

DEFINING CRITICAL AREAS THROUGH DISPERSION AND DENSITY OF VEGETATION INDEX IN RELATION TO POPULATION. STUDY CASE: IAȘI CITY

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Abstract. In this study the spatial distribution of green areas and the correlation of these with population density in the built up area of Iasi city have been investigated and evaluated. In order to do so, interconnections between density of green spaces (including NDVI) and distribution of population at two scales: district scale and 250 sqm scale have been determined with the final purpose of defining critical areas. Comparison of green spaces per capita at district and grid scale reveal that the regions which have the least green space area per capita and vegetation cover density can be defined as critical areas, occupying 16.3% of the total grids and 73% of total population. The results of this study could be introduced as action areas for improving the quality of green spaces in Iași.

Introduction

Green spaces in urban areas are very important due to numerous functions: ecological, aesthetical, social, economic. The green space is a basic infrastructure of the city that brings tremendous contributions to the city aesthetically and ecologically, as well as to community pride, public health and quality of life (Low, Gleeson, Green, & Radovic, 2007). The ecological function represents the most important function of the urban green areas due to benefits to other environmental components: improving air quality through the absorption of sulfur oxides, carbon monoxide and nitrogen oxides (Miller, 1997), erosion control and run-off prevention (Solecki, Patrick, Grady, Cox, & Ervin, 2008), water purification (Streich, Rodie, & Gaussion, 2003) or microclimate moderation by reducing the effect of urban heat islands.

Green spaces from the urban areas can be defined as: “all publicly owned and publicly accessible open space with a high degree of cover by vegetation, e.g. parks, woodlands, nature areas and other green space. It can have a designed or planned character as well as a more natural character. Only areas that can be

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entered and used from ‘within’ are included” (Schipperijn, Stigsdotter, Randrup, & Troelsen, 2010).

The aim of this study is to identify the spatial distribution of green areas, followed by the correlation of the density of population with green areas in built up area of Iasi city. Based on this hypothesis, the research focuses on determining interconnections between the density of green spaces and the distribution of population at two scales: district scale and 250 sqm scale, with the final purpose: establishing some spatial pattern and defining critical areas. Based on the results of the analyses, the districts and grids have been classified according to different limits provided by legislations (green area per capita).

2. Materials and methods

In order to highlight the critical areas through the process of correlation between spatial distribution of green areas and population within Iași city several data sources had to be matched to create a valid database, being adjusted according to our field observations and NDVI (Normalized Difference Vegetation Index) for a better understanding of the distribution of critical areas.

2.1 Study area

The studied area is represented by the build-up area of Iasi city, located in the north-eastern part of Romania (27035'E - 47009'N), with a surface of 6670 ha, being the fourth largest city of the country, with a population of 263410 inhabitants (Central commission for population census, 2011). The surface of green space per capita is 21.29 sqm/ per capita (Agency of Environmental Protection , 2011), lower than the limit establish by law – 26 per capita. Thus the study of critical areas defined by the lack of the green spaces in some districts of the city represents an actual and relevant study, and the obtained results (charts and maps) could be useful in green area management and urban planning.

For a better identification of the critical areas, the built-up area was analyzed at three different scales:

- a. the urban scale of Iași, for a general image of the distribution of population and urban green vegetation (density of population and NDVI);
- b. the district scale (39 districts) of Iași city, for a better comparison among neighborhoods;
- c. the built-up area divided into 250 sqm grid for the micro scale evidence of the critical areas.

2.2 Data collection

Geospatial analysis methods were used to identify the distribution of population and urban green areas, needing the following spatial data:

- a. City population for each address;
- b. The delineation of green urban areas which were extracted from orthorectified aerial images (2005);
- c. The existing buildings from the city which were used for correcting the delineation of urban green areas.
- d. The delineation of districts from Iași (Stoleriu Oana, 2008);
- e. Calculating the NDVI according to LANDSAT images

$$\text{NDVI} = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}}$$
- f. Dividing the surface area into 250 sqm grid.

2.3 Data analysis

The data were analyzed so as to distinguish different correlation between population and urban vegetation across Iași city.

The density of population and urban green areas were calculated using IDW method. IDW interpolates a surface from points using an inverse distance weighted technique (ESRI Support Center, 2010).

NDVI index has been calculated as a measure of vegetation distribution and density. Vegetation has a high reflectance in the NIR bands of a sensor system because of the internal reflectance by the mesophyll spongy tissue of a green leaf (Campbell, 2002).

The density of urban green areas has been calculated by splitting the urban green polygons in smaller ones and transforming them to points and then applying the IDW technique. The surface of green spaces have been transferred to grid polygons (250 sqm) and classified from lowest proportion to highest. Correlation between urban green areas and population has been realized at grid scale to emphasis critical areas. According to the index, regions with low green areas values (<20 sqm/per capita) and with high density would get the lowest values, being considered critical regions.

The entire database was processed using several specialized software (ArcGIS 9.3, ENVI 4, TNT Mips6.9, AutoCad Map 3D 2010), resulting a complex spatial database which was analyzed by comparing different situation across the urban territory.

3. Results and discussions

Urban green spaces are made up of parks, gardens and recreation venues, informal green spaces such as river or sea fronts, green spaces surrounding historical sites, railway corridors and indigenous vegetation types (Gupta, Kumar, Pathan, & Sharma, 2012).

3.1 Green areas typology

Iasi urban green areas can be classified according to different criteria considering the administration, their function, the access, the planning etc., but the more important is that the current study is focusing on the degree of covering by vegetation. Thus they were classified into three main types:

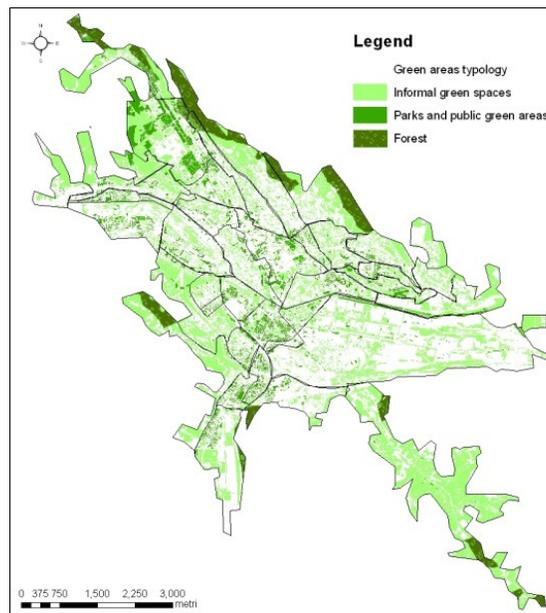


Fig. 1 Green area typology

- a. parks and public gardens (that represent 14% of the total, with the largest surfaces located in the northern part of the city);
- b. Forests, with 11% (located in periphery, being part of the largest protected forests perimeter that were planted for stabilizations of the hills affected by landslides) (Nicoară & Bomher, 2010);
- c. the main part – informal green spaces (75%) could not be included in others categories, being wide spread all over the city. The official report concerning the green spaces classified according to the law 47/2012 modifying and completing the law no. 24/2007 that provide the direction for green spaces inside built-up area of the cities, include a surface of 659.9 ha, that situate the ratio per capita (21.29 sqm) over the lower limit provided by the law: 20 sqm/per capita.

3.2 Distribution of population

The city of Iași has had a territorial evolution influenced by numerous factors (historical, economical, geographical and political). The current shape of Iași has been defined by commercial routes but also by geographical conditions. Nowadays, Iași, the fourth largest city in Romania (Central commission for population census, 2011), is a complex organism, but with big differences in population distribution and all the consequences arising. The largest density of population is located in several districts, most of them in the west and south-west parts of the city (Alexandru cel Bun-Dacia, Păcurari-Canta, Nicolina, CUG, Podu Roș), concentrating more than half of the total population. The main factor of this high concentration of population is due to fast growth urbanization in the late '70. The industrialization politics had a major role in the structure of the urban territory through the construction of a large industrial platform (in the south – eastern part of Iasi) and of the workers' districts endowed with all the socio-economic utilities necessary for the rural population attracted by the Iasi factories. (Stoleriu & Stoleriu, 2004).

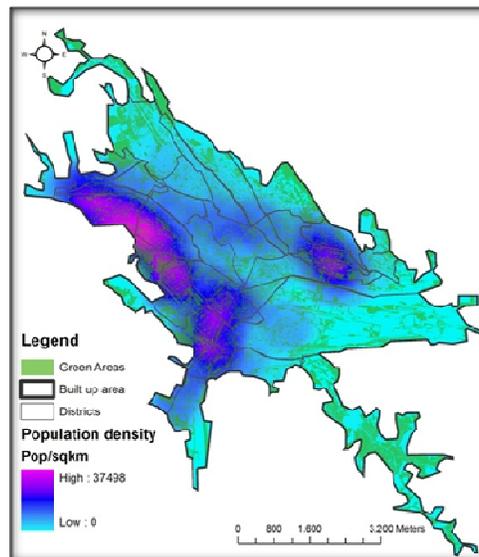


Figure 1 Density of population and distribution of urban green areas.

The city has been divided into 39 districts (Stoleriu Oana, 2008), but only the first 10 populated districts accumulate 56% of the total population. The

distribution of population reveals high densities in the SW of the city, where the working class districts were built. The largest density of population is located in 3 big areas (Dacia-Alexandru, Cantemir-Podu Ros, Tătărași), where the average density varies from 10,000 persons/sqkm to 38,000 persons/sqkm) while the average is 3200 people/sqkm. Lower densities can be found in the NE districts, where the individual residential houses dominate.

3.3 Distribution of urban green areas

Having these high concentrated districts, the question arises whether there is enough urban green space for these. The 10 most populated districts (56% of total population) include only 20% of total urban green areas. The lowest percentage of urban green areas for the top 10 populated districts are located in Mircea cel Bătrân, Nicolina and CUG neighborhoods, where the intensively built-up areas didn't allowed developing further green spaces. The only district with a high percentage of urban green area is Galata Case, with a higher percentage of urban green area than population.

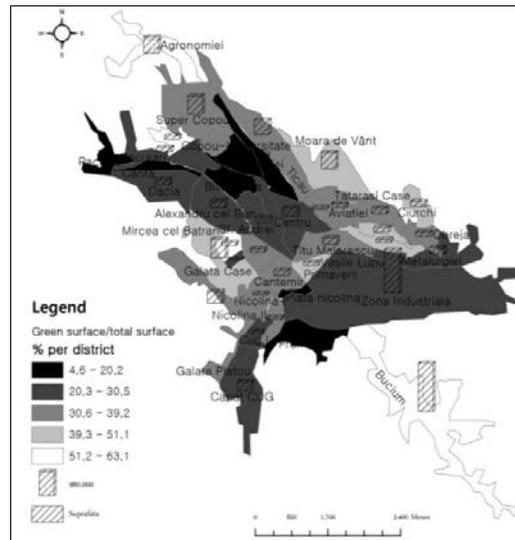
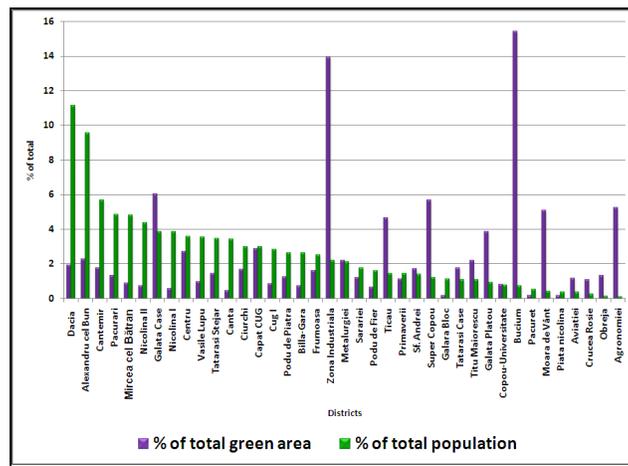


Figure 2 Distribution of urban green area per district

Districts which have the highest amount of urban green areas are the ones considered peripheral and where the built-up area is rather occupied by private houses (Bucium, Agronomiei, Ticau, Galata Patou) or the ones where the largest

parks and public gardens are located (Super Copou), and of course the Industrial Area which legally had to have at least 20% green area from the total surface of the industrial construction (Hotărârea nr. 525, 1996).

Table 1 Population and green areas per district



The percent of urban green areas from the total surface of the districts reveals some interesting facts. The districts with the highest percentage (>40%) of urban green areas are at the periphery of the city, and most of them are mixed districts with private houses and agricultural usage (Bucium, Moara de Vânt, Ciurchi, Galata, Copou). Some of the districts have a high percentage of green spaces due to parks and open public spaces (Super Copou, Primăverii). At the same time, districts with the lowest percentage (less than 20%) are located in the north-western side of the city and the reasons for the low values are due to high concentration of buildings and major role in transportation (Canta, Păcurari, Păcureț, Billa-Gară, Sărăriei, Piața Nicolina), because of mixed function of the districts (cultural and educational - Copou-Universitate) or because of uncontrolled urban sprawl (Frumoasa, Sărăriei).

3.4. Vegetation index for Iași city

NDVI separates vegetation from other ground cover materials, obtaining data revealing five categories for NDVI, from lowest values (between 1 and 2) and highest values (8 and 10). Areas with lower NDVI were located in the central part of the city in Bahlui and Nicolina floodplains, due to the prevalence of grass and in

the district with high density of buildings with low surface of free space that could be covered by vegetation.

Higher values of NDVI were located in the northern part of the city where the green spaces are very large, such as the Botanical Garden, Copou and Expozitiei Parks (founded in 1963, 1833 and respectively 1923) with tree vegetation and higher leaf canopy that has a high reflectance in the NIR bands than other types of vegetation. The surface occupied by forests is also larger in this part of the city (parts of Brândușa, Țicău, Breazu and Ciric forest). Other regions are located in south of the city, due to the presence of forest areas: Galata, Bucium (case in which the orchards and vineyards play an important role).

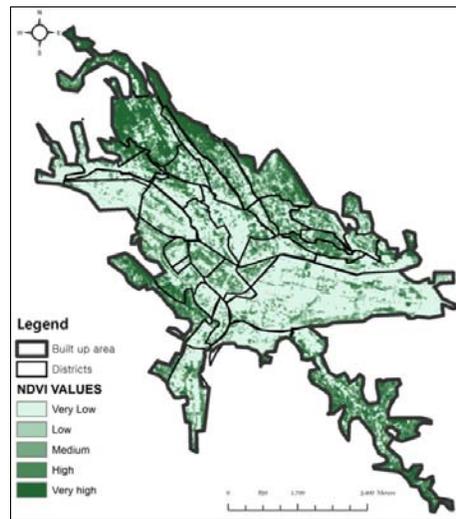


Figure 3 NDVI for Iași City

3.4 Critical Areas

The green index map was created using the results extracted from NDVI and the urban green areas delineation resulting a green area density index (using an 250 sqm grid). The final result was divided by population, showing the critical grids or those areas where a high population and a less vegetation surface are concentrated. The values are different from the official ones, as the study takes into consideration all urban green spaces, while official data takes into consideration only the ones administrated by local authorities (Agency of Environmental Protection , 2011).

It is obvious that the higher populated districts are considered critical areas, most of them being located in the south-western and western part of the city.

Another region with a lack of urban green areas can be identified within the north-eastern, side due to a domination of dense collective buildings. The existing correlation that can be found is between the age of buildings and the critical grids. The explanation is that most of the collective districts (and buildings) were built during 1960-1985, during the industrialized phase of the communist regime (Stoleriu Oana, 2008).

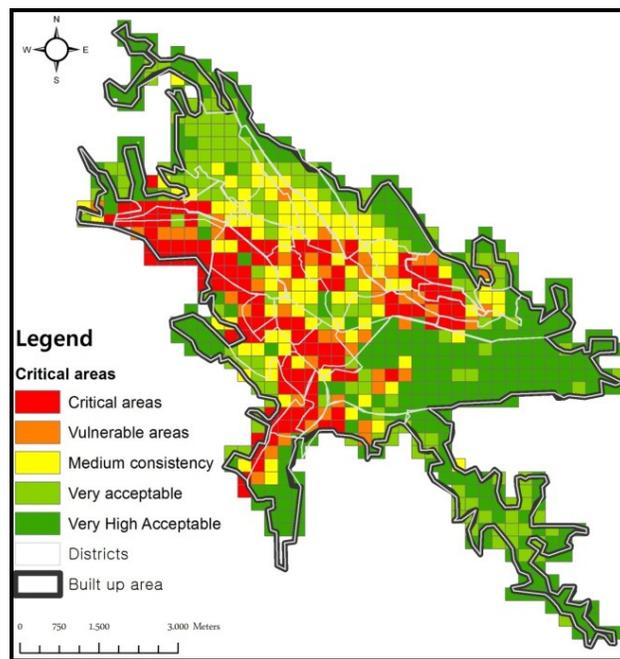


Figure 4 Critical areas in Iași Municipality

The critical areas are defined by the lower limit of 20 sqm of urban green area per capita which is established by law, although our study includes all urban green area located in the city, while the official classification takes into consideration only public green spaces (Agency of Environmental Protection , 2011). Consequently, 16.6 % of the grid is represented by critical areas that represent a major issue for the quality of life and of the environment. The next class is represented by the limit of 40 sqm per capita (6.8 %) which is still considered vulnerable for the standards of living in urban environment.

Although only 23.4% are considered vulnerable or critical, the amount of the inhabitants that are located inside those grids represents 87% of total population.

The areas with a high index for urban green areas (63%) (acceptable and very acceptable) are located at the periphery of Iași and at the outside of the built-up area (represented by forests, crops, private gardens etc.). The population located inside these areas represents only 3% of the total. These inhabitants have an explicable position (correlated with green density index) due to the spatial evolution of the city (Țicău district is considered rural even if is located inside the city), the evolution of the social-economic conditions of the city after the fall of the communist regime resulting in high class residential districts (Bucium, Copou-Bellevue).

The above discussion denotes the importance of including the distribution of population while evaluating the urban green area. As land resources are becoming scarce and globally urban areas are growing at fast rates, the availability of land is always a question, planners have no other options than to go for high rise development. But high-rise development area needs to have more amounts of good quality green spaces (Gupta, Kumar, Pathan, & Sharma, 2012).

Conclusions

The results of this study emphasize that the ex-industrial districts are the most critical areas, revealing that city subsystems as city districts or regions should be considered more in urban environmental planning. In addition, considering that more than 70% of the population is included in critical areas, the high cost of land and long process of change of use in Iași municipality decrease the whole city's opportunities.

The study demonstrates that remote sensing images together with GIS are a valuable tool for evaluating the urban green structures. GIS can be an effective tool in preserving and monitoring green and open spaces in an urban area (Ruangrit & Sokhi, 2004)

The analysis of the population, green areas and the determination of critical areas highlights the following:

- From the viewpoint of green spaces topology, 75% were integrated in the class of informal green spaces, 25% being represented by forests, gardens and public green spaces.
- The highly populated districts are located in the western and south western parts of the city, while the first 10 highly populated districts concentrate 56% of total population.
- NDVI registered lower values in regions situated in the central part of the city in Bahlui and Nicolina floodplains, due to the prevalence of herbaceous vegetation and in the districts with high density of buildings. Regions with higher values of NDVI were located in the northern part of the city where the green spaces are very large, or in southern part - due to the presence of forested areas.

- 23.4% of the studied area is considered vulnerable or critical, but the amount of inhabitants that are located inside represents 87% of the total population, revealing a major problem in the south-western, western and north-eastern parts of the city.

Developing and conserving the actual urban green area, strengthening this scientific segment on urban analyses along with public participatory and administrative involvement will stabilize the beneficial role of urban green space on the quality of life and will forward Iași to a more livable city.

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