureş city, which mutually support each other, are represented by:

- The Central area - with complex functions of public interest.
- The Residential area - with supplementary functions.
- Areas with parks, green areas and recreation facilities.
- Areas of special use, such as roads, railways or air routes,
- Areas with industrial facilities.

Among the dysfunctions resulted from the analysis of the functional areas within the administrative boundary of Târgu-Mureş city, the following are noted:

- The small extent of central area (only 153 hectares of the entire administrative territory of Târgu-Mureş city) which leads to a high density of public institutions; also, due to residential expansion into the central area and the high density of commercial facilities, the central area is overcrowded, especially during the week.
- The reduced share of green areas (9.93%) triggers less urban comfort, with negative ecological implications. In 2015, for example, only 0.06 m^2 of green space/ inhabitant was recorded in Târgu-Mureş city, fact that emphasizes the need to extend this type of area.
- In some sectors, street density is low, street are narrow-width, which also

leads to overcrowding, especially during peak hours.

Chapter 6 shows the results of the SWOT analysis and the projected choromatic model of Târgu-Mureş city.

The elaboration of SWOT analysis helped identify the development opportunities and the main risks to which the territory of Târgu-Mureş city is exposed. The analysis included listing the main strengths and weaknesses by category of components: spatial relations the city develops on different levels, the natural supporting component, environment and quality of living, the anthropogenic component (population and human resources), infrastructure development, public services, land, land-use, services (education, health), tourism, economic development (industry, agriculture, trade).

Results of this analysis showed the influence of land morphology on the development of Târgu-Mureş city and its main dysfunctions due to the relief morphometric and morphological characteristics.

From the geomorphologic perspective, Târgu-Mureş city is located on a non-homogeneous surface, represented by the elements of Mureş river valley, river meadow, with the terraces 1, 2 and 3, and the slopes bordering Mureş river valley. Both the hilly area and the river terraces are favorable to various urban development possibilities, leading to a stratified layout of the city's built-up area.

The analysis on the evolution of the city considering the historical and cartographic sources, highlighted the territorial expansion supported by the demographic and economic growth, determined mainly by the development of industry in the city. Thus, starting from a nucleus situated around the medieval fortress of Târgu-Mureş, the extension of the built-up area eventually integrated the rural settlements of Mureşeni and Remetea.

The urban physiognomy (structure, texture and architectural style) highlights three distinct areas: the central area, overlapping the old, medieval nucleus; the area of the middle districts; and the peripheral residential area.

The extension of the city predominantly towards south-west direction is determined by the restraints towards the other directions (limitations being represented by Mureş river valley and the hilly massifs with morphometric characteristics that are restrictive to dwelling) and by other features in favor of city development.

Currently, it is notable the extension of the built-up area, which leads to the reduction of the green space. This extension towards the high-slope area also determines

disequilibrium in the anthropogenic and natural systems.

Along with the socioeconomic aspects, modern techniques of analysis demonstrated that, due to its geomorphologic characteristics, the topography provides favorable conditions for the future sustainable development of the analyzed territory, complying with the current requirements.

Following the elaboration of the geomorphologic map, we found the most favorable sectors for development, specifically the meadow sector and the terraced area, which allow for urban development within the limits imposed by flood risk.

In the present study, GIS technology was used in order to categorize the administrative territory of Târgu-Mureş city by classes of probability of landslide occurrence. The following regulations and norms were considered: the methodological norms, data from natural landslide risk maps (GD 447/2003) and the guide for the elaboration of landslide risk maps to ensure the stability of constructions - GT-019-98.

It has been identified that 4.9% of the administrative territory of Târgu-Mureş city has a high probability of landslide occurrence as a result of multiple causative and triggering factors (areas with values of the average hazard coefficient in the range of 0.5 - 0.68).

The analysis on the distribution of built-up area based on the probability of landslide occurrence reveals a number of 27 buildings located in areas that could be affected by active dynamics, whose effects were also observed in the field.

This methodological approach was based on the use of GIS-specific techniques and methodologies, on the monitoring and mapping of active landslides and their occurrence probability, to reduce specific negative consequences and set up measures to prevent and mitigate material losses, to enforce new regulations for the authorization of new constructions in these areas.

We consider thematic maps extremely useful (the map of slope direction, the map of fragmentation density, the map of depth fragmentation of relief, the geomorphologic map comprising the current geomorphologic processes as well as risk maps for landslides and floods). They can play a significant role in decision-making as regards future development directions and particularly on restrictions imposed to the authorization of construction permits.

In chapter 4 entitled “Morphology and Urban Dynamics of Târgu-Mureş city”, the distribution of residential districts on morphogenetic levels was analyzed, both at present

and during different periods of time (1776, 1910, 1941).

The zoning of urban morphodynamics in relation to slopes, fragmentation and relief energy was also elaborated.

Current morphodynamics identified in the slope area brings some difficulties in the process of spatial planning. This is why slope and riverbed processes were analyzed in detail, along with risks associated with the geomorphologic processes, which allowed for zoning of the geomorphologic risk.

The morphometric and morphological data analysis provides extremely important information to experts in spatial development and sustainable planning of Târgu-Mureş city to be considered when proposing the city's future development directions, focusing on the probability that some geomorphologic processes that induce risk should occur.

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