MULTICRITERIAL ANALYSIS OF THE RELIEF SUITABILITY FOR SPATIAL PLANNING IN GURUSLĂU DEPRESSION

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ABSTRACT. – Multicriterial analysis of the relief suitability for spatial planning in Guruslău Depression. The present paper aims to assess the suitability for spatial planning of a depression area. For this purpose, a spatial analysis model was developed using GIS techniques, integrating databases representing the morphometric parameters of the relief (depth of fragmentation, density of fragmentation, surface exposure, slope) and additional criteria (land use, the geology and the soil erosion rate.) These were qualitatively evaluated on a scale from 1 to 5 (1-very favourable; 5-unfavourable) and were used to generate the map of relief suitability for spatial planning. The obtained results highlight the fact that the analysed area has high and very high favourability for spatial planning, both as a whole and at the level of the individual analysis of the territorial administrative units.

Keywords: morphometric parameters, GIS techniques, relief suitability, spatial planning

1. INTRODUCTION

Spatial planning is one of the main challenges of the contemporary society, being an efficient tool to control the harmonious development of territorial structures. One of the factors involved in spatial planning and development is the relief. It imprints a series of aspects at territorial level through morphometry and morphodynamics, through the spatial arrangement, but also through the geological peculiarities, that, in relation to the various anthropic activities, can generate valences of favourability or restrictivity (Irimuş, 2006).

The morphometric characteristics of the relief refer to the measurement and mathematical analysis of the configuration of the earth surface, the shape and dimensions of its landforms (Clarke, 1966; Irimuş, 1997; Rudraiah et al, 2008). The analyses based on morphometric parameters of relief have increased considerably in recent years (Rudraiah et al, 2008; Deepika et al, 2013; Joseph Markose et al, 2014), based on the development of GIS spatial analysis techniques (Schwanghart, Kuhn,

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2010; Pande et al, 2015; Marian et al, 2016; Jaiswara et al, 2021).The morphometric parameters represent a useful tool in the field of spatial planning (Roșca et al, 2016; Bilașco et al, 2016; Irimuș et al, 2017; Soni, 2017), being used in the development of space management studies (Mahajan et al, 2018; Langat et al, 2020). The raster analysis are useful to develop action plans on alternative land use planning, based on the natural potential of the territory (Kar et al, 2009; Abdeta et al, 2020). Besides, the risk management can be achieved through morphometric analysis (Gajbhiye et al, 2014; Sestraș et al, 2019).

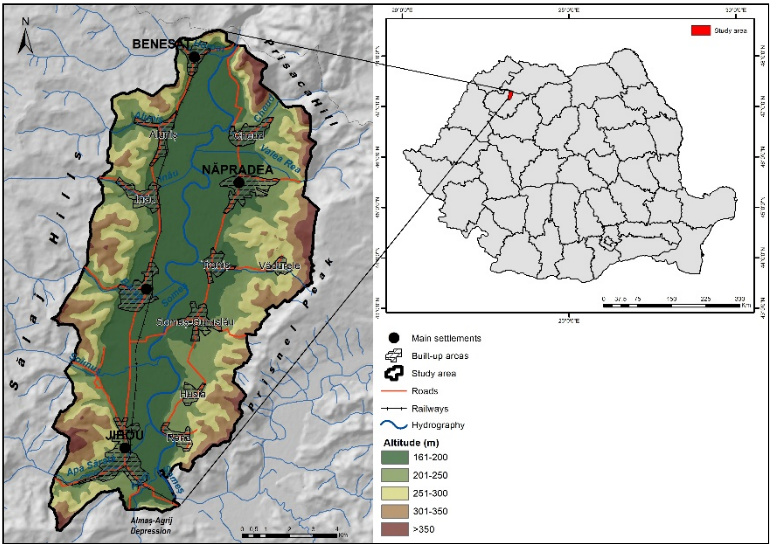

Fig. 1. Geographical position of the Guruslău Depression

The Guruslău Depression is located in Sălaj County, on the middle course of Someș River (fig. 1). The western limit (V) is represented by the Western Hills, through the Sălaj Hills subunit and the eastern (E) one is represented by Prisnel Peak. In the northern (N) part, the Guruslău depression corridor is bordered by the Dealul Mare-Prisaca massif and the Țicău Gorge (administrative boundary with Maramureș County), while in the southern (S) part the boundary is represented by Dumbrava Hill. It is delimited by the adjacent main peaks (Runcului Hill – 375,4 m, Bârsei Hill – 411,6 m, Chicera Hill – 437,7 m, Iacobula Peak – 473,1 m, Țicla Peak – 454,7 m, Rona Peak – 437,4 m), which allowed its individualization as a distinct unit within the Someș Corridor. It has a spatial extension of approximatively 14.000 ha and includes most of the communes Benesat, Năpradea and Someș-Odorhei, as well as one of the main urban centres in the county, the city of Jibou.

The study area is drained by the Someș River, the most important water source in the region and is transited by the road (DN 1H national road) and the railway, which connect the two counties and favour the flows of people, mass and energy. It has an agricultural specificity, because of the small (500 inhabitants) and medium sized (500-1500 inhabitants) rural settlements located in the area and because over 50% of its surface is agricultural land. The only urban centre, the city of Jibou, has industrial activities, mainly units of light and artisanal industry, which have experienced a revival in the last ten years through European programs.

2. METHODOLOGY

The techniques based on geoinformation software have developed in recent years and have facilitated the quantitative approach to the spatial configuration of the territory (Rudraiah et al, 2008; Joseph Markose et al, 2014). In this purpose, raster analysis is a useful tool to highlight specific geographical aspects (Wu et al, 2007), to develop optimal land management strategies (Joseph Markose et al, 2014; Diprizio et al, 2018) and to identify locations for a specific type of intervention in the territory (Halder, 2013; Dezsi et al, 2015; Zhang et al, 2021).

The existing studies (Kaur et al, 2014; Jaiswara et al, 2021) address the issue of relief morphometry analysis in areas of similar spatial extension to the Guruslău Depression, mainly river basins (Joseph Markose et al, 2014; Soni, 2017; Langat et al, 2020; Strapazan et al, 2021).

The accuracy of a morphometric analysis depends on the resolution of the digital elevation model (DEM) and spatial analysis techniques (Jaiswara et al, 2021). In this paper, the morphometric parameters were calculated using the EU-DEM database, with a spatial resolution of 25 m, which is suitable for the objectives of this research.

The morphometric parameters used to implement the spatial analysis model are depth of fragmentation, density of fragmentation, slope and exposure of the surfaces. Moreover, there were used additional analysis criteria – land use, geology and soil erosion rate, which have the ability to influence the balance of favouritism-restrictivity in relation to various anthropogenic activities and types of development. All these databases were integrated into the spatial analysis model, resulting the map of relief suitability for spatial planning.

The first step was to generate the maps needed for the implementation of the spatial analysis model. The maps of the four morphometric parameters of the relief used in the present study were generated by the extensions of the Spatial Analyst Tools menu from ArcGIS. Besides, at this stage the soil erosion rate map was generated, implementing the USLE model proposed by Moțoc et al (1975), adapted to the territory of Romania. In addition, there were generated the maps of land use, based on the information provided by the Corine Land Cover (CLC) databases, version 2018, as well as the geological map of the study area. These two maps were initially in vector format, so that they had to be converted to raster format in order to be integrated into the spatial analysis model.

The next stage involved the reclassification of the obtained rasters, in 5 value classes, with the purpose of finding the best possible integration of these classes in order to apply the formula for generating the suitability map of the territory. After this, the resulting maps were qualitatively evaluated on a scale 1 to 5 (1-very favourable; 5-unfavourable), to create a common grid of values. Each of the analysed factors was evaluated in order to establish the favourability classes, depending on the way in which they influence the spatial planning process (Teaci, 1960; Daneshvar, 2014; Bilaşco et al, 2016).

The final step was to generate the suitability map for spatial planning, by integrating the obtained databases in the spatial analysis model (fig. 2). The following formula was applied using the Raster Calculator extension in ArcGIS software:

(*”Depth of fragmentation”**1 + *”Density of fragmentation”**1,5 + *”Exposure of the surfaces”**2 + *”Slope”** 4,5 + *”Land use”**3 + *”Soil erosion rate”**4,25 + *”Geology”**0,25) / (1+1,5+2+4,5+3+4,25+0,25)

The weighted average formula was chosen as the calculation method, as it best illustrates the spatial distribution of the suitability of the territory and the differentiated contribution of the various factors in generating conditions and limitations in relation to the anthropogenic component. The weights allocated to the factors were based on the subjective assessment of their individual importance and the issues identified in the territory.

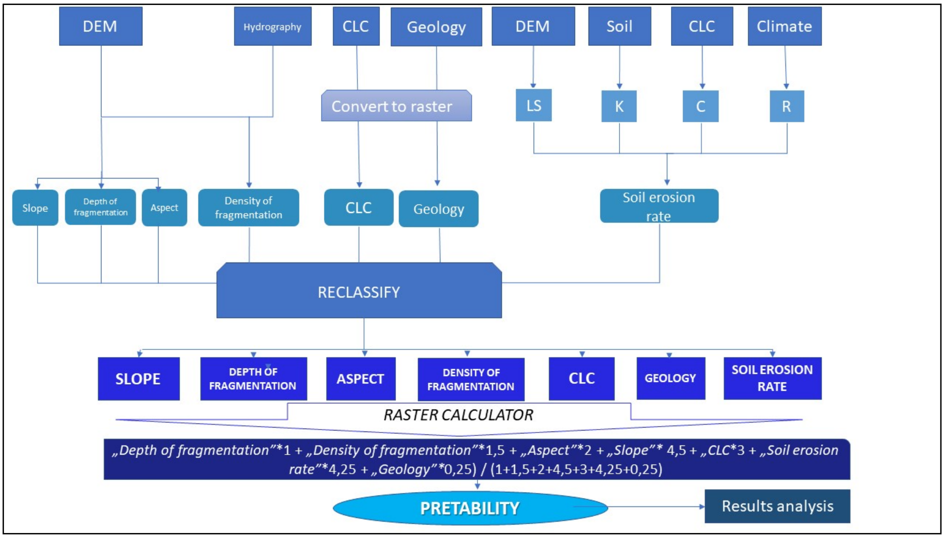

Fig. 2. Methodological flow chart

3. RESULTS

3.1. Analysis of the factors used in the implemented model

3.1.1. Depth of fragmentation

The depth of fragmentation of the relief expresses the difference in altitude between points or elevations from the interfluvial space and thalweg (Irimuș et al, 2005) related to the reference unit of 1 km^2. It validates the values of morphodynamics within the study area and indirectly suggests relief suitability for spatial planning.

Within the Guruslău Depression, the values of this parameter are between 14 m and 355 m, with the average of 131 m. The first three value classes, between 14 m and 180 m, occupy approximatively equal area in the territory, totalling over 75% of the total, while the highest values occupy only 3,6% (Table 1). The lowest values also highlight the most favourable areas for spatial planning. These are distributed in the meadow area and terraces of the Someș River (fig. 3.), while the higher values correspond to the marginal morphological units (glacis surfaces, slopes) belonging to the Sălaj Hills, with higher altitudes.

Table nr. 1. The distribution of the fragmentation depth classes for studied area

Depth of fragmentation (m)	**Area**	
	Km^2	%
14 - 70	36,1	24,8
70,1 - 127	38,9	26,7
127,1 - 180	39,1	26,8
180,1 - 259	26,2	18
259,1 - 355	5,3	3,6

3.1.2. Density of fragmentation

The density of fragmentation expresses the length of the hydrological network related to the surface of the studied area, being expressed in km/km^2 (Irimuș et al, 2005). The values of this indicator, between 0 and 2,86 km/km^2, with an average of 0,80 km/km^2(Table. 2), confirm both the dynamic relationship between the hydro-climatic environment and the lithological factor and the dynamics of anthropic (agricultural) interventions in the recent 70 years in this depression area. Most of the territory, almost 43%, has the minimum values of the fragmentation density, while only about 3% have values of over 2,4 km/km^2. The highest values are located in the proximity of the main watercourses in the area (Someș, Vădurele, Apa Sărată, Aluniș etc) (fig. 4) and in the confluence areas, a fact highlighted especially in the southern part of the study area.

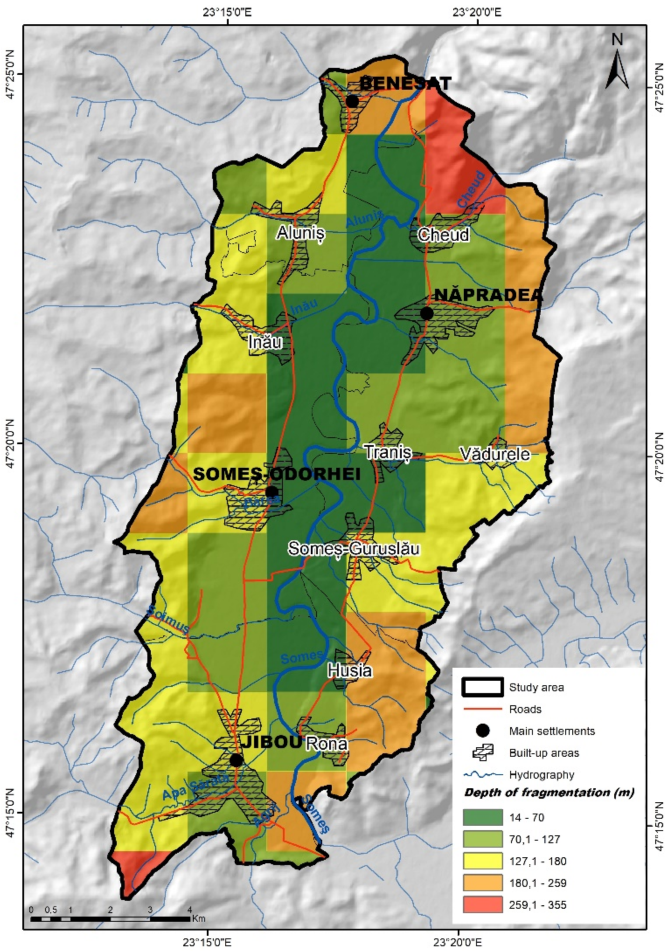

Fig. 3. Depth of fragmentation map

Table nr. 2. The distribution of the fragmentation density classes for studied area

Density of fragmentation (km/km²)	Area	
	Km²	%
0 - 0,57	60	42,6
0,58 - 1,1	33	23,4
1,2 - 1,7	28	19,9
1,8- 2,3	16	11,3
2,4 - 2,86	4	2,8

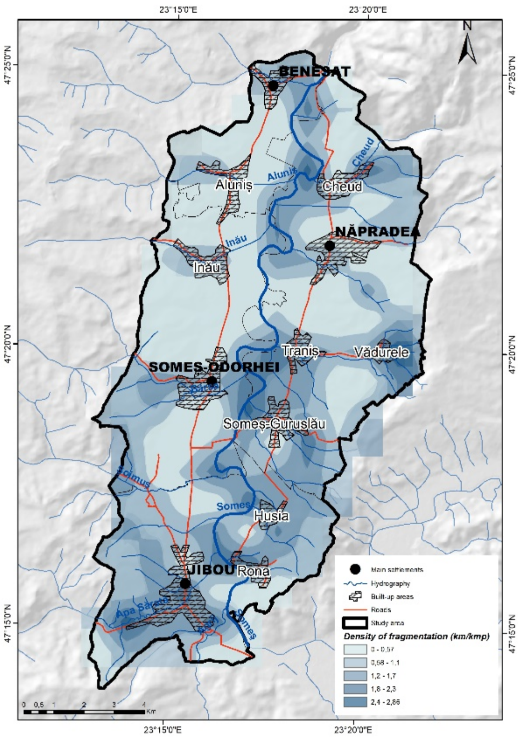

Fig. 4. Density of fragmentation map

3.1.3 Slope orientation

The slope orientation conditions both the dynamics of the natural processes (climate, hydrography, vegetation, fauna, soils) of the territory and the anthropic activities (agricultural, agro-pastoral, forestry). The analysis of this parameter within the Guruslău Depression highlights the predominance of the northern and north-eastern slopes (fig. 5), which has a negative impact on the productivity of agricultural land. About a third of the territory has this orientation (33%), while the southern and south-western slopes occupy the smallest area, having only 19% of the total (Table 3). Regarding the other two categories of slope orientation, they have equal weights, of about 24%.

Table nr. 3. The distribution of the slope orientation classes for studied area

Slope orientation	**Area**	
	Km^2	%
Shady (N, N-E)	48,0	33,3
Half-shady (N-V, E)	34,6	24,0
Half-sunny (S-E, V)	34,2	23,7
Sunny (S, S-V)	27,3	19,0

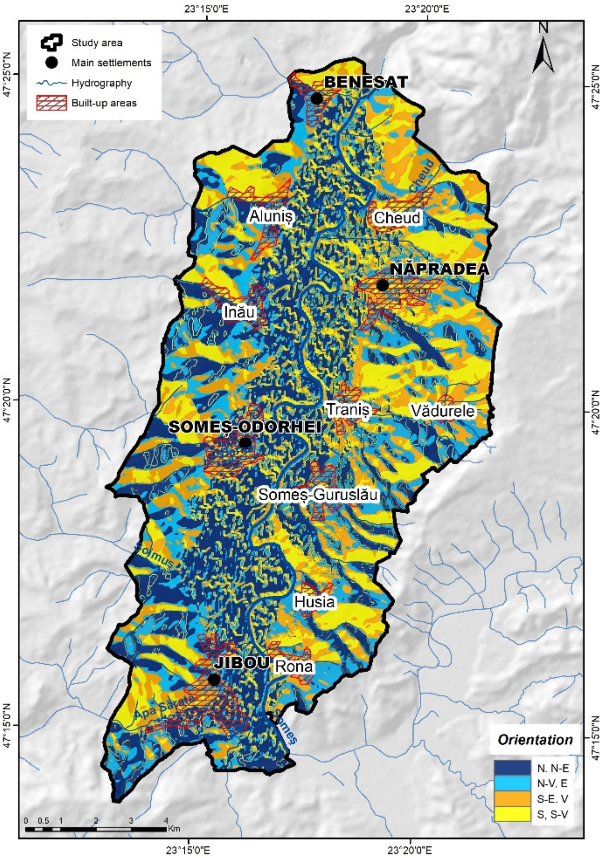

Fig. 5. Slope orientation map

3.1.4. Slope

Slope is a factor that conditions the intensity of geomorphological processes, their spatial extension, soil erosion and, implicitly, the association of geomorphological hazard and risk in the territory, thus having a high impact on the degradation of agricultural land (Moțoc, 1983). In relation to the spatial planning, the slope intervenes as a factor with limiting potential which, corroborated with other aspects of the substrate (petrography, orientation), imprints characteristics that influence the suitability in relation to various types of spatial planning. When the accumulation of the limiting factors tends to exceed certain values, there are highlighted certain areas which, in the plans and maps (e.g., zoning map, landslide risk map) for spatial planning, are established as areas with a ban on certain types of interventions (e.g., permanent or temporary construction interdiction/non aedificandi).

The analysis of the slope of the Gururslău Depression shows the increase of the values from the centre to the periphery (fig. 6), which correlates with the hypsometric values, that increase in the same way. Most of the territory has the values of the slope in the interval 0^0 - 2^0, occupying about 40% of the total, while the maximum values of this parameter, over 20^0, are distributed on less than 3% (Table 4). The latter are located at the slope units of the hills that border the depression (Runcului Hill, Bârsei Hill, Prisaca Hill etc.). This fact highlights a high suitability for spatial planning from the perspective of the analysed indicator, all the more so as the inhabited areas (rural and urban built-up areas), have low values of the slopes.

Table nr. 4. The distribution of the slope classes for studied area

Slope (^{0})	**Area**	
	Km^2	%
0 - 2	58	40,1
2,1-5	22,2	16
5,1-10	29,9	20,7
10,1-20	30,5	21
20,1-39,76	3,4	2,2

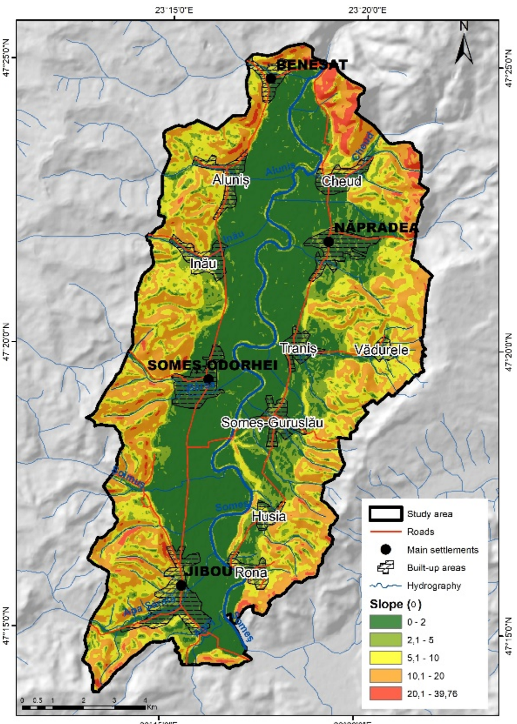

Fig. 6. Slope map

3.2. Analysis of the soil erosion rate

The soil erosion rate map was generated based on the implementation of the Universal Soil Loss Equation (USLE) model proposed by Moţoc M. et al (1975), valid for the territory of Romania, in the GIS environment, according to the following formula:

A= R * K * C * Ls,

where: A = annual soil loss
R = rainfall erosivity factor
K = soil erodibility index
Ls = slope and steepness factor
C = cover and management factor

The analysis of the spatial distribution of the surface soil erosion rate shows that the values of this indicator in the Guruslău Depression are between 0 and 33 t/ha/year (Costea et al, 2022). Over 96% of the study area has a very low soil erosion rate (Table 5), while the areas with high rate of soil erosion have very low percentages, below 0,5%. It is highlighted the fact that the soil erosion does not have a high impact on the suitability for spatial planning, as this process manifests itself on isolated areas. Such areas are located towards the periphery (fig. 7.), such as near the villages of Rona and Husia, in the southeast, or in the east of Năpradea commune.

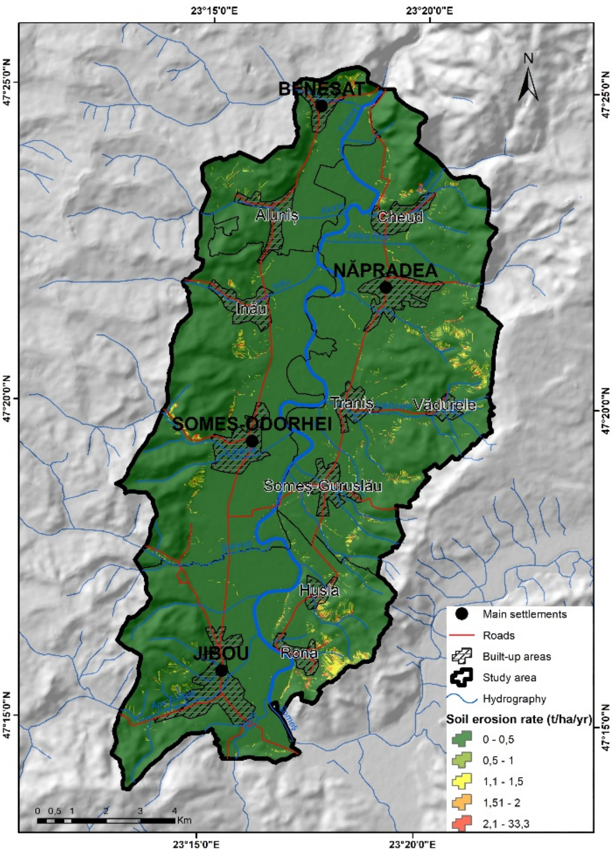

Fig. 7. Soil erosion rate map

Table nr. 5. The distribution of the soil erosion rate for studied area

Soil erosion rate (t/ha/year)	Area	
	Km^2	%
0 - 0,5	139,09	96,7
0,51 - 1	2,91	2,0
1,01 - 1,5	1,04	0,7
1,51 - 2	0,39	0,3
2,01 - 33,3	0,44	0,3

3.3. Analysis of the land use

According to the Corine Land Cover database, 13 categories of land use were identified in the study area (fig. 8). Of these, agricultural land, which includes non-irrigated arable land, pastures, complex cultivation patterns, transitional woodland-shrub, orchards and vineyards, covers approximatively 57% of the total, while non-agricultural land, including built-up areas, forests, inland marshes, occupies approximatively 43% (Table. 6). Non-irrigated arable land and broad-leaved forests have the largest extension, while the lowest shares belong to mixed forests and vineyards, the latter being located only in the commune of Someș-Odorhei.

Table nr. 6. The distribution of the land use categories for studied area

Land use categories	Area	
	Km^2	%
Mixed forests	0,25	0,17
Vineyards	0,25	0,17
Inland marshes	0,61	0,42
Transitional woodland-shrub	0,65	0,45
Industrial of commercial units	0,74	0,51
Orchards	0,98	0,67
Water courses	3,74	2,57
Complex cultivation patterns	6,79	4,67
Land occupied by agriculture, with areas of natural vegetation	7,99	5,5
Pastures	12,48	8,58
Urban and rural land	12,69	8,73
Broad-leaved forests	43,83	30,15
Non-irrigated arable land	54,36	37,4

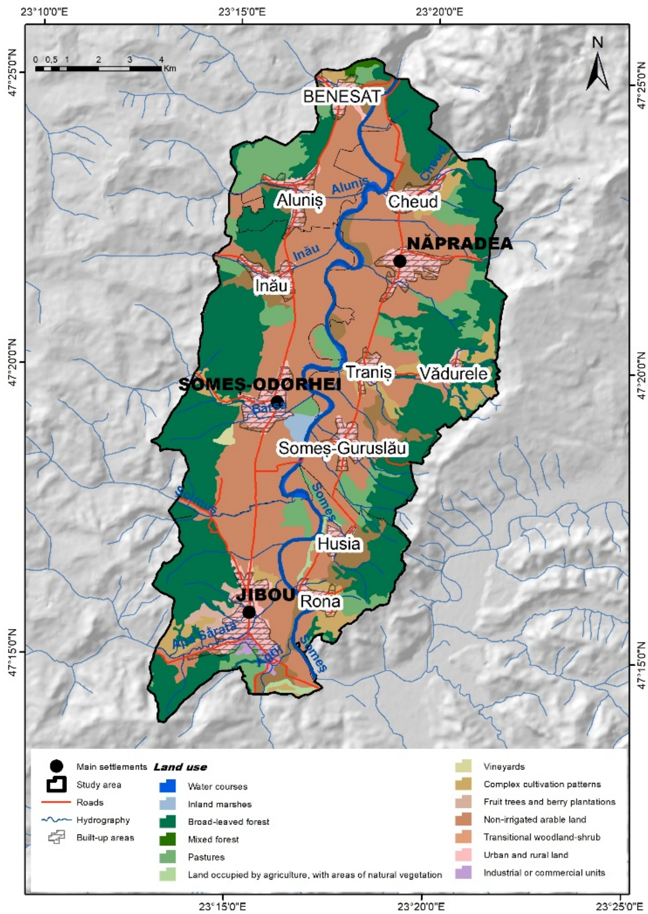

Fig. 8. Land use map

3.4. Analysis of the geology of the studied area

The distribution of the geological entities within the Guruslău Depression highlights the predominance of the category of red purple clays, belonging to the ”Jibou formation”, which occupies approximatively one third of the total (34,43%) area (Table 7). Besides, the categories of sedimentary rocks, including gravels and sands, are very widespread in the territory, as well as formations that include different categories of clays (fig. 9). The smallest spatial distribution belongs to the crystalline rocks, coming from the surrounding massifs (Dealul mare and Meseș), which occupy insignificant percentages, below 1%.

Table nr. 7. The distribution of the geological entities for studied area

Geological formations	Area	
	Km²	%
Crystalline limestones	0,06	0,04
Marls, coal shales, limestones	0,26	0,18
Colluvial deposits	0,45	0,31
River deposits	2,23	1,53
Marly clays, sands, gravel	2,49	1,72
Limestones, marls, gypsum, sandstones, clays	2,81	1,93
Marls, red clays	3,48	2,40
Mica schist, paragnaise	3,69	2,54
Marls, limestones, tuff, gypsum, salt	3,95	2,72
Delluvial deposits	7,67	5,28
Gravel, sands and clayey sands	27,81	19,14
Sands, gravels	40,38	27,79
Red purple clays	50,04	34,43

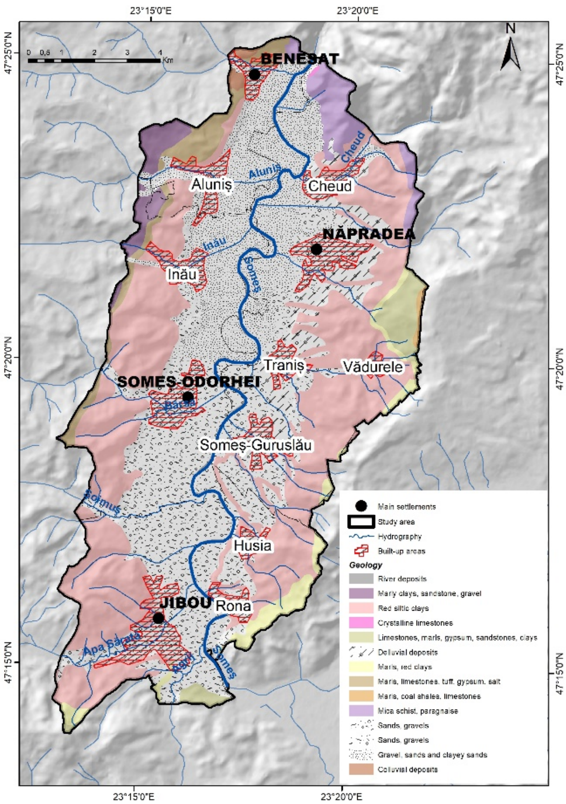

Fig. 9. Geological map

3.5. Analysis of the suitability for spatial planning

The evaluation of the Guruslău Depression from the perspective of the favourability for spatial planning was based on the performance of the suitability map, according to the spatial analysis model. There were obtained 5 favourability classes, where 1 – very favourable and 5 – unfavourable.

The spatial distribution of the classes obtained in the study area (fig. 10) shows the predominance of the high favourability class (30%), which, together with the very high favourability class, cover a total of over 40% of the depression.The average degree of favourability also has a significant percentage, over 25%, while the unfavourable areas occupy only 14%. In addition, the most restrictive suitability class has a weight of less than 20%. Is is located mainly at the periphery of the study area and is influenced by the morphometric parameters, so that the less favourable areas are those where the depth of fragmentation, density of fragmentation and slope have the highest values. However, it can be deduced that most of the studied area has favourable conditions for spatial planning from the perspective of the indicators considered.

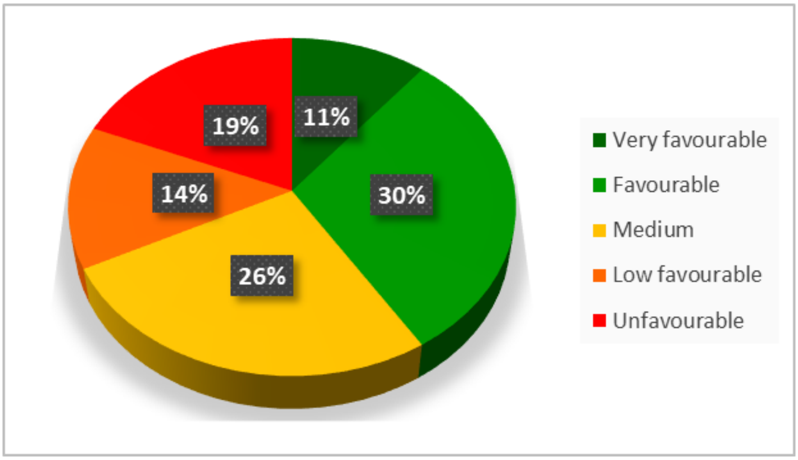

Fig. 10. Distribution of the favourability classes

The distribution of the favourability classes (Table 8) in the territorial-administrative units from the Guruslău Depression highlights the fact that in the Năpradea commune there is the largest area (7 km^2) which has a maximum suitability class. It is because of its spatial extension in the meadow area and terraces of the Someș River, where the depth of fragmentation and the slope have the lowest values.

Table nr. 8. The distribution of the favourability classes in the territorial-administrative units of the Guruslău Depression

Favourability class	**Area (km^2)**			
	Jibou	Benesat	Năpradea	Someș-Odorhei
Very favourable	4	1	7	3
Favourable	7	5	17	13
Medium	11	5	17	4
Low favourable	8	3	4	4
Unfavourable	6	0	10	10

The smallest distribution of this class is in the Benesat commune (1 km^2). The largest areas from the ”unfavourable” class are located in the communes of Năpradea and Someș-Odorhei, because of the hot-spots with high values of the soil erosion rate, occupying about 10 km^2 in each of them. This class is missing from the Benesat commune, while in the city of Jibou it has about 6 km^2. The ”favourable” and ”medium” classes occupy equal areas both in the communes of Năpradea and Benesat, of 17 km^2, respectively 5 km^2, having the largest spatial distribution at the level of these units. In Someș-Odorhei commune, the largest spatial extension has the ”medium” favourability class (13 km^2). This is also for the case of the city of Jibou, where the mentioned class covers 11 km^2, followed by the ”unfavourable” class (8 km^2). It is important the fact that in the case of Jibou, the highest favourability class has the lowest spatial extension (4 km^2), this being compensated by the large area of the ”favourable” class (7 km^2).

The analysis of the favourability classes in the built-up areas (fig. 11) highlights that most of them have the first three classes, which also applies for the proximal area, making possible the expanding of the built-up area. Besides, additional surfaces can be introduced in the agricultural circuit.

The ”unfavourable” class is missing from all of the built-up areas, except for the village of Cheud, where a small area with this class can be identified in its north-eastern extremity, at the contact with Prisaca Hill. Besides, the ”very favourable” and ”favourable” classes are missing from this village, the best value being that of the ”medium” class. This also applies for the villages of Vădurele and Rona. The explanation for this distribution lies in the case of Vădurele village from the fact that it is located towards the periphery of the depression, in areas with higher altitudes and slopes, related to Prisnel Peak, while in Rona there is a more accentuate dynamic of the substrate, that is also obvious in the distribution of the soil erosion rate (fig.7). However, most of the built-up areas have high degrees of suitability, in the ”favourable” and ”very favourable” classes, with smaller areas in the ”medium” class. This is obvious in the case of the villages of Benesat, Năpradea, Traniș, Someș-Guruslău and Husia, while in Somes-Odorhei, Inău and Aluniș there are also areas from the ”low favourable” class, but with a very small spatial extension.

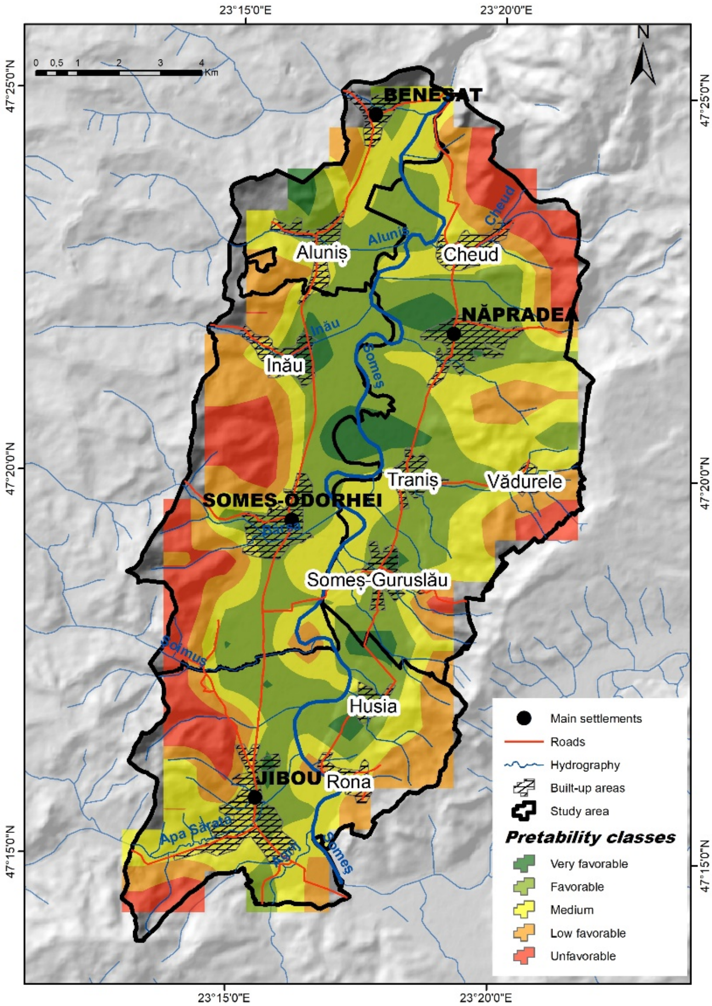

Fig. 11. Suitability map

In the case of Jibou city, the situation is more pronounced, with all classes present, except the ”unfavourable” one. The largest area is classified as ”medium” and ”favourable”, while the ”low favourable” class is located only in the north-western extremity of the built-up area. The most favourable areas are located in the northern part of the city, in the industrial zone, thus making it possible to expand it. Moreover, the favourable areas are also located in the proximity of the city, which makes possible the expanding of the built-up areas, but also of the agricultural one.

CONCLUSIONS

The analysis of the morphometric parameters of the relief, along with the soil erosion rate, land use and geology from the Guruslău Depression, and their integration in a spatial analysis model resulted in the identification of the differences in the suitability for spatial planning in relation to the anthropic interventions. The results obtained are of practical importance from the perspective of the possibility of integrating them into the spatial planning plans and development strategies. The distribution of the relief suitability in the Guruslău Depression highlights a spatial variation that, generally, shows a decrease from the centre to the outside, reflecting the way of synergistic combination of the characteristics considered in the analysis.

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