IDENTIFICATION OF SUITABLE GREEN AREAS FOR LEISURE AND RECREATION PLANNING, USING REMOTE SENSING TECHNIQUES AND GIS SPATIAL ANALYSIS.

CASE STUDY: ZALĂU CITY

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Abstract: - Identification of suitable green areas for leisure and recreation planning, using remote sensing techniques and GIS spatial analysis. Case study: Zalău city. The economical and social development that many cities have known in the recent decades has led to significant changes in terms of how the land is used. The analysis of how land use has changed in these areas highlights the emphasized and significant restriction of the territories occupied mainly by pastures, orchards, forest, areas suitable for development and improvement of leisure and recreation facilities. The need for space for recreation and leisure development resides in the need for a harmonious development of the human community and regional planning in accordance with the legislation. The study aims at identifying the areas which are suitable for setting local green spaces using remote sensing techniques and spatial analysis in the GIS environment for Zalău, a city which has known a very sudden expansion in the recent years.

Key-words: green areas, parks, remote sensing, NDVI, G.I.S. spatial analysis

1 Introduction

From the perspective of public administration, the green areas located inside the settlements are population-oriented facilities with the main purpose of providing the most favourable services for leisure and recreation. The concept of green areas destined for rest and recreation highlights several territorial facilities among which the most important are parks, green areas created in the vicinity of homes, public gardens, sport fields etc.

The development of residential areas has usually been made in the disadvantage of green areas by eliminating pastures, grasslands, orchards and sometimes forests from the agricultural use of the land. Irrational exploitation, without an appropriate sistematisation of the built-up areas leads inevitably to a major shortage in the areas destined for leisure and recreation.


This communication identifies the problems affecting the urban areas in Europe, focusing on four prioritary themes: urban environmental management (discusses the role of NGOs and of the civil society in the local planning and the new administrative systems), urban transport (deals with the problem of trasport management, the general tendency of traffic development), sustainable building (is concerned with the legal basis of the building regulations, the efficiency in the use of energy and resources etc.), urban design (highlights the problem of green areas, the relationships between the city centre and the suburbs, the present conditions of historical buildings).

In the member states of the European Union the issue of green areas is determined both through the specific legislation and the decisions and actions of the local authorities.

The objectives in the field of green areas are established through the Governmental Decision.
114/2007 which modified the GD 195/2005 concerning the environmental protection and the 24/2007 Law concerning the administration of green areas in urban areas: the green areas’ protection and preservation for the conservation of biodiversity, the expansion of green areas so that they provide 20 m²/inhabitant until 2010 and 26 m²/inhabitant until 2013 by including the areas with ecological or socio-cultural potential in the category of green areas, by identifying the territories with a scarce representation of green areas and the expansion of areas covered with vegetation, the regeneration, expansion and the improvement of the green areas’ composition and quality.

Green areas, as fields covered with vegetation, can be spatially identified inside or outside the built-up areas and some of these surfaces (e.g. forested areas), which have as their main purpose the provision of leisure and recreation are located both inside and outside the urban areas.

By analysing the urban evolution of Zalău a major discrepancy becomes obvious through the expansion of built-up areas on the surface of existing green areas (civil buildings and places of worship were built inside the main city parks- Heroes’ Park, Youth’s Park, Dumbrava Park- which has led to massive deforestation of trees and bushes and thus, partially and sometimes totally altering the surfaces of these parks as well as their landscape, without considering their ecological and economical values).

The Zalău Municipality currently owns a surface of 73,000 m² represented by parks (the Central Municipal Park has 4.6 hectares, the Heroes’ Park has 0.7 hectares, the Youth’s Park has 2.1 hectares and the Brădet Park has 0.4 hectares), street green areas with a surface of 13 hectares, neighbourhood green areas among blocks of flats, with an area of 59.3 hectares, hedges totalising a length of 73 kilometres, 49160 trees and bushes and a surface of 9.300 m² planted with flowers [Fig. 1].

![Map of existing green areas](Fig. 1. Map of existing green areas)
In the last few years the green areas have been increasing in the Zalău Municipality, thus the surface distribution of urban areas has changed according to the General Urban Plan, most of the times without a clear policy formulated by the local administration.

The identification of green areas which are suitable for recreation and sport is made by defining a complex model of spatial analysis which is structured in three main parts: a spatial analysis model for the identification of possible locations for the creation of new green areas and a GIS model of spatial analysis for identifying the territories which are suitable for the creation of recreational green areas, considering the morphometric restrictivity and the surface.

2. Identification of possible locations for green areas

The analysis of vegetation and the identification of changes in the areas occupied by vegetation are key elements in the evaluation and monitoring of natural resources, mainly applicable to monitoring studies and the identification of protected areas and areas suitable for leisure and recreation. Thus, the detection and the quantitative assessment of the green vegetation represents one of the main applications of remote sensing in the management of environmental resources and in the decision-making for natural areas’ rehabilitation.

2.1 Identification of green areas using the NDVI model

The Normalized Difference Vegetation Index (NDVI) was included in the scientific literature by Rouse in 1973, with the intention of mapping the plain vegetation from the USA using ERTS satellite images (the first generation of Landsat images).

The NDVI (Normalized Difference Vegetation Index) is one of the most well-known and used indices for the spatial analysis and the identification of vegetation areas. The NDVI, as a method of spatial analysis, offers a standardised method of comparing the “green” of vegetation using satellite images. The main bands used in the process of deriving the NDVI are represented by the near infrared band and the red band from the electromagnetic spectrum.

The result of deriving the NDVI using the two electromagnetic bands is represented by a raster database with values ranging between -1 and 1, which represent the approximate value of the areas with or without vegetation. The values closer to +1 indicate a high consistence of the vegetation, while the values closer to -1 indicate the areas without any vegetation, with baren soil or rock. The NDVI is useful in the mapping of vegetation areas, vegetation types, health status, land use etc.

2.1.1 Database

For the spatial analysis model which has as its main purpose the identification of the available green areas which can be developed for leisure and recreation, we used a specific database for attaining this goal [Tab. 1].

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Database (name)</th>
<th>Structure type</th>
<th>Attribute</th>
<th>Database type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Limit</td>
<td>vector</td>
<td>area</td>
<td>primary</td>
</tr>
<tr>
<td>2.</td>
<td>Satellite images</td>
<td>band 4</td>
<td>raster (tif)</td>
<td>primary</td>
</tr>
<tr>
<td></td>
<td>Landsat 8</td>
<td>band 5</td>
<td>raster (tif)</td>
<td>primary</td>
</tr>
<tr>
<td>3.</td>
<td>NDVI</td>
<td>grid</td>
<td>value between -1 and 1</td>
<td>derived</td>
</tr>
</tbody>
</table>

The limit of the study area is represented by the limit of the administrative territory of Zalău Municipality which was included in the spatial analysis model as a poligonal vector structure with the main purpose of better identifying the satellite images to be used. The Landsat 8 spectral bands were obtained without any cost by downloading them from the site earthexplorer.usgs.gov for the development of the NDVI model. By following the selection methodology [Fig.2] of these satellite images we identified and used the LANDSAT 8 satellite images taken in 20 July 2014 for deriving the NDVI.
Fig. 2. Framework of area selection

The selected spectral bands which were used for deriving the NDVI are represented by band 4 – RED (0.630 – 0.680 µm) and band 5 – NEAR INFRARED (0.845 – 0.885 µm) [Fig. 3 and Fig. 4] with a resolution of 30 m.

Fig. 3. Band 4 (RED)

Fig. 4. Band 5 (NEAR INFRARED)

The red band is used for differentiating between the different plant species and for determining the limits between the different soil categories, geological structures and engineering works. The near infrared band is useful in determining the vegetal biomass, in the identification of cultures, to highlight the contrast between soil-culture and land-water, to differentiate the aquatic from the dry surfaces.

2.1.2 NDVI derivation

The derivation of the NDVI was accomplished using the functions of spatial analysis available in the ArcGis 10.1 software, by using the specific formula of the index which is integrated in the spatial analysis formula implemented in the software through the Spatial Analyst extension and the Raster Calculator tool.

The formula for calculating the NDVI is represented by a ratio between the difference of
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band 5 (near infrared) and band 4 (red) and the sum of the two spectral bands.

\[
\text{NDVI} = \frac{\text{NIR} - \text{Red}}{\text{NIR} + \text{Red}}
\]

where: NDVI – Normalized Difference Vegetation Index  
NIR – near infrared spectral band (Near Infra Red – band 5 Landsat)  
R – red spectral band (visible, Red – band 4 Landsat)

By using the Raster Calculator tool which is integrated in the Spatial Analyst Tools, the NDVI equation was implemented as a spatial analysis equation:

\[
\text{Float}(\text{"4.tif"} - \text{"3.tif"}) / \text{Float}(\text{"4.tif"} + \text{"3.tif"})
\]

The result of this spatial analysis equation is represented by a raster database with values of the cells ranging between -0.43 and 0.49 [Fig.5].

For a better discrimination between the vegetation areas and the areas without any vegetation, the values of the NDVI were classified by attributing negative values to the areas without vegetation and gradual, above-zero values to the areas with vegetation, according to the degree of vegetation coverage (Păcurar et al. 2013).

The quantitative analysis of NDVI which was performed at the level of the entire study area using the values’ histogram [Fig.6] highlights a high density of the areas with values above 0 and between 0 and 0.1 (areas with rare vegetation), 0.3 and 0.48 (areas with very dense vegetation) and a relatively low to average density of the values 0.1 and 0.3 which are associated with areas which are covered with vegetation to an average extent.

After analysing the results of the derived NDVI one can notice the high availability of the areas which are suitable for the development of green areas with a leisure and recreation purpose.
At the same time the existing green areas are shown to be scarcely available inside the built-up areas and the development of the built-up areas lacks a clear policy concerning the management of green areas according to the development of built-up areas (the green areas which were identified on these surfaces are almost inexistent).

3. GIS spatial analysis model for identification of surfaces displaying pretability to the development of green leisure areas

The GIS spatial analysis model represents the second part of the complex spatial analysis model and is realised through an identification and an integrated analysis of the morphometric constraints (considering the topography of the whole territorial administrative unit of the Zalău Municipality) as well as through the surface constraints integration (considering the minimum legislative regulations).

3.1 Morphometric constraints in the green areas’ identification process

In the territorial planning process, the morphometric criteria seen as constraints from a territorial planning perspective are taken into account when the goal is set for the possible future leisure activity area identification.

For the model establishment the slope and density fragmentation have been taken into account as criteria composing the main restrictions in the identification model and leisure activities proposal, by integrating at the same time the results of the NDVI-model, as an input database for the existent available green spaces.

3.2 The database

The model is developed on the basis of primary modelled data as well as on derived ones, resulted from the NDVI model derivation process and from the use of the digital elevation model. The main database’s structure that is introduced in the equation model consists of: contour lines, hydrography, the territorial administrative unit’s limits, the digital elevation model, slope, density fragmentation [Table. 2].

<table>
<thead>
<tr>
<th>No.</th>
<th>Database (name)</th>
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<th>Attributes</th>
<th>Database type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Contour lines</td>
<td>Vector</td>
<td>height</td>
<td>primary</td>
</tr>
<tr>
<td>2.</td>
<td>Hydrography</td>
<td>Vector</td>
<td>-</td>
<td>primary</td>
</tr>
<tr>
<td>3.</td>
<td>Territorial administrative unit’s limits</td>
<td>Vector</td>
<td>-</td>
<td>primary</td>
</tr>
<tr>
<td>4.</td>
<td>Digital elevation model</td>
<td>Grid</td>
<td>height</td>
<td>modelled</td>
</tr>
<tr>
<td>5.</td>
<td>Slope</td>
<td>Grid</td>
<td>degrees</td>
<td>derived</td>
</tr>
<tr>
<td>6.</td>
<td>Density fragmentation</td>
<td>Grid</td>
<td>meters</td>
<td>modelled</td>
</tr>
<tr>
<td>7.</td>
<td>NDVI</td>
<td>Grid</td>
<td>Parameter value</td>
<td>modelled</td>
</tr>
</tbody>
</table>

The contour lines have been obtained through the vectorising of the 1:25000 scale maps having a practical use in the building of the digital elevation model and being considered as primary databases for the model’s construction.

The interpolation process, namely the Topo to Raster function, will lead to the digital elevation model construction by taking into account the hydrography so as to generate a correct DEM from a topographical point of view.

The slope is an absolutely necessary parameter used in the identification process of green spaces, due to the fact that it can be a triggering factor for certain hillslope processes (as a qualitative element) and a relief generating factor as well, on account of the
hillslope processes (seen from a quantitative perspective). Taking into account the two types of spatial analysis of the quantitative and qualitative declivity, Irimuş et al. (2005) propose a slope classification on six intervals that will be used in the present study and integrated in the spatial analysis model as a restricting factor.

The slope analysis at the Zalău territorial administrative unit level shows a great extension of the surfaces with slopes between 5° and 15°, summing up to a surface of 56.44 km², representing 62% out of the total territorial administrative unit, followed by the 2° and 5° slope category covering 18.52 km², namely 21% of the total surface, whereas the 0°-2° and 2.1°-5° slope categories with a percentage of 17% out of the total built-up area, namely 25.4 km².

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The density fragmentation or relief energy represents the difference between the point of highest altitude and the lowest point on the surface unit, having a direct influence on the development of leisure activities areas due to the high or low altitudinal areas. A surface displaying a high vertical fragmentation will induce a restriction for the developing of territorial landscape planning at a local level and for the development of technical infrastructure specific to a certain planning, namely in the present case, for the local community’s leisure activity areas.

In general, the methodology for the database construction related to the fragmentation density makes use of a 1 km² surface as a reference unit, but taking into account the demands imposed by the present study (where there are relatively small surfaces under 1 hectare), using the hectare as a reference surface for the map creation and implicitly for the database related to the relief energy is considered as more appropriate.

The analysis of the fragmentation density reveals a very big expansion of surfaces with a high fragmentation density, up to 20 m on the reference surface, and a small expansion of the surfaces with a great fragmentation density, above 20 m on the reference unit, generally identified at the contact of Meseșului Mountains with the Meseșului Hills, surfaces covered by a very good and dense vegetation, especially with deciduous and coniferous forests.

The territorial surfaces suitable for planning green spaces on which very low values of the fragmentation density have been identified are relatively little, occupying just 4.02 km², namely 4% of the Zalău administrative unit’s total surface.

Each element of the database is included in the spatial analysis model as a parameter according to its specific nature, insisting on the identification of surfaces that can be used for the development of leisure activity areas.

### 3.3 Spatial analysis

Using the information extracted in the phase of building the specific databases that are also very necessary for the model completion, the authors have identified the quantitative values defining the surfaces with pretability for each parameter [Table 3], values used in the spatial analysis process (Bilașco et al., 2013).

#### Table 3. The parameters used in the modelling process

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameter</th>
<th>Pretability Values</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>NDVI</td>
<td>≥ 0.1 and ≤ 0.3</td>
<td>The values of the NDVI index between 0.1 and 0.3 identified on the analysed surface are specific to the grass territories and to the low density vegetation terrains, characteristic to the maximum pretability territories for the present purpose; the parameters up to 0.1 have been excluded as they define territorial surfaces with poor vegetation (where supplementary works regarding their development would be needed) and the territorial surfaces identified by NDVI values higher than 0.3 represent surfaces that define territories with very dense vegetation, namely forest areas in this case (inducing a restriction due to the forest-like manner of planning when it comes to this type of surfaces).</td>
</tr>
<tr>
<td>No.</td>
<td>Parameter</td>
<td>Pretability Values</td>
<td>Observations</td>
</tr>
<tr>
<td>-----</td>
<td>-------------------------</td>
<td>--------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>2.</td>
<td>Slope</td>
<td>≥ 0 and ≤ 15</td>
<td>Slope intervals with surfaces slightly sloped up to moderately sloped have been taken into account and considered as very good and good pretability surfaces for their planning as leisure activities due to the existing possibility for undertaking planning works specific to this type of locations.</td>
</tr>
<tr>
<td>3.</td>
<td>Fragmentation depth</td>
<td>≤ 5 m</td>
<td>The high differences in level on the surface unit lead to a high restriction due to the impossibility of actually making the necessary development works. Because the identification of leisure activities’ possible locations is desired, the authors consider that the territorial reference units where there is a &lt;5m level difference have a pretability in the indentification of the final objectives of the model.</td>
</tr>
</tbody>
</table>

The Overlay technique facilitates the spatial analysis on the basis of several territorial components so as to highlight a certain specific location for the study area. In order to underline the surfaces with a pretability to leisure activity planning, the raster-raster Overlay technique has been employed through the raster layers combination of grid type, represented by the modelled databases and the derived ones that were previously presented (Bilaşco et al., 2013).

The model’s completion needed a spatial analysis equation to be developed, comprising the structures in the raster basis and functions of the ArcGIS program, implemented in the Raster Calculator module under the following form:

\[
("NDVI" \geq 0.1) \& ("NDVI" \leq 0.3) \& ("Slope" \leq 15) \& ("FragmentationDepthOfRelief (m)" \leq 5)
\]

The result, following the integration of the spatial analysis equation in the Raster Calculator module in ArcGIS, consists of a grid type raster database that has as “attributes” (values) the values of “0” and “1”, “0” standing for areas with no pretability for the planning and development of green areas for leisure purposes and “1” representing the surfaces with a 100% pretability, identified on the basis of the parameters taken into account, for the development of the afore mentioned spaces [Fig. 7].

The analysis of the resulted database shows a very high extension of the restricting areas situated especially on the slopes of the Meseş Mountains and their contact with the Meseşului Hillslopes, as well as in the Almaş-Agrij Depression. Surfaces that show pretability can be identified especially in the low area of the Zalău Depression and at its contact with the Meseşului Hills in the wide valley areas draining the two morphological units.

From the point of view of a quantitative analysis of surfaces occupied by restrictive areas and by pretable ones, the authors observe a great expansion of the restrictive surfaces on the Meseş Mountains and Almaş-Agrij Depression relief units with 19.2 %, representing 7.76% of the total Zalău territorial administrative unit surface, as opposed to the surfaces displaying pretability representing 0.05 %, namely 0.16 % out of the total surface. This aspect can be explained through the restrictive configuration of the topography in the two morphological units.

The widest of areas with pretability for development of leisure spaces covers the Zalău Depression and the Meseş Hills morphometric units with percentages of 1.73 %, namely 1.5 % out of the total Zalău territorial administrative unit area, surfaces that can be compared with the restrictive ones displaying a very great span at the level of the Zalău territorial administrative unit, namely 27.89 % and 35.22 %. The big areal differences between the restrictive surfaces and the ones displaying pretability can be first of all explained through the very great territorial extension of the Zalău Depression and of the Meseşului Hillslopes on the administrative territory of the Zalău Municipality.
The surfaces with pretability have displayed the widest area (1.73 km²) in the Zalăului Depression, followed by other areas in the Meseșului Hillslopes (1.05 km²).

In the built-up Zalău Municipality area the same great differences can be observed between restrictive areas and the ones with pretability, the ones with maximum pretability occupying 0.62 km² (6 % out of the total built-up area), whereas the restricting surfaces occupy the wide area of 10.19 km² (94 % out of the total built-up area).

3.4 Identification of the areas with pretability according to surface dimensions

Once the spatial analysis model was run on the raster-type data, areas with pretability that are compact have been identified, having surfaces between 0.05 ha and 26.45 ha.

For the identification of areas with pretability, when it comes to leisure activities, we have chosen only those surfaces wider than 1 ha during the selection from the polygon-type vector database resulted from the conversion of a raster representing the identified areas from which the polygons under 1 ha have been eliminated.

On the basis of this methodology the authors gathered a number of 60 polygonal surfaces identified in the interior and exterior of the built-up area of Zalău municipality, surfaces that can be proposed for planning [Fig. 8].

4. Conclusions and recommendations

GIS model application for spatial analysis in the projecting and planning of green areas is very useful and eases the amount of work that the territorial planners have to do.

As a result of the final analysis of the model run on the basis of the existing raster data for the restrictive areas and for the ones showing pretability to planning leisure green areas, as well as on the basis of the vector-format database representing polygonal areas with surfaces wider than 1 ha, as well as their validation on the field, the authors propose the following [Fig. 9]:
Fig. 8. **Surfaces displaying pretability for further planning**

Fig. 9. **Planning proposals**
1. Modernisation of the Municipal Central Park by trees and shrubs planting and the green areas development that would serve several purposes (leisure activities, sport, picnic, relaxation);

2. Development for leisure and recreation purposes of the green area identified in the Dumbrava Nord neighbourhood, close to the Emergency Hospital of Zalău, with a total surface of 11.42 hectares;

3. Proposal for the creation of a separate built-up area and its insertion in the functional areas of the Zalău Municipality as a green area for leisure activities and sports. The needed surface for insertion within the built-up areas has been identified as a surface displaying pretability during the spatial analysis model and it is situated on the Mâţei River in the place called Brădet Forest-Park.

The spatial analysis model used in the present study allows an identification on the basis of the obtained results, and it allows a series of proposals to be made for the development and planning of green areas and leisure activities.

The model can be improved by the introduction in the spatial analysis equation of other factors that can induce restrictions regarding green spaces development, as well as by using primary databases or modelled ones superior in quality, such as higher resolution satellite images.

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**Bibliografie**

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