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# Favourable and Restrictive Geographical Factors in the Development of Zalău Municipality

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**A B S T R A C T**

The natural background is one of the main conditions for urban development. In this context, the present study analysed the way in which the relief influenced the Zalău city's spatial development in time. Geomorphological restrictiveness was determined by relief fragmentation, slope and aspect, forming together a territorial model of evolution. In addition to the geomorphological characteristics of the area, other factors that contributed to the development of this settlement were the climate, the hydrographical network, the vegetation, the soil and the historical-geographical factors. A semi-quantitative model, described by the Romanian Governmental Decision 447/2003, was applied, enabling the calculation of the average landslide hazard coefficient and the generation of its corresponding map that made possible the identification of potential future landslide areas. The study area generally had a low (0.01-0.10) and average (0.11-0.26) landslide susceptibility. A series of cartographical materials were also analysed, including shooting master plans from 1939, topographic maps from 1970 and orthophotographs from 2005, which were used to identify the evolution of the built-up area. Its spatial growth mainly took place towards the north-east, directly influenced by the population growth and the favourable geomorphological factors (slope angle smaller than 5° and altitude values below 250 m). These results were based on geomorphological mapping and GIS analysis and had a high practical importance in the study of urban evolution.

## 1. INTRODUCTION

City development is a complex process which must consider the main geographical elements which characterise any urban settlement. In the development of Zalău city, the main geographical factors have played an important part in guiding the city's directions of development and establishing its value at a regional and national level.

When urban areas are characterised by a period of dynamic development, the analysis of the natural, geomorphological context in which human activities take place, is a necessary task [1]. Thus, the morphological analysis represents the starting point for identifying the favourable and restrictive geographical elements of Zalău city. The applied methodology enables us to identify the areas prone to geomorphological hazards and other relevant geographical factors. The study analyses the relationships established between the geographical elements, the urban built-up area and the development of the territory.

## 2. THEORY AND METHODOLOGY

This research focused on Zalău city has produced in time a series of scientific works which also make reference to the elements of favourability and restrictiveness.

I. Mac and Maria Hosu (2010) [2], analysed the natural constraints which limited to some extent the development of Zalău city. The tectonic and structural constraints were determined by the presence of the Meseş horst, characterised by a steep front towards the north-west, the lithological constraints were given by the sedimentary deposits which covered the crystalline foundation of the Zalău Depression and the morphologic and hydrographical constraints were the result of a connection between the relief of hills and piedmonts included in the Zalău Depression. The same study also presented the three main hydrographical convergences which had an important role in determining the geomorphological characteristics of the urban built-up area.

The first of the three was represented by the convergence of the Meseş stream with the Zalău Valley, the second was situated at the convergence of the Sărătura and Caselor streams with the Zalău Valley, and the third was the convergence of the Miţii and Crişenilor rivers with the Zalău Valley. In addition to this, the critical environmental events which occurred in the city and six risk areas for the Zalău municipality were presented, including the left slope of the Meseş Valley, the area of Gh. Lazăr Street, the area of the water tanks, the area of the Poporului Park, the areas Traian, Vişinilor and Dumbrava II.

Starting from the results of this study, further research was considered necessary, based on field observations which would enable the analysis of the present situation. In order to identify the natural elements which had a favourable, but mostly a restrictive role in the spatial expansion of the city, the morphometric maps of the area were analysed. Both the analysis of the slope angle and the hypsometry were important for determining if conditions were appropriate for human activities and for the growth of the residential areas, but also for vulnerability assessment. The analysis of the slope angle included five slope angle categories: 0-2°, 2.1-5°, 5.1-15°, 15.1-20° and 20.1-29.7°, as well as the analysis of hypsometry, which also took into account the main characteristics of the morphology. A series of cartographical materials were also analysed, including shooting master plans from 1939, topographic maps from 1970 and orthophotographs from 2005, which were used to identify the evolution of the built-up area.

Through map analysis and field observations, a high landslide frequency was determined in the built-up area. As the identification of prone areas to geomorphological hazard was necessary for establishing the prevention and mitigation measures needed for risk reduction [3], a landslide hazard assessment was performed using the semi-quantitative method described by the Romanian Governmental Decision 447/2003 [4]. Using GIS techniques, several thematic maps were created taking into account the importance of each potential hazard factor in the landslide development and evolution. The estimated value and the spatial distribution of each factor was done individually for the lithological, geomorphological, structural, hydro-climatic, hydrogeological, seismic, forest and anthropic coefficients, all of these being used to determine the average hazard coefficient and its corresponding map.

## 3. RESULTS AND DISCUSSION

### 3.1. Advantages of the geographical position

The city of Zalău lies at the intersection of the parallel 47°10' north latitude with meridian 23° 05' east longitudes, in the southern part of the Zalău Depression. The urban area of Zalău is situated in the centre of the Sălaj county, in north-western Romania, on the Cluj-Napoca – Satu Mare – Petea axis, represented by the national road 1F and E 81. The city lies at almost equal distance from the three resident cities of the surrounding counties, Cluj-Napoca, Baia-Mare and Oradea, and at a longer distance from Satu-Mare [5].

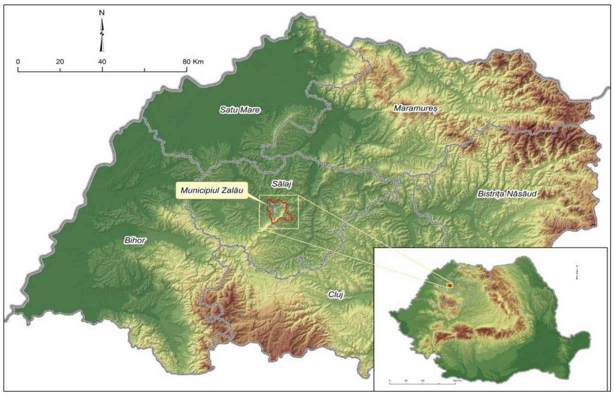


Fig. 1. Geographical position of Zalău city.

The Zalău municipality has an efficient transport infrastructure, being connected to the European road network. Its main road connections include DN 1/E 81, with a length of 86 kilometres towards Cluj-Napoca, DN1 H/DN 1 C with 108 kilometres linking it to Baia Mare, DN 1/HDN 1 with 117 kilometres towards Oradea and DN 1 F/E 81-DN 19 with 119 kilometres towards Satu Mare. 159 kilometres of railroad connect the city to Cluj-Napoca, while the length of the railroad towards Baia Mare has 81 kilometres and the one connecting Zalău with Satu Mare has 124 kilometres.

The urban administrative unit of Zalău includes the Meseş Mountains in the east and south-east and Stâna town to the south-east of Meseş Mountains, in the Agrij hydrographical catchment, with an area of 90.86 km², out of which 77 km² are occupied by the town [6].

### 3.2. Territorial evolution

Until the 12th century, the territorial evolution of Zalău city had been rather slow, but after this period it began to make important steps (fig. 2).

However, urban development was limited to some extent by territorial constraints. This was mainly determined by the geomorphological component and therefore a territorial extension towards less difficult and less costly directions could be noticed [7].

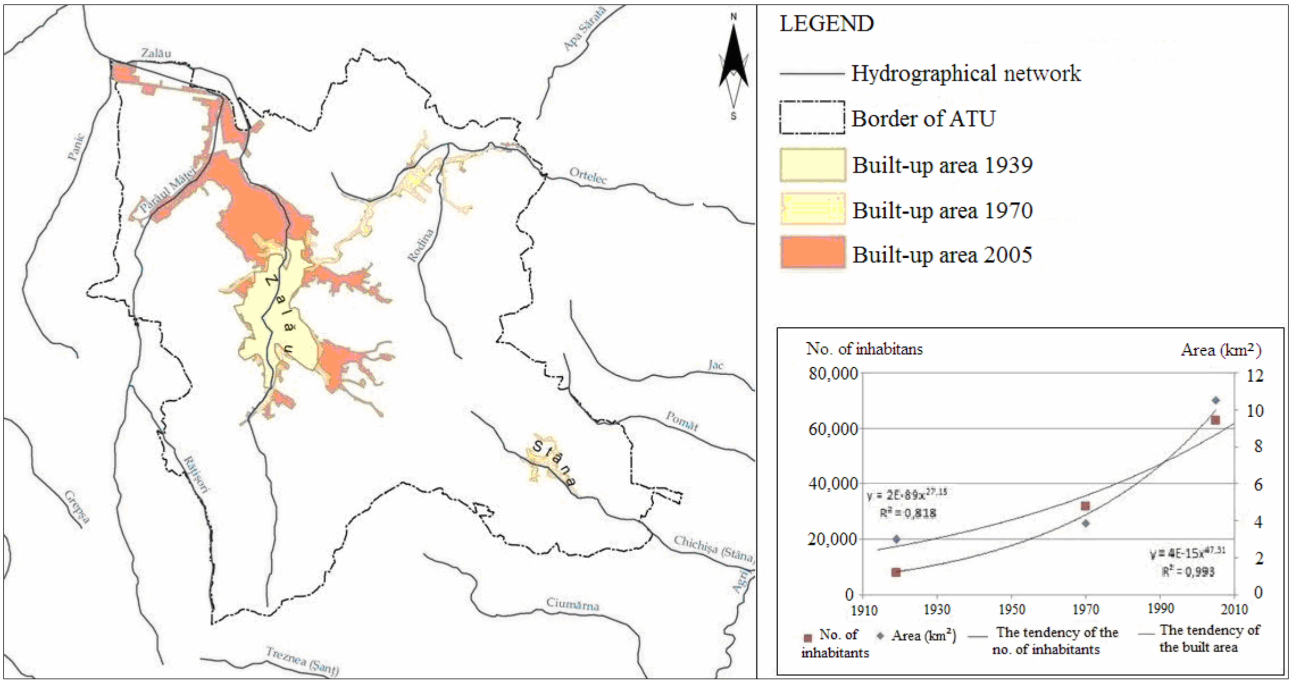


Fig. 2. The spatial-temporal evolution of Zalău city between 1919 and 2005.

The spatial-temporal evolution of Zalău city was illustrated on the map from figure 2 by overlaying the following cartographic documentations: shooting master plans 1:200,000 from 1939, topographic maps 1:25,000 from 1970 and orthophotoplans from 2005. By analysing the built-up area, one could notice that it extended from 3.1 km² in 1939 to 10.55 km² in 2005. This growing trend was related with the evolution of the number of inhabitants, which increased significantly from 8,340 residents in 1930 to 62,927 in 2002 [8]. The city of Zalău developed in a "constrained morphological area" where three morpho – hydrographical convergences could be distinguished (fig. 3), with intermediate sectors in-between.

The first convergence was represented by the Meseş stream flowing into the Zalău River. Upstream from this point, there was the oldest part of the settlement, which dated back to the 12th-15th centuries, when Zalău had only agricultural, trading and administrative functions. In the next centuries, 16th-19th, the settlement extended downstream. In the first phase of urbanization, the central market and the main buildings of public importance were built on the Meseş alluvial cone. The surrounding terraces and the alluvial and colluvial deposits were occupied by houses. Between 1900 and 1960, the city advanced downstream on Zalău River and developed its cultural role. An explosive development took place after 1968, when several large, industrial establishments were built. As a consequence, the city extended intensively to the north, through houses built on terraces and on the glacis, inhabited by people who had migrated from rural areas and other urban settlements.

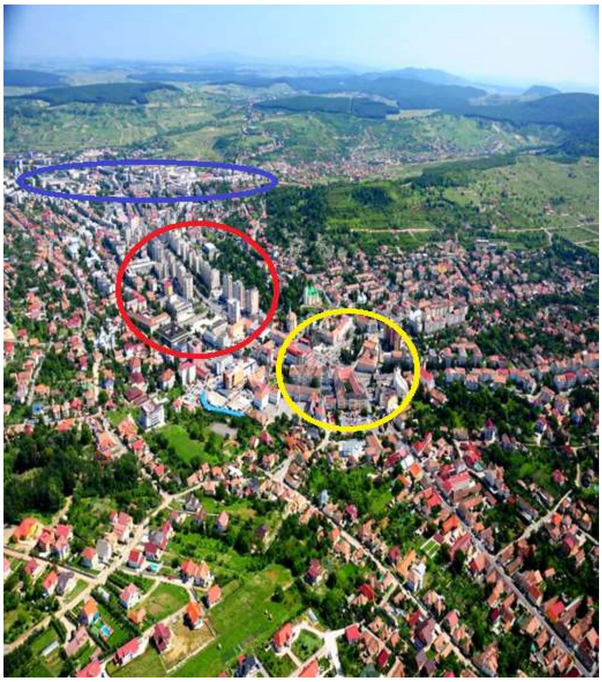

Fig. 3. The territorial evolution of Zalău city: ▮ the first convergence, ▮ the second convergence, ▮ the third convergence*(source: Radu Căpîlnaşiu, 2012)*.

The second morpho-hydrographical convergence was represented by the Sărata and the Caselor streams, flowing into the Zalău River. This area offered a lot of space for the new urban civic centre, where modern apartment blocks of up to 10 floors were built. The neighbourhoods Dumbrava I and II lied towards the west on the terrace and on the neighbouring slope, while the right slope, steeper and affected by landslides, limited the construction of buildings. A second main road intersection as well as the main bus station and some industrial companies were built there.

The third morpho – hydrographical convergence, determined by the contact of the Miţii and the Crişenilor valleys with Zalău valley, created a large and symmetrical floodplain, while the terraces unfolded on the left side. This area, having a good building potential, was occupied by the main industrial zone, the railway station and a third modern road intersection. Together with the longitudinal extension of the city, a transversal one also took place in the Dumbrava Nord neighbourhood, which developed on the 8 to 10 metre and on the 30 to 35-metre terraces. Some houses were extended up to the superior terraces and also on the slopes, which generated stepped apartment blocks and access ways oriented perpendicular to the level curves, increasing in this way the value of investments. In addition to this, an extension of the inhabited area took place through new, individual houses at the foot of the Meseş Mountain and near the Zalău-Aghireş road [9].

According to the General Urban Plan (GUP) from 2006-2007, the built-up area had 2,587.25 ha as opposed to its previous 1,787.69 ha, because of expansions through the Zonal Urban Plans (ZUP) and the GUP, as a consequence of the construction demands issued by private owners, services suppliers, and by industrial and agro-zootechnical units. The industrial zone from the northern part of the city continued towards Panic and Hereclean villages through a zone of industrial services and Stâna town was also included in the built-up area of Zalău. As the peri-urban areas of the city were not yet developed, extensions were needed towards Moigrad for tourism, towards Hereclean as an industrial zone and towards Meseşeni-Aghireş as a residential zone [10].

### 3.3. Natural favourability

*The relief* has an important role in the placement and development of any settlement.

Zalău city is located in the southern part of the Zalău Depression, at the contact of the Silvaniei Hills and the Meseş Mountains, in the western and north-western foothills, which favoured the establishment of this settlement. The relief of Zalău administrative territory could be divided into five altitudinal classes (fig. 4). The first level includes the floodplain, having the lowest altitudes: 197-280 m. The altitude of the second height interval spans between 280.1 m and 345 m and belongs to the terraced slopes. The third interval spans between 345.1 m and 425 m and includes the piedmont level, represented by the Parameseşan Piedmont. The fourth height interval includes the lower mountain between 425.1 m and 534 m, while the last level continues into the mountain area with the interval of the higher mountains, between 534.1 m and 727 m, represented mostly by the Meseş Mountains.

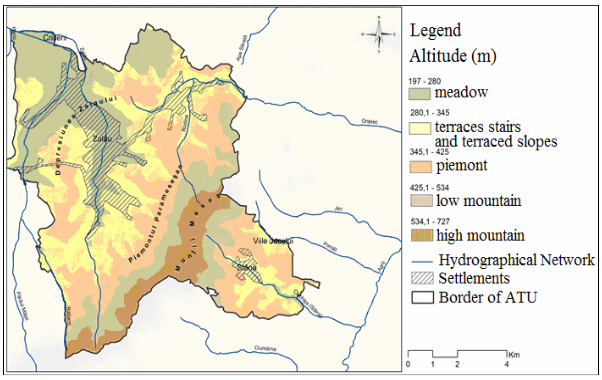


Fig. 4. Hypsometric map.

Zalău municipality is mostly situated on the floodplain and on the lower terraces, which form a depression flanked in the south by the steep slope of the Meseş, with a height difference of 200-300 m, as well as on the right, by the upper terrace of the Ortelec valley. All these represent favourable areas for constructions.

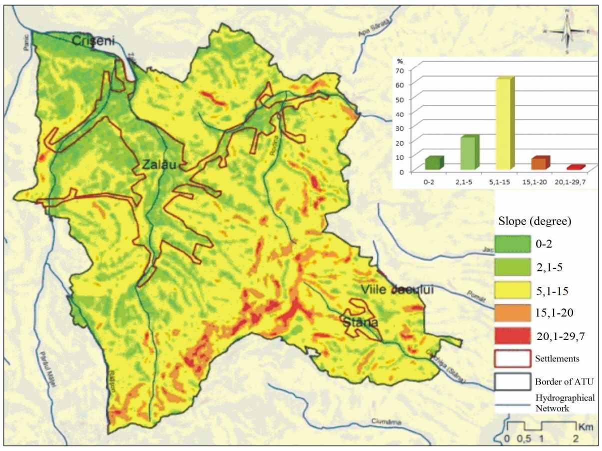


Fig. 5. Geodeclivity map.

The geodeclivity (fig. 5) of the area can be classified into five slope angle categories: 0-2° very slight slopes, 2.1-5° slight slopes, 5.1-15° moderate slopes, 15.1-20° steep slopes and 20.1-29.7° very steep slopes. One can notice that the 5.1-15° interval is dominant, representing 70% of the area, while steeper slopes are in the south and south-eastern parts of the administrative territory and represent about 8%. Inside the built-up area, the slope angle ranges between 0-5°, representing about 30% of the territory, with the best conditions for human activities and constructions.

*The favourable climate* contributed in its turn to the development of this settlement. The climate is mostly temperate with submontane characteristics, which determine high values of precipitation. Average multi-annual air temperature ranges between 9 and 10

°C in the built-up area and decreases to 6-8°C in the eastern part, on the western Meseş slope.

The average monthly value of solar radiation, which ranges between 110-117 kcal/cm², and the mild influence of western and eastern winds favoured the development of complex agricultural practices (fruit trees, vines, grains, vegetables), used to meet the primary needs of the population.

The duration of sunshine varies during the year, most of the sunshine hours are during summer, while in winter the amount of sunshine is minimal. Thus, from May to August, the average sunshine duration is of 9 hours/day, representing enough thermal energy to be converted into other useful forms of energy for human activities.

The sunshine duration varies also from one year to another, the year 2000 having the longest sunshine interval, when the annual temperature also reached the highest level, showing the direct relationship between the two climatic parameters.

Table 1. The duration of sunshine. Annual average at Zalău weather station.

| **Year** | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sunshine hours | 2,002 | 2,265 | 2,253 | 2,273 | 2,061 | 1,961 | 2,071 | 2,086 | 2,151 | 2,357 | 2,007 | 2,141 |

The average temperature in January is around -3 °C, while in June it reaches about 19°C. Rainfall also varies during one year: 80 mm in May, 120 mm in June, 80 mm in July and August. The cloudiness, which depends on atmospheric dynamics and on morphography, fluctuates according to season, with high values in December and January and lower values in late summer and early autumn [11].

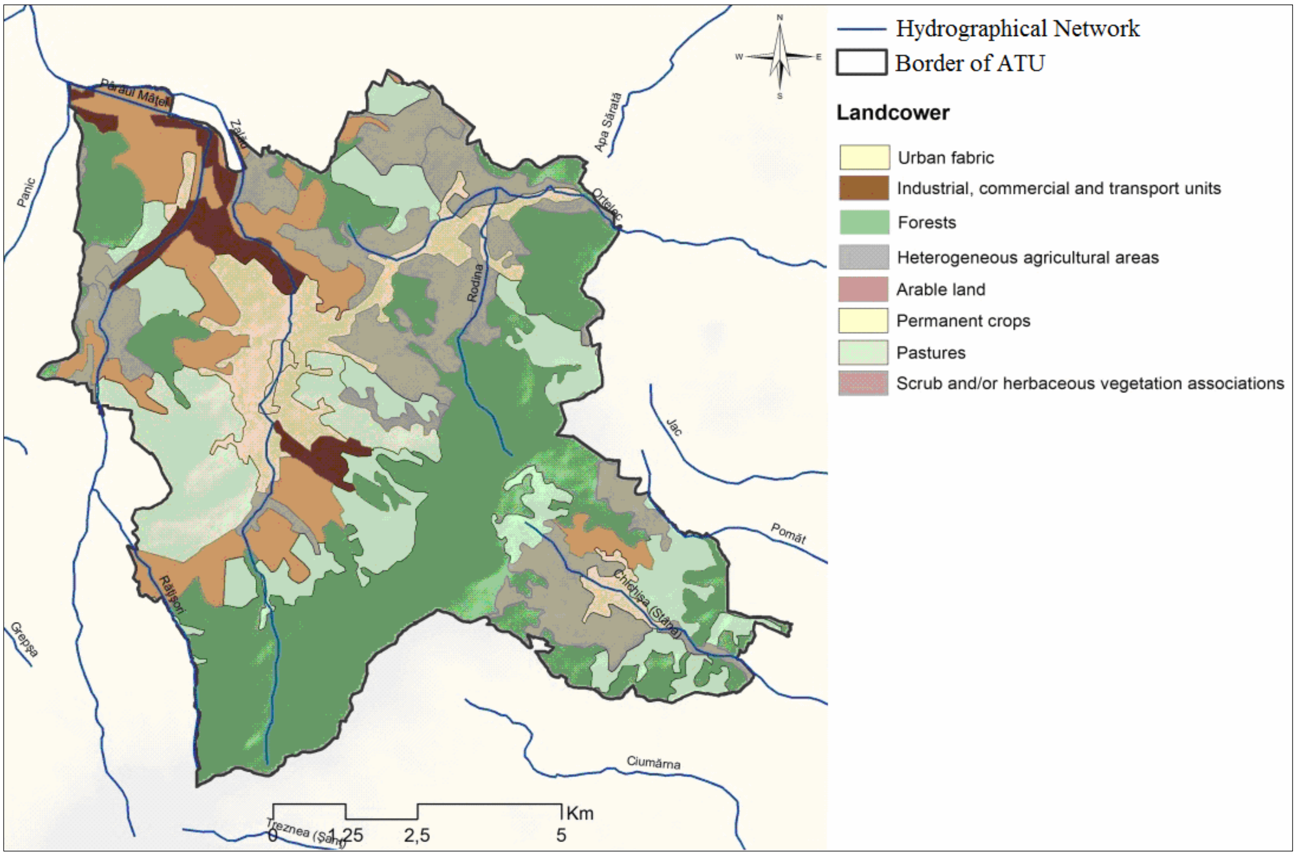


Fig. 6. Land use in Zalău city.

*The natural vegetation* from the study area falls within the west European zonality, including the nemoral level on hills and plateaus, with its oak sublevel, and the nemoral level of low mountains with beech sublevel. The herbaceous vegetation, the forest associations of the Meseş mountains as well as the meadows, pastures and hayfields from the piedmont hills represent favourable economic premises for the people who live here [9].

*Soil* has always been the most important natural resource of this area, used in one of the oldest human activities: agriculture. Agricultural production depends on soil fertility and its qualities are reflected in land use.

The wide range of landforms, the different temperature and humidity conditions favoured the formation of zonal, azonal and intrazonal soils. The soils with the largest expansion in this area are the Luvisoils and the Cambisoils. The Luvisoils are common to the Meseş piedmont area, on interfluves and on glacis slopes. The Albic Luvisoils occupy relatively flat areas and are favourable to the extension of the built-up territory. Eutricambosols are the most common soils in the study area and have a higher productivity, being covered with meadows and forests, or orchards and crops. The Districambisols can only be found on the Meseş peaks, being favourable for agricultural purposes. The intrazonal soils are represented by Cernisoils and Protosoils. The first are found in the northern part of the territory and are used for different crops, but also as meadows and pastures. The latter are spread on the slopes, used as arable land or pastures [12].

An important *historical and geographical element* of Zalău city is Porolissum Roman castrum. In the close vicinity of the city there is a former Dacian settlement which eventually became the Roman castrum Porolissum.

Fig. 7. Porolissum Roman castrum [13].

This was the strongest defensive fortification from the north-western part of Dacia Roman Province that became a municipality in the second century. The centre of Zalău settlement belonged at that time to the free Dacians, very close to the border. The trading connections were enabled by the presence of the imperial road between Porolissum and Napoca that passed through Zalău and represented the passage from Central Europe to the heart of Transylvania, the well-known "salt road".

Evidence of human existence within the territory of Zalău city was found to date even 6500 years ago. Important elements belonging to the Roman culture as well as Dacian coins were discovered in the central and western city area and on the Miţii Valley, proving that the area was continuously inhabited by Dacians and economic relationships were established with the town of Porolissum. After the conquest of Dacia by Trajan (106), the border of the Roman Empire was marked by the Meseş Mountains, the free Dacian tribes living in the north, while the Roman border fortifications with cannons, walls, ditches and defence earth walls were present in the east and south-east [14].

### 3.4. Natural restrictive elements

Along with the elements that have favoured the development of the city, there were present a set of restrictive elements. The relief, the climate, the hydrology and vegetation as well as the anthropogenic intervention in the study area led to the development of extensive erosion processes.

Among these *geomorphological processes* we underline: the *surface erosion* that is present on adjacent surfaces of the interfluvial areas, as well as on bare lands. *Vertical erosion*, especially *gullying,* is another common erosional process in Zalău. The Paramesesan Piedmont, because of its slope angle of 15 degrees, is liable to surface erosion as well as to vertical erosion, but also to other slope processes. Gully high risk areas can be found in Dumbrava Nord, Simion Bărnuţiu, Traian and in Brădet. These areas require mitigation measures against ravine and torrent extension. The hills which are exposed to narrowing through *regressive erosion* are: Malu, Cucu Mic, Cucu Mare, Panicului [15].

Using the method described by the Romanian Governmental Decision 447/2003, the average landslide hazard coefficient was calculated for the city of Zalău starting from the causing factors and their coefficients.

*The lithological coefficient* was based on the geological map 1:200,000, where the lowest value (<0.10) was given to massive rocky areas and the highest value (0.51-0.80, >0.80) was attributed to saturated, fat clays, silt and small to medium loose sands. *The geomorphological coefficient* was calculated starting from the Topographical map 1:25,000, which was used to generate the Digital Elevation Model and, eventually, the hypsometric and slope angle maps, which were necessary to determine the spatial distribution of the geomorphological coefficient. *The structural coefficient*, Kc=0.35 corresponded to medium-high probability. *The hydro-climatic coefficient* (Kd) was determined starting from the multi-annual average rainfall map included in the Romanian Climatic Atlas from 2010 [16]. According to meteorological data, the average rainfall amount reached approximately 600 mm/year, the value assigned to the hydro-climatic coefficient being 0.60, which corresponded to high landslide probability. *The hydrogeological coefficient*, Ke = 0.4, due to large areas where the groundwater level reached up to 5 metres in depth, corresponded to an average-high probability of landslide occurrence. *The seismic coefficient* (Kf) had the value 0.7 and described the areas with high landslide probability because the city was situated in an area with a seismic intensity of 6 degrees on the MSK scale. *The forest coefficient* (Kg) was calculated in accordance with the Corine Land Cover data base: the areas covered with broadleaf forests received the value 0.1, the orchards and vineyards - 0.5, the agricultural areas with complex cultivation - 0.5, the arable non-irrigated areas - 0.9 and the deforested areas along with the grasslands received high values - 0.95. *The anthropic coefficient* (Kh) received the value 0.1 in the areas without any infrastructure, all the other areas covered with buildings received the value 0.95, which was the equivalent of very high probability of landslide occurrence. According to the values of the average hazard coefficient (fig. 8) the study area could be classified into:

- *low landslide potential*, the values of the average hazard coefficient ranging between K(m) = 0.0003 – 0.10;
- *average landslide potential*, the values of the average hazard coefficient ranging between K(m) = 0,11 – 0,26 [17].

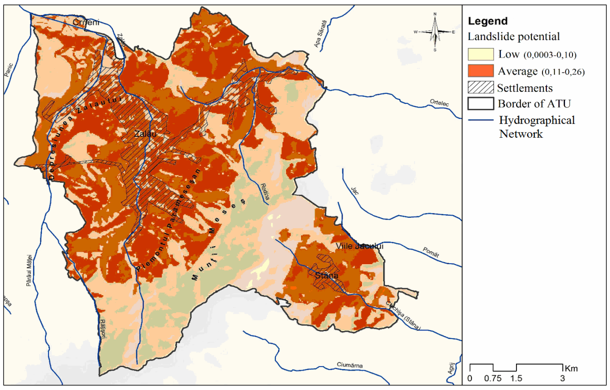


Fig. 8. Landslide potential map.

The average hazard coefficient (fig. 9) had values ranging between 0.003 and 0.026, with the highest values in the built-up area of Zalău, in the north-eastern, western and south-eastern part of the city.

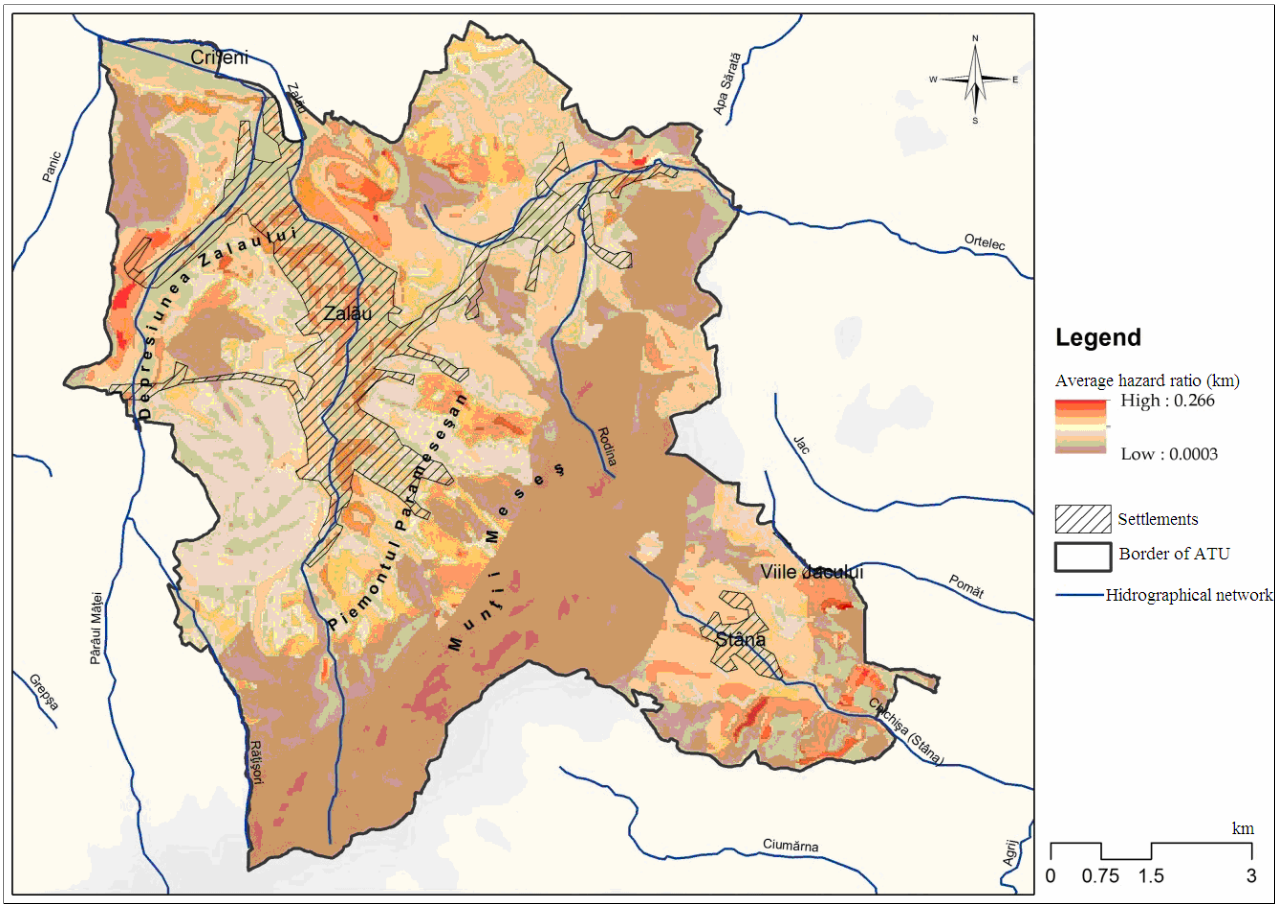


Fig. 9. Average risk coefficient map.

The lowest values characterised the Meseş Mountains and the north-western part of the city, due to the rocky lithology and the forested areas which determined higher slope stability.

Six landslide areas could be identified in Zalău municipality which determined risk situations in the built-up area: the left slope of the Meseş valley (Brădet neighbourhood, Stadion neighbourhood, Olarilor street), the area of the Gheorghe Lazăr street (the Central Park - cemetery – courthouse area), the Ortelec area (fig. 10), the water tanks and the clay quarry), the Poporului Park area, the Traian – Vişinilor area, the Dumbrava II area. In addition to these, a low and average landslide potential characterised other areas as well and there were several landslides on the steeper slopes of the Ciobanului, the Malu, the Crişenilor and the Herecleanului Hills.

Fig. 10. Landslides in the Ortelec area.

From a hydrographical point of view, the city of Zalău is drained by the Zalău River and its tributary, the Miţii Valley. The Zalău, a right tributary of the Crasna River, drains its waters and develops its upper course in the administrative territory of Zalău municipality, having its springs on the western slopes of the Meseş Mountains. Most of the water supply has a rainfall and snowfall regime, while an important role in water discharge is also played by groundwater during summer and autumn. Nevertheless, the water supply of the city is still a difficult issue. The water resources of the alluvial cones, glacis, piedmonts and terraces, as well as of the rivers that flow from the Meseş Mountains are not sufficient to satisfy the necessary water for the population. Currently, the Zalău municipality has a centralized system of drinking water using the Vârşolţ surface source, but the quality of the water is inadequate because of malfunctions affecting the water treatment plant and because of inadequate water transport and distribution networks [5].

The restrictiveness of the territory is determined by the existence of a series of *territorial constraints*. According to I. Mac and Maria Hosu (2010), these constraints are:

- the *tectonic and structural* constraints. These are determined by the Meseş horst, with a steep front towards the north-west, where altitude oscillations determine risk situations;

- the *lithological* constraints. These are caused by the sedimentary deposits which cover the crystalline foundation of the Zalău Depression. Geomorphologically, these deposits are susceptible to landslides, falls and erosion;

- the *morpho-hydrographical constraints*. These are the result of a connection between the relief of the hills and the piedmonts that surround the Zalău Depression and the streams that gather their waters from this area. Lower areas are affected by excessive humidity, with negative effects on settlements, while deforestation of the slopes leads to powerful flash floods, which determine significant erosion of the land surrounding Zalău city [2].

Due to the fact that urban development is limited on certain directions, Zalău is mainly characterised by longitudinal expansion, following the least difficult and expensive directions.

## 4. CONCLUSION

Zalău Municipality, situated in the Zalău Depression, in the Crasna Hills and in the Parameseşan Piedmont, has a sheltered local climate and presents favourable premises for practising a complex agriculture, which has contributed in time to population growth and to the development of the settlement even since ancient times. During its existence, Zalău has been a medieval village, a medieval fair, a town, reaching nowadays the position of a municipality.

The relief is a main element in defining the evolution of Zalău, hence the longitudinal expansion of the city. Landforms have a balanced spatial occurrence and the terraces, glacis and piedmont structure represent a favourable factor in the development of the city. Due to the predominant geodeclivity average ranging between 5° and 15°, the urban territory is included in the area of accessible socio-economical activities.

The spatial placement of the hydrographical network represents a restrictive factor, as the supply of drinking water is currently a main problem for Zalău. Other restrictive elements are represented by multiple geomorphological processes, especially landslides, which have low and average potential of occurrence within the city limits.

The constrained territory of Zalău city is the result of many cumulated elements: the topography, the lack of a well-developed hydrographical network, as well as of a groundwater system, and its clay deposits.

Taking into account the above-mentioned elements, Zalău municipality should carefully plan its future development projects.

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