Scientific Papers. Series B, Horticulture. Vol. LXX, No. 1, 2026
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

SPATIAL ANALYSIS OF GREEN INFRASTRUCTURE IN CLUJ-NAPOCA AND ITS IMPLICATIONS FOR URBAN AIR QUALITY

Iulia COROIAN, Rodica SOBOLU, Luisa ANDRONIE, Ioana POP, Cristian PUIE, Andrei CÎMPEAN

University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca,
3-5 Calea Mănăștur Street, 400372, Cluj-Napoca, Romania

Corresponding author emails: luisa.andronie@usamvcluj.ro, rodica.sobolu@usamvcluj.ro

Abstract

This research analyzes the spatial distribution and total surface area of green spaces in Cluj-Napoca with the objective of evaluating their contribution to urban air quality. Geospatial datasets were retrieved from the Copernicus platform, including layers on vegetation cover, built-up areas, hydrographic elements, and additional urban features. These data were integrated into AutoCAD and subsequently processed in PyCharm, where spatial analyses enabled the precise delineation of vegetated areas and the assessment of their citywide distribution. On this basis, the green space per capita indicator was computed, offering a quantitative perspective on urban sustainability and the potential role of vegetation in mitigating air pollution. In addition to the quantitative evaluation, the study advances recommendations for the expansion and optimization of green areas in sectors exhibiting insufficient vegetation. These proposals are intended to enhance ecological connectivity, improve air quality, and reinforce the resilience of the urban system. The results emphasize the necessity of continuous monitoring and strategic planning of green infrastructure, underlining the strong linkage between urban development dynamics, ecosystem functioning, and human well-being.

Key words*: green space, urban sustainability, AutoCad.*

INTRODUCTION

Urban green spaces play a fundamental role in supporting environmental quality, public health, and urban resilience, particularly in rapidly developing metropolitan areas. In this context, the municipality of Cluj-Napoca, located in north-western Romania in the central region of Transylvania, provides a relevant case study for assessing the spatial distribution and structural configuration of urban vegetation within a complex and heterogeneous urban landscape. The city has undergone significant expansion and functional transformation in recent decades, leading to increased pressure on land resources, changes in land-use dynamics, and growing concerns regarding the spatial equity and accessibility of green infrastructure. The relationship between green infrastructure and air quality is particularly relevant in contemporary urban planning, as vegetation can contribute to the reduction of airborne pollutants by capturing particulate matter on leaf surfaces, absorbing gaseous pollutants, and moderating urban heat-island effects that may intensify atmospheric pollution.

This study integrates geospatial datasets derived from official administrative sources, OpenStreetMap building footprints, and high-resolution orthophotography in order to extract, classify, and evaluate the spatial extent of urban green spaces at the neighborhood level. The methodological framework combines ArcGIS Pro-based raster classification using the Iso Cluster Unsupervised algorithm with automated spatial processing performed in the PyCharm environment and subsequent visualization in AutoCAD. (Cooper & Chiaradia, 2020) This workflow enables both the delineation of vegetation patterns and the quantification of district-level indicators related to built-up areas, green space distribution, and urban morphology. Beyond the cartographic identification of vegetated areas, the analysis places particular emphasis on the interpretation of results in relation to World Health Organization (WHO) (WHO, 2017) guidance concerning green-space availability, accessibility, and potential public-health benefits. The main objective of this study is to analyze the spatial distribution and structural configuration of urban green infrastructure in Cluj-Napoca using GIS-based

classification, automated spatial processing, and CAD-based visualization. Specifically, the study aims to identify and classify vegetated areas from high-resolution orthophotographic data, quantify green-space surfaces and built-up footprints at the neighbourhood level, compare the spatial distribution of vegetation across urban districts, and interpret the results in relation to environmental quality and potential air-quality mitigation. The study also seeks to highlight neighbourhoods with reduced green-space availability and to provide a spatially explicit basis for supporting sustainable urban planning strategies focused on ecological connectivity, environmental resilience, and improved urban living conditions.

MATERIALS AND METHODS

The implications for urban air quality were assessed using the spatial distribution and extent of green infrastructure as environmental proxy indicators. Vegetation cover was considered relevant due to its potential role in pollutant retention, particulate matter interception, temperature regulation, and mitigation of urban environmental stress.

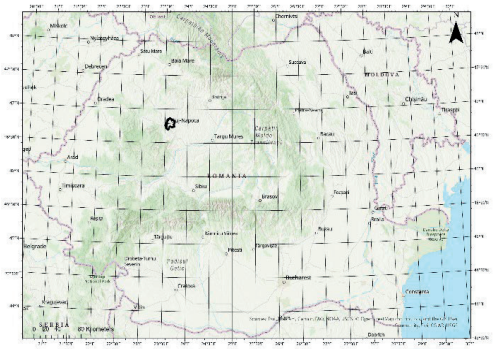


Figure 1. Romania

Therefore, district-level indicators such as green-space area, vegetation percentage, built-up footprint area, and the relationship between vegetated and impervious surfaces were used to evaluate the potential contribution of green infrastructure to urban air-quality improvement. Cluj-Napoca is a municipality located in north-western Romania (Figure 1), more specifically in the central region of Transylvania, covering an area of approximately 180 km².

The administrative boundary of the municipality of Cluj-Napoca (Figure 2), together with the delimitation of its internal neighbourhood units (Figure 3), was acquired through the Geo-Spatial application and managed in Arcgis Pro. (Geo-Spatial, 2025)

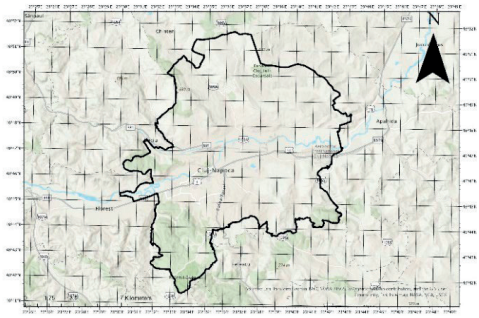


Figure 2. The Administrative Boundary of the Municipality of Cluj-Napoca

This platform provides access to georeferenced vector datasets derived from official territorial and cadastral sources, ensuring the accuracy and reliability of the spatial limits used in the analysis. The downloaded layers served as the foundational geographic framework for subsequent spatial processing and thematic evaluations conducted in this study. The building footprints used in this study were obtained from the GeoFabrik platform, which provides regularly updated extracts of OpenStreetMap (OSM) (OpenStreetMap, 2025) data in vector format. GeoFabrik's (OpenStreetMap Data Extracts, 2025) datasets are derived from the global OSM database and include georeferenced building polygons that are extracted, processed, and organized by geographic region.

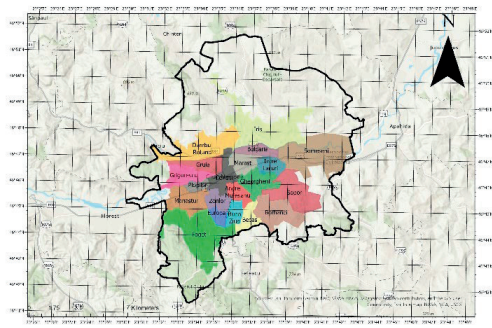


Figure 3. The Limitation of the Internal Neighbourhood

This source ensures high spatial coverage, open accessibility, and compatibility with standard GIS workflows. The building layer downloaded from GeoFabrik served as a fundamental dataset for delineating the built environment within the study area and for conducting subsequent spatial analyses related to urban structure, land use, and the quantification of built-up surfaces. The orthophotoplan presented in Figure 4 was generated based on an aerial survey flight conducted over the Municipality of Cluj-Napoca. Several photogrammetric cameras were mounted on the underside of the aircraft and were programmed to acquire successive images at predefined time intervals.

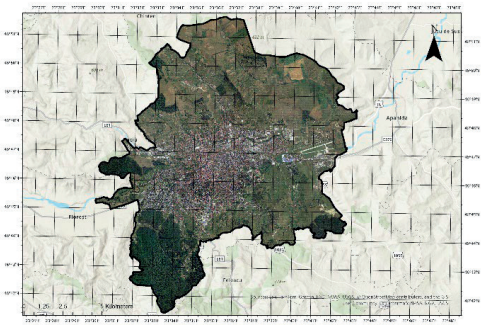


Figure 4. The orthophotoplan of Cluj-Napoca

The collected imagery was subsequently processed using specialized photogrammetric software, resulting in the final orthophoto product. The Iso Cluster Unsupervised Classification algorithm available in ArcGIS Pro performs an automated, data-driven segmentation of raster imagery based on the statistical similarity of pixel values (McGee, Parece, & John, 2023) A five-class configuration was selected because it provided the clearest visual separability between the main land-cover categories present in the urban orthophoto, namely impervious surfaces, bare or sparsely vegetated areas, vegetation, building rooftops, and surfaces with strong spectral contrast such as industrial roofs or construction areas. When applied to an orthophoto, the algorithm analyzes the spectral characteristics of each pixel, typically the red, green, and blue bands, and groups them into a predefined number of clusters that represent internally homogeneous and externally distinct spectral classes. Iso Cluster uses an iterative procedure derived from the ISODATA (Iterative Self-Organizing Data Analysis) algorithm, which repeatedly calculates class means, assigns pixels to their closest spectral centroid, and updates these centroids until convergence is reached or a maximum number of iterations is achieved (Lemenkova P., 2021).

This process allows the algorithm to partition the orthophoto into clusters corresponding to visually or spectrally distinct land-cover types such as vegetation, built-up surfaces, bare soil, transportation infrastructure, or water bodies (Lemenkova P., 2021)

Because the method is unsupervised, no prior training data are required; instead, the classification emerges solely from the intrinsic spectral structure of the image. This makes Iso Cluster particularly useful for preliminary land-cover identification, exploratory spatial analysis, and automated extraction of thematic information from high-resolution orthophotography. However, as the resulting clusters are not semantically labeled, they require post-classification interpretation and validation against ground truth or auxiliary datasets (Jia, 2006). The left image illustrates the result of an unsupervised Iso Cluster classification applied in ArcGIS Pro to the 2018 orthophoto of the Municipality of Cluj-Napoca, constrained by the administrative boundary of the city.

The Iso Cluster algorithm automatically grouped image pixels into five spectral classes based on their statistical similarity across the RGB bands, without prior training samples. Each class represents a dominant land-cover or surface type characterized by similar reflectance properties. The numerical class labels shown in the legend **(**values 1-5**)** do not imply a hierarchical order but serve solely as identifiers for the resulting clusters: class 1 (gray**)** predominantly corresponds to impervious surfaces such as roads, paved areas, and dense built-up zones, where reflectance is relatively uniform and low in the visible spectrum; class 2 (yellow) is mainly associated with bare soil, sparsely vegetated areas, or dry surfaces exhibiting higher reflectance in the visible bands; class 3 (green) represents vegetated surfaces, including urban green spaces, parks, gardens, and other areas with active vegetation

cover, characterized by higher reflectance in the green band; class 4 (blue) corresponds largely to building rooftops and compact built structures, showing distinct spectral behavior compared to roads and vegetated areas, class 5 (red) highlights surfaces with strong spectral contrast, such as industrial roofs, construction sites, or mixed materials, often occurring as fragmented patches within the urban fabric.

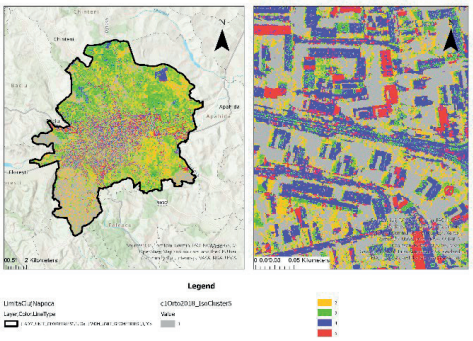


Figure 5. Iso Cluster classification applied in ArcGIS Pro

The spatial distribution of these classes reveals the heterogeneity of land cover across Cluj-Napoca, with a clear concentration of impervious and built-up classes in the central urban area and a higher proportion of vegetated and less disturbed surfaces toward the peripheral zones.

The right image presents a zoomed-in detail of a representative urban area, emphasizing the pixel-level structure of the Iso Cluster classification. At this scale, the discrete nature of the raster classification becomes evident, with individual pixels and small pixel groups clearly delineating buildings, streets, courtyards, and vegetated patches. This detailed view highlights the strengths and limitations of the Iso Cluster approach in high-resolution urban imagery, particularly the occurrence of mixed pixels and spectral confusion between adjacent land-cover types in dense urban environments (Coroian, et al., 2021).

Recent advances in geospatial automation and computer-aided design have significantly expanded the role of scripting languages in the control and customization of CAD environments. In this context, Python has emerged as a widely adopted solution for automating CAD-based workflows, owing to its flexibility, readability, and extensive ecosystem of libraries for numerical computation, data processing, and spatial analysis. Programmatic control of CAD software is typically achieved through application programming interfaces (APIs) and COM (Component Object Model)–based architectures, which enable external scripts to interact directly with native CAD objects, layers, and drawing properties. Such approaches have been successfully applied in a variety of engineering and construction-related applications, including automated geometry handling, design verification, and the integration of CAD data with computational analysis pipelines. Previous studies have demonstrated that scripting-based CAD automation can substantially reduce manual intervention, enhance reproducibility, and improve efficiency in complex or repetitive design tasks (Moghadam, 2019).

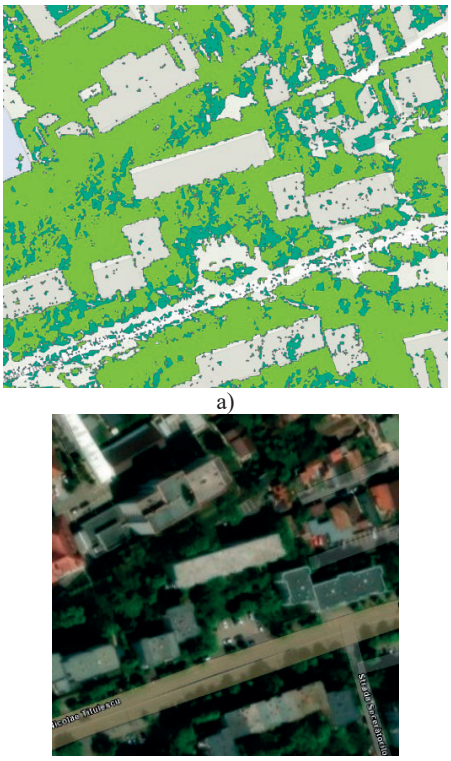
RESULTS AND DISCUSSIONS

Based on the Iso Cluster unsupervised classification, the generated spectral classes were analyzed in relation to their spatial distribution, vegetation cover, and potential implications for urban air quality in Cluj-Napoca. The classification results show a clear spatial contrast between the central urban area, dominated by impervious and built-up surfaces, and the peripheral or semi-peripheral areas, where vegetated surfaces are more frequent.

Following the assessment of the classified raster, Classes 2 and 3 were selected as representative of vegetation cover, as they consistently corresponded to urban green spaces, parks, gardens, tree-covered areas, and peri-urban vegetated zones. The presence and spatial continuity of these green areas are relevant for urban air-quality regulation because vegetation can contribute to the reduction of airborne pollutants through particle deposition on leaf surfaces, pollutant absorption, shading effects, and the mitigation of urban heat island intensity.

The selection was supported by visual interpretation of the classified raster in comparison with the original orthophoto, which confirmed the dominance of vegetative features within these classes. The remaining classes were associated primarily with impervious surfaces

and built-up areas and were therefore excluded from the vegetation analysis.



a)

b)

Figure 6. Iso Cluster classification applied in ArcGIS Pro

The left image illustrates the vegetation layer extracted from the Iso Cluster unsupervised classification, in which the selected spectral classes corresponding to vegetated surfaces have been isolated and displayed as discrete polygons. The right image presents the corresponding orthophoto of the same urban area, serving as a reference for visual validation (Horkaew, Puttinaovarat, & Paramate, 2022).

A comparative analysis of the two images reveals a strong spatial correspondence between the polygons derived from the Iso Cluster classification and the green areas visible in the orthophoto (Lemenkova P., 2202). In particular, the classified polygons accurately delineate tree canopies, lawns, and other vegetated patches, demonstrating that the unsupervised classification effectively captures the spatial extent and distribution of urban green spaces (Figure 6 a). This visual agreement supports the reliability of the Iso Cluster approach for vegetation extraction from high-resolution orthophotography data (Figure 6b).

Following the initial processing of the datasets in ArcGIS Pro, the resulting spatial layers were subsequently imported into AutoCAD and processed using Python scripts developed in the PyCharm environment. The Python-based workflow included coordinate data handling, layer classification, surface and perimeter calculation, spatial overlay between vegetation classes and administrative boundaries, attribute extraction, and the generation of statistical summaries.

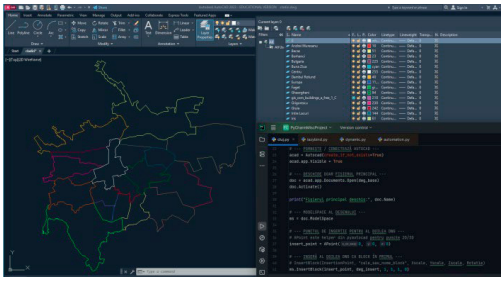


Figure 7. The administrative boundaries

These operations allowed the automated quantification of green areas within the analyzed urban sectors and improved the transparency and reproducibility of the geospatial processing workflow (Lemenkova P., 2015).

As a first step, the administrative boundaries of the city districts were incorporated, establishing the spatial framework for the analysis (Figure 7). The workflow was then extended by adding the building footprints, which enabled a more detailed representation of the urban fabric. In the final stage, the green space layer was integrated, allowing for the accurate delineation and spatial valuation of vegetated areas within the urban system (Figure 8).

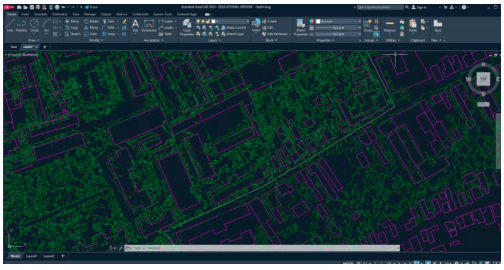


Figure 8. The green space layer and the building footprints

The district-level indicators were derived through a polygon-based spatial overlay procedure implemented in the PyCharm environment. First, the administrative boundaries of the districts were used as the reference spatial units. The building footprint layer was intersected with each district polygon in order to calculate the built-up area at the district level. Similarly, the vegetation polygons obtained from the Iso Cluster raster classification were overlaid with the district boundaries to determine the green-space area for each district. The computed spatial indicators were subsequently visualized and represented in AutoCAD, enabling a clear and structured cartographic interpretation of the results (Figure 9).

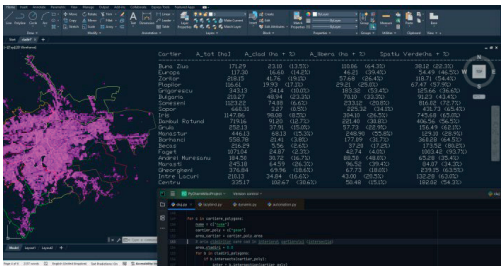


Figure 9. The building footprint area

The analysis reveals that the highest absolute values of green-space coverage are concentrated in Someșeni, Iris, and Sopor, all of which are characterized by low construction density and predominantly vegetated land use.

Someșeni records the largest extent of green space, totaling 816.02 ha (72.7%) of the district surface, out of a total area of 1123.22 ha (Figure 10). The built-up footprint remains comparatively limited (74.08 ha; 6.6%), reflecting a semi-periurban spatial configuration dominated by open and vegetated land.

District	Total area (ha)	Built-up area (ha and %)	Open area (ha and %)	Green space (ha
Buna Ziua	171.29	23.10 (13.5%)	110.06 (64.3%)	38.12 (22.3%)
Europa	117.30	16.60 (14.2%)	46.21 (39.4%)	54.49 (46.5%)
Zorilor	218.15	41.76 (19.1%)	57.68 (26.4%)	118.71 (54.4%)
Pioplor	116.61	19.93 (17.1%)	29.21 (25.0%)	67.47 (57.9%)
Grigorescu	343.13	34.14 (10.0%)	183.32 (53.4%)	125.66 (36.6%)
Bulgaria	210.27	48.94 (23.3%)	70.10 (33.3%)	91.23 (43.4%)
Someseni	1123.22	74.08 (6.6%)	233.12 (20.8%)	816.02 (72.7%)
Sopor	660.31	3.27 (0.5%)	225.52 (34.1%)	431.73 (65.4%)
Iris	1147.86	98.08 (8.5%)	304.10 (26.5%)	745.68 (65.0%)
Dambul Rotund	719.16	91.20 (12.7%)	221.40 (30.8%)	406.56 (56.5%)
Grula	252.13	37.91 (15.0%)	57.73 (22.9%)	156.49 (62.1%)
Manastur	446.13	68.13 (15.3%)	248.90 (55.8%)	129.11 (28.9%)
Borhanci	558.78	21.41 (3.8%)	177.09 (31.7%)	360.28 (64.5%)
Becas	216.29	5.56 (2.6%)	37.20 (17.2%)	173.52 (80.2%)
Faget	1071.94	24.87 (2.3%)	42.74 (4.0%)	1003.42 (93.7%)
Andrei Muresanu	184.50	30.72 (16.7%)	88.50 (48.0%)	65.28 (35.4%)
Marasti	245.18	64.59 (26.3%)	96.52 (39.4%)	84.07 (34.3%)
Gheorgheni	376.84	69.96 (18.6%)	67.73 (18.0%)	239.15 (63.5%)
Intre Lacuri	210.13	34.84 (16.6%)	43.00 (20.5%)	132.28 (63.0%)
Centru	335.17	102.67 (30.6%)	50.48 (15.1%)	182.02 (54.3%)

Figure 10. District-level distribution of built-up areas, open areas, and green-space coverage in Cluj-Napoca

From the perspective of WHO guidance, the high proportion of continuous green surfaces provides favorable ecological support and air-quality mitigation potential. In this study, accessibility was interpreted through the spatial relationship between green-space distribution and the built-up urban fabric. The assessment focused on the continuity, proximity, and territorial availability of vegetated areas within each district, allowing the identification of urban sectors where green infrastructure is more spatially connected and those where it appears more fragmented or constrained by dense construction.

In Iris, green space accounts for 745.66 ha (65.0%) of the total 1147.86 ha, while the built-up area remains moderate (98.08 ha; 8.5%). Vegetation forms an extensive and relatively continuous matrix around the residential areas, indicating a balanced relationship between urbanized and natural land cover.

In this study, the interpretation of green-space distribution across neighbourhoods was carried out with reference to World Health Organization (WHO) guidance concerning the role of urban green infrastructure in supporting environmental quality and public health. The assessment focused on two main spatial indicators derived from the geospatial analysis: the total green-space area and the percentage of vegetation coverage within each district. These indicators were used to compare the territorial availability of green spaces and to identify districts with high or low vegetation coverage. Rather than considering only the absolute extent of vegetated areas, WHO emphasizes the importance of indicators related to spatial accessibility, per-capita availability, and the functional distribution of green spaces within the urban fabric, as these factors are more closely associated with population health outcomes and environmental well-being (WHO, 2017). On this basis, the comparative assessment of neighbourhoods in Cluj-Napoca integrates both land-cover characteristics and their potential alignment with WHO-oriented criteria for health-supportive urban green infrastructure.

In relation to WHO recommendations, the district demonstrates strong territorial green-space availability; however, full compliance can

only be assessed when considering per-capita indicators and spatial accessibility for residents.
Sopor is characterized by a predominantly green landscape structure, with 431.73 ha (65.4%) of vegetated area out of a total of 660.31 ha, and an extremely low construction density (3.27 ha; 0.5%). This profile indicates an emerging development area where urbanization processes are still incipient. Under WHO principles, Sopor presents substantial potential for preserving and planning green infrastructure proactively; however, the functional utility of these areas will depend on future urban expansion dynamics and the integration of accessible recreational spaces.
Overall, these districts represent the most vegetation-rich sectors of the city in absolute spatial terms. While their land-cover composition aligns with the ecological objectives promoted by the WHO, further assessment based on green space per inhabitant and spatial accessibility is required to evaluate compliance with public-health-oriented urban planning criteria.
At the opposite end of the spectrum, the lowest absolute values of green-space surface area are observed in Buna Ziua, Europa, and Plopilor. These districts display higher construction densities and more compact urban morphologies compared with the vegetation-rich peripheral districts.
Buna Ziua registers the smallest total green-space extent, with 38.12 ha (22.3%) out of a total surface of 171.29 ha, while the built-up footprint accounts for 23.10 ha (13.5%). The reduced share of vegetated land, in conjunction with ongoing residential densification, indicates a predominantly compact urban pattern. From the perspective of WHO guidance, this configuration may imply limited access to nearby recreational green areas and potential exposure to higher environmental stress factors, particularly in relation to heat-island and air-quality conditions.
In Europa, green space amounts to 54.49 ha (46.5%) of a total of 117.30 ha, whereas the building footprint represents 16.60 ha (14.2%). Although the relative proportion of vegetation is moderate, the absolute surface remains restricted due to the small spatial extent of the district. In the context of WHO recommendations, this situation suggests that the availability of accessible public green areas may be constrained at the neighborhood level, especially in zones with higher residential concentration.
Plopilor includes 67.47 ha (57.9%) of green space within a total area of 116.61 ha, along with 19.93 ha (17.1%) of built-up surfaces. Despite a comparatively higher relative percentage of vegetation, the total green-space area remains limited, reflecting a compact urban structure with fragmented vegetated patches. In relation to WHO guidance, this configuration highlights the importance of improving spatial connectivity and the functional accessibility of existing green spaces to ensure equitable, health-related benefits for residents.
Taken together, these districts illustrate the areas of the city with the lowest absolute availability of green space, where urban densification processes may challenge the integration of green infrastructure. From a public-health perspective, they represent priority areas for targeted interventions aimed at increasing accessible, well-distributed urban green spaces in line with WHO recommendations. For a more focused interpretation, several representative residential districts were selected, namely Mănăștur, Gheorgheni, Zorilor, Andrei Mureșanu, Buna Ziua, and Grigorescu. These districts were chosen because they are important residential areas within Cluj-Napoca and present different degrees of urban density, development pressure, and green-space availability. Within the highly demanded residential districts of Cluj-Napoca, the largest absolute green-space surfaces are recorded in Gheorgheni, Mănăștur, and Grigorescu, which together concentrate the highest availability of urban green infrastructure within this subgroup of neighborhoods (Nap et al., 2020). Gheorgheni records the highest level of green-space availability among the analyzed districts, characterized by continuous and well-structured vegetated areas integrated within the residential fabric. Consistent with WHO guidance, the spatial configuration of the district suggests good short-distance accessibility and a favorable potential for per-capita green-space provision.
In Mănăștur, the absolute extent of green space is substantial; however, the relative proportion of vegetation is lower due to the compact, high-density urban structure. From a WHO perspective, the effectiveness of green spaces in

supporting public-health outcomes depends primarily on their internal distribution and accessibility within residential clusters.

Grigorescu combines moderate urbanization with structurally connected vegetated areas, particularly along major landscape corridors, which enhances recreational accessibility and contributes to environmental quality in line with WHO principles.

Among the remaining districts, Zorilor is characterized by a relatively favorable green-space profile; Andrei Mureșanu presents fragmented but functionally valuable vegetated areas, whereas Buna Ziua exhibits the lowest availability of green space, reflecting an increasingly dense and compact urban pattern.

Overall, Gheorgheni and Grigorescu display the strongest alignment with WHO environmental-health objectives, while Mănăștur requires greater attention to intra-neighborhood accessibility. Buna Ziua emerges as the most vulnerable case due to its limited and spatially constrained green-space resources.

CONCLUSIONS

The objective of this study was to analyze the spatial distribution and structural configuration of urban green infrastructure in Cluj-Napoca, using GIS-based classification, automated spatial processing, and CAD-based visualization. The study aimed to identify vegetated areas from high-resolution orthophotographic data, quantify green-space surfaces and built-up footprints at district level, and interpret the results in relation to environmental quality and potential air-quality mitigation.

This study aimed to assess the spatial distribution and structural configuration of urban green infrastructure in Cluj-Napoca by integrating GIS-based Iso Cluster classification, Python-based spatial processing, and CAD-based visualization. The main objectives were to identify vegetated areas from high-resolution orthophotographic data, quantify green-space surfaces and built-up footprints at district level, and interpret the spatial patterns of vegetation in relation to urban morphology, environmental quality, and potential air-quality mitigation.

At the opposite end, districts such as Buna Ziua, Europa, and Plopilor exhibit reduced absolute green-space availability and more compact urban structures, reflecting ongoing densification processes and increased landscape fragmentation. From a WHO-oriented perspective, these neighbourhoods represent priority intervention areas where the integration of accessible and well-distributed green spaces is essential for mitigating environmental stress factors and supporting public-health outcomes.

Within the group of highly demanded residential districts, Gheorgheni and Grigorescu show the strongest alignment with WHO environmental-health objectives, owing to their structurally connected and functionally coherent green-space networks. By contrast, Mănăștur, despite holding a substantial territorial extent of green (Geo-Spatial, 2025)accessibility due to its compact and high-density urban fabric. Buna Ziua emerges as the most vulnerable case, with limited and spatially constrained vegetation resources that may restrict compliance with accessibility-based green-space targets under continued urban development. From a practical planning perspective, these results can support municipal decision-making by identifying districts where green-space interventions should be prioritized. Areas with limited or fragmented vegetation, such as Buna Ziua and compact residential sectors, should be considered priority zones for increasing green-space coverage, improving ecological connectivity, and integrating new vegetated corridors into future urban development plans.

Overall, the study highlights the value of integrating unsupervised classification techniques, Python-based automated spatial processing, and CAD-based visualization for the quantitative assessment of urban green infrastructure. The novelty of this workflow lies in the combination of raster-based vegetation extraction, vector-based spatial overlay, automated area computation, and cartographic representation within a single reproducible processing chain. Compared with conventional manual approaches, this integrated GIS–Python–CAD workflow reduces repetitive operations, improves consistency in district-level calculations, and facilitates the rapid generation of spatial indicators for urban green-space assessment. The results provide a spatially explicit basis for supporting urban planning strategies aimed at enhancing ecological

connectivity, improving environmental quality, and promoting equitable access to urban green spaces in Cluj-Napoca.

REFERENCES

Cooper, C. H., & Chiaradia, A. J. (2020). sDNA: 3-dspatialnetworkanalysisforGIS,CAD,CommandLine Python. *Elsevier*.

Coroian, I., M., N., Pop, I. Matei, F., Sălăgean, T., Deak, J., . . . Ficior, D. (2021). Using GIS analysis to assess urban green space in terms of real estate development. *Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Horticulture, 78(1*.

Geo-Spatial. (2025, 11 23). *https://www.geo-spatial.org/descarcare/date/administrative-boundaries*. Retrieved from https://www.geo-spatial.org/.

Horkaew, Puttinaovarat, S., & Paramate. (2022). A geospatial platform for Crowdsourcing Green Space Area Management Using GIS and Deep Learning Classification. *International Journal of Geo-Information, 11*.

Jia, X. (2006). Remote Sensing Digital Image Analysis: An Introduction.

Lemenkova, P. (2015). Analysis of Landsat NDVI Time Series for Detecting Degradation of Vegetation. Geoecology, and Sustainable Use of Mineral Resources. *Science to Practice, Begorod, Russia*.

Lemenkova, P. (2021). ISO Cluster Classifier by ArcGIS for Unsupervised Classification of the Landsat TM Image of Reykjavík. *Bulletin of Natural Sciences Research, 11*, 29-37.

Lemenkova, P. (2202). SAGA GIS for Information Extraction on Presence and Conditions of Vegetation of Northern Coast of Iceland Based on the Landsat TM. *Acta biologica marisiensis, 3*, 10-21.

McGee, P., Parece, T., & John. (2023). *Remote Sensing with ArcGIS Pro (Second Edition).*

Moghadam, P., &. (2019). Automated construction progress monitoring using computer vision and CAD Integration. *Automation in Construction, 103,* , 66–79.

Nap, M., -E., Salagean, T., Pop, I. D., Matei, F., Coroian, I., & Suba, E. E. (2020). THE USE OF GIS IN REAL ESTATE. *Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. IX*.

OpenStreetMap. (2025, December). Retrieved from https://www.openstreetmap.org/#map=12/46.7597/23.5643&layers=CDG

OpenStreetMap Data Extracts. (2025, December). Retrieved from https://download.geofabrik.de/

WHO. (2017). *World Health Organization Regional Office for Europe. (2016). Urban Green Spaces and Health: A Review of Evidence. Copenhagen: WHO Regional Office for Europe.*