

Environmental impact assessment of uncontrolled urban sprawl in a peri-urban area: A case study of Cluj-Napoca municipality, Romania

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Keywords: environmental impact assessment; urban sprawl; peri-urban forest; RIAM; GIS; checklist; Făgetul Clujului wooded area; Cluj-Napoca, Romania

Abstract: This paper aims to investigate the environmental impact of uncontrolled urban sprawl on the peri-urban Făgetul Clujului wooded area. This area is a partially conserved peri-urban forest and a ROSCI Natura 2000, located in the southwestern part of Cluj-Napoca Municipality in Romania. To assess the environmental impact, a standardized checklist based on national regulations and a modified rapid impact assessment matrix (RIAM) were used to obtain environmental scores for 30 key points in the area. The QGIS and IDW (Inverse Distance Weighting) methods were used to combine the main assessment scores to create a general impact map. The assessment outcomes confirm that there are significant negative impacts on environmental components in this peri-urban wooded area, such as abiotic and biotic components, in those peripheral areas that are recently built, developed, or expanded. This study provides an effective, transparent, and integrated methodology for assessing the impact of uncontrolled urban sprawl on the environment. It can help local decision-makers and experts in designing and developing sustainable strategies for environmental management and urban planning.

1. Introduction

According to Eurostat (2020), in 2018, 39.3% of the European Union population lived in cities, 31.6% in small towns and suburbs, and 29.1% lived in rural areas. By 2050, 82% of Europeans are expected to live in cities (EEA, 2023). In North American and European metropolitan zones, cities expand spatially even as their population declines (Karsten, 2007; Rienow et al., 2014; McKinney et al., 2018). The reasons for this phenomenon are economic, such as the general increase in the standard of living, developments in the real estate market, and social-cultural, such as the almost total disappearance of multigenerational households in contrast to the increase in popularity of individual housing.

The issue of uncontrolled urban expansion has become one of the most challenging and difficult-to-manage problems in urban, environmental, and territorial planning. Due to this reason, a great deal of emphasis is placed on controlling this phenomenon, firstly by understanding it, and secondly, by creating administrative and economic instruments to curb it (Galster, 2001; Ewing, 2008; EEA, 2006).

The uncontrolled urban sprawl is defined as "the physical pattern of low-density expansion of large urban areas, under the influence of the market, predominantly in the surrounding agricultural areas" (EEA, 2006) or "an unplanned and uneven development pattern set in motion of a multitude of processes and leading to inefficient use of resources" (Bhatta, 2010).

Galster (2001) describes urban sprawl as "a pattern of land use in an urban area that registers low values in a combination of eight distinct dimensions: density, continuity, concentration, clustering, centrality, mixed land use, and proximity". By measuring these dimensions and using geometric indicators (e.g., Weighted Urban Proliferation or WUP, EEA, 2016), it becomes possible to separate sprawl from the simple horizontal development of the city and compare situations from different contexts (Mouratidis, 2018; Salom-Carrasco and Zornoza-Gallego, 2024; Coheci and Petrișor, 2023).

The unreasonably low density of private residences is perhaps the most important aspect of the suburbs that manifest "sprawl". These are dominated by single-family homes, in many cases with generous individual yards. Still, the inefficient use of space is determined mostly by the geometric patterns of the development, not just the type of housing. As one of the main drivers of such development is the free market unfettered by restrictive planning measures, constructing infrastructure and buildings is often done starting with the cheapest land. Therefore, in the first stages of the absorption of territory by the city, development tends either to start from random points, without any connectivity or coherence, or to expand the area, by "jumping" over certain surfaces of land. This phenomenon is known as "leapfrogging" (Torrens and Alberti, 2000), and its main impact on the coherence of the territory and landscape consists in the alternation in patches between the built space and agricultural lands or natural areas.

This way of assimilating the landscape can be diminished by the progressive "filling" of the gaps (urban infill development) (Abedini and Khalili, 2019; Mohammadi-Hamidi et al., 2022). In a growing and expanding city, through urban planning policies focused on densification, land in such neighborhoods can increase in value, and land use can diversify, under normal market conditions, mitigating the undesirable effects of the above-mentioned phenomenon. The territorial reality shows us that city limits that show uncontrolled expansion tend to materialize in the long term in low-density neighborhoods without urban planning in this direction.

Another mode of development associated with uncontrolled urban sprawl is along major roads (Habibi and Asadi, 2011). We often see a linear and radial "diffusion" of the suburbs starting from the center of the city, and the spatial distribution and density of the built-up area do not necessarily depend on the proximity to the center.

Of significant importance, especially when it comes to the belief of the public and decision-makers on the manifestation of the phenomenon, is the pace at which the suburb develops and the interface of the process with the natural landscape. Since the time only the appearance of a house, a group of houses, or an access road is visible, it is easy to judge the impact as being strictly punctiform. Although the above-mentioned elements, taken individually, are insignificant in terms of urban landscape permeation, their influence is revealed over time due to the cumulative and synergistic nature of their varied impacts (e.g., socioeconomic, cultural, and ecological).

Regarding the social and economic impact of this phenomenon, both positive and negative influences are noted. On the one hand, such neighborhoods satisfy a demand arising from the desire of residents to have privacy, quietness, and a spacious yard (Bruegmann, 2005). On the other hand, however, the negative impact may be less obvious, often being noticed indirectly, decades after the area's development. From an economic but also environmental point of view, large individual homes are correlated with a greater consumption of territorial resources (Dura-Guimera, 2003; Haber, 2007) and suburbanization is viewed as a factor of zonal segregation based on social and financial status (Brade et al., 2009).

Uncontrolled urban sprawl has detrimental effects, one of which is the reliance on personal automobiles. Due to the location of these areas to city centers and their pre-

dominant residential nature, citizens living in the peri-urban areas experiencing uncontrolled expansion must travel longer distances from their homes to their workplaces. This results in more negative environmental impacts, as highlighted by Okeke et al. 2020.

According to Haber (2007), humanity faces three great "ecological traps" that it cannot avoid: land, food, and energy. Of these, land is the most seriously threatened. One of the main impacts of suburban sprawl on the landscape is the removal of land from its natural state or agricultural use. Therefore, the absorption of fertile land in urban space means taking it out of the agricultural circuit for an indefinite period, which could create serious problems for the next generations, especially considering the current pace (EEA, 2023).

Another important aspect characteristic of uncontrolled urban sprawl is the fragmentation of the landscape and forest (Vogt et al., 2019). In the case of agricultural land, the homogeneity of the zone is changed and, if a plot is completely embedded in a residential district, it can end up being taken out of operation due to interference with the population. If the urban expansion targets natural or secondary natural areas (in the case of formerly arable lands in Romania), the fragmentation of the landscape has a significant impact on the habitats and species. In pace with habitat loss due to urbanization, average patch size, total core area, and habitat cohesion decrease, while patch density, edge density, and shape complexity increase (Liu et al., 2016). This process affects ecological corridors and can lead to the elimination of certain more sensitive species, decreasing biodiversity and implicit resilience to anthropogenic pressures. All these environmental impacts constrain natural areas from providing vital ecosystem services and biodiversity essential for the growing urban system.

2. Materials and Methods

2.1. Uncontrolled urban sprawl of Cluj-Napoca Municipality

Cluj-Napoca Municipality is a fast-growing city that is becoming a hub for education and innovative technology at both regional and national levels. This development has led to an increasing need for new types of urban spaces, such as industrial, commercial, transportation, recreational, touristic, and residential areas.

The Cluj-Napoca Metropolitan Zone (CNMZ) was implemented in 2008 to address the need for urban space. The metropolitan zone has brought about complex and diverse relationships and benefits. One of the benefits is that the municipality of Cluj-Napoca can use the space available in the adjacent communes to fulfill certain urban functions. The residential function is the most outsourced and this opportunity, coupled with lax administrative policies and an increase in the demand for space, has resulted in uncontrolled urban sprawl.

The built-up area of Cluj-Napoca Municipality has increased by over 128% between 1990 and 2008 and it is home to only 80,000 people (Baciu et al., 2018). This suggests that the region is experiencing large-scale territorial assimilation, which is likely a result of development policies aimed at using the demographic potential generated by favorable socio-economic conditions in the region.

These policies seem to materialize through a pronounced horizontal territorial expansion, an easy spatial development pattern in the Romanian political-administrative context (Suditu et al., 2010). Communes such as Florești, Baciu, Feleacu, Apahida, and Gilău perform direct residential functions in the metropolitan urban system. So, the localities in the first ring of the metropolitan zone represent vital space for the horizontal development of the Cluj-Napoca city (IUDS Cluj-Napoca Metropolitan Zone 2021-2030).

Baciu et al. (2015) approached the current expansion trends of the Administrative Territorial Unit (ATU) Florești, which is the most populated village in the Cluj-Napoca Metropolitan Zone and Romania. They saw clear urban aspects in the commune's development, such as groups of duplexes, blocks with four floors, and commercial and industrial units. Additionally, they found specific patterns of uncontrolled urban

expansion in the southern part of the administrative unit, including dispersed development and new residential nuclei.

Similar patterns of territorial expansion can be seen in the surrounding areas of the Cluj-Napoca administrative territory, developed through the same fundamental mechanisms (Figures 1a and b). The satellite images below show signs of poor urban planning, represented by the lack of continuity between existing urban developments. This results in the creation of empty spaces, devoid of access infrastructure or residential attractiveness, which may never be naturally filled (even if subject to current residential market conditions and investors' speculations).



(a)

(b)

Figures 1. The urban sprawl in the Bună Ziua neighborhood between the year 2003 (a) and year 2020 (b); in addition to rapid real estate development, the disappearance of agricultural parcels and their replacement with dysfunctional, "forgotten" areas between new development cores is seen. Image: Google Earth, 2022

The Integrated Urban Development Strategy of the Cluj-Napoca Metropolitan Zone 2021-2030 (IUDS Cluj-Napoca 2021-2030) highlights the issue of insufficient urban space in the municipality. The problem arises from the sudden polarization of Cluj-Napoca Municipality and the geographical limitations of the area. The localities in the first ring on the West-East axis have experienced the greatest increase due to the topography of the Someșului Mic River Valley, while the infrastructure on the North-South axis is deficient. The urban and peri-urban land has been inappropriately used and developed wherever geographic conditions permit, leading to the problem of insufficient urban space. Although individual phenomena may be small and easy to overlook, the cumulative effect of urban development on available land and the environment is significant.

2.2. Study area (*Făgetul Clujului peri-urban forest and wooded area*)

Făgetul Clujului is a peri-urban forest and wooded area located on the southwestern border of the Cluj-Napoca municipality, as part of the Feleacului Hills, a geographical subunit of the Someșan Plateau. It's worth noting that only a part of the peri-urban forest that was analysed overlaps with a Natura 2000 site (Făgetul Clujului - Valea Morii, which is identified as ROSCI0074). According to the Natura 2000 Standard Data Form, the protected area covers 1,667 hectares (Management Plan of ROSCI0074 Făgetul Clujului - Valea Morii, 2016), but a significant part of the forest is not included in this site of community importance.

On the territory of the site, there are two marsh habitats, six forest habitats, and five meadow habitats of community interest. In the Natura 2000 Standard Sheet (updated in 2011), only three habitats are mentioned (e.g., 9170 - *Galio-Carpinetum*

oak-hornbeam forests, 7230 - *Alkaline fens*, and 7210 - *Calcareous fens with Cladium mariscus and Caricion davallianae* species).

The site has been declared for the conservation of twelve species of community interest (e.g., four species of plants, one species of reptile, and seven species of invertebrates). Further studies related to the development of the management plan have found four more species of community interest. The conservation status of the four plant species listed in the Natura 2000 standard sheet was found to be poor and threatened by local urban sprawl. Additionally, twenty-four more plant species that are of conservation interest were found, some of which are protected at the national level or have close ecological relationships with fauna species of community interest.

The management plan has found urban expansion in the area and the northern limit of the site as the major threat to forest habitats and species. This is due to the continuous land consumption caused by human activities such as the expansion of the inner city, construction and transport infrastructure, removal of vegetation for construction and clear-cutting, drainage works, and the introduction of non-native and invasive species.

Based on the current General Urban Plan of Cluj-Napoca Municipality (2014-2024), the forested territory is either outside the urban area or marked as a "zone naturally protected by conservative interest - proposed" if it falls within the urban area. These areas are part of the reference territorial unit "intravilan forests" and they are protected from any change in land use. However, forestry operations and infrastructure work are allowed in these areas. The Local Urban Planning Regulation of 2018 prohibits certain activities in the forested areas, including the access of any vehicles (other than those used for forestry purposes), parking of vehicles, any permanent or permanent construction, earthworks, systematization works, and fencing of the forest or parts of it, regardless of the ownership structure. Therefore, the forested areas are not directly threatened by any uncontrolled urban expansion arising from changes in land use.

In the study area, there is a new forest park (Forest Făget 1.0 Project) developed by Cluj-Napoca City Hall (in 2021). It covers an area of around 40 hectares and the park's landscaping interventions (e.g., benches, an amphitheater, and an educational platform), were made with minimal impact on the natural landscape (Sevianu et al., 2021).

Since the Făget forest and the nearby wooded areas are not a part of the protected natural area or the forest park, it can be inferred that the entire forest is subject to both conservation goals and concerns about the negative impact of human activity. This is particularly true for the forest segments found in the northern part of the Natura 2000 site, which are found near the city and, therefore, more vulnerable to human pressures.

The study area was delimited by considering the existing sources of present pressures and future threats, including both developed and developing areas next to the Făgetul Clujului forest area, as well as the three sectors of interest with specific natural and urban socio-economic characteristics. These three sectors are as follows (Figure 2):

1. *The sector with conservation status (ROSCI0074 Făgetul Clujului-Valea Morii and Natural Reservation Făget Forest):* This area is a protected natural area, and it has a state of environmental stability and ecological balance. The intensity of potentially insignificant anthropogenic impacts, pressure, or threat activities is low.

2. *The sector with forest without conservation status (in the north and northeastern part) and partially wooded areas (east, also called Pădurea Clujenilor):* This area is a fragile one, subject to current pressures and future threats generated by the uncontrolled expansion of constructions, roads, and other anthropogenic developments. The current and potential impacts are significant and permanent here.

3. *The mixed sector (with Făget 1.0 Forest Park, a recreational area of 40 ha),* a sector that has old anthropogenic interventions (plantations) and current (forest-park developments for recreational and educational activities). There are potentially significant impacts from recreational overexploitation and future development here.

The study area is in the proximity of the Mănăştur and Europa neighborhoods in the northern part and the northwestern corner, the area adjoins the Vivo shopping

complex and small residential complexes. Only communication routes and semi-abandoned pastures are related to human activities on the entire western border. In the eastern and southern parts of the study area, there are few inhabited areas and agricultural lands. Significant anthropogenic interventions are present both at the boundaries of the study area and on the surface of area 2. These interventions include the change of land use for the construction of residential areas and infrastructure, as well as related activities. Among the affected areas, the Colonia Făget (in the central part of the area) and the extensions of the residential units (in the northern part of the area) stand out with accentuated suburbanization, economic development, and clear trends of urban sprawl.

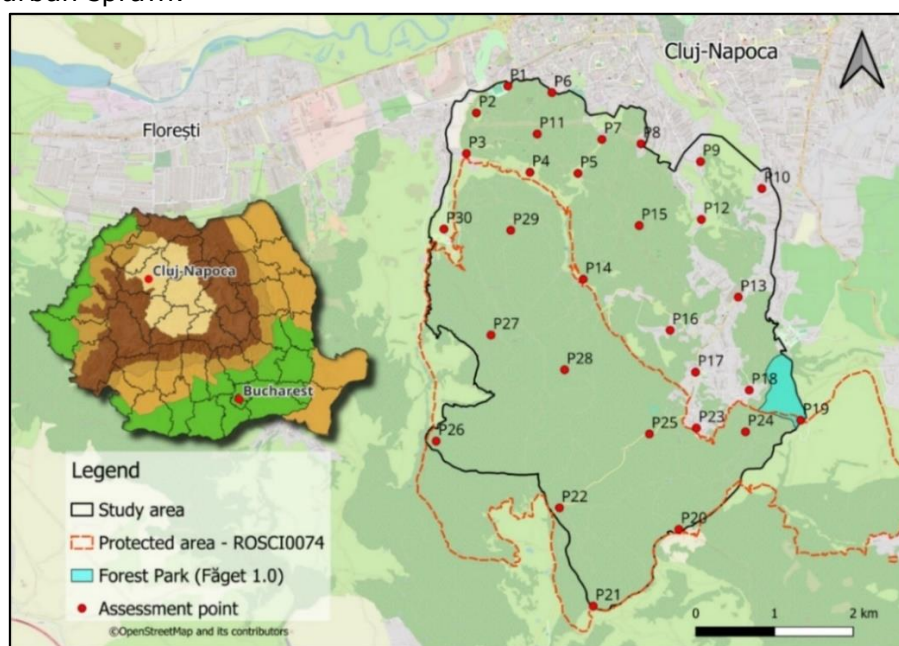


Figure 2. The geographical location of the study area (Făgetul Clujului peri-urban area).

Făgetul Clujului forest is found within the proximity of the built-up urban area of Cluj-Napoca Municipality. It is a representative example of a peri-urban forest and provides all ecosystem services and typical landscapes (e.g., traditional forestry practices can also be seen here). The current composition, structure, and uses of the forest are a result of the historical interaction between man and nature through forestry practices, and more recently, due to its proximity and easy access, it has become a popular spot for scientific, educational, and recreational activities (Sevianu et al., 2021).

Deac et al. (2014) noted that in Cluj-Napoca Municipality, the aesthetic and ecological values of landscapes do not always coincide. For instance, natural forests, being perceived as wild habitats, are not as desirable as other types of green spaces. In addition, Cluj-Napoca is a municipality that lacks a proper green infrastructure by contemporary standards of urban development; green spaces here are strongly disconnected and their surfaces are small. A well-preserved peri-urban forest like Făgetul Clujului can become a crucial element in the future green space system of the city, especially in the scenario where the city will develop rapidly around it.

2.3. Methodology of environmental impact assessment (EIA)

We have developed a methodological framework to assess the environmental impact of uncontrolled urban expansion in the study area. This framework integrates the information obtained from authorities, earlier studies, official reports, and field documentation in a semi-quantitative and transparent manner. The final synthesis and justification of the results can be communicated at levels of detail. We assert that, in the case of uncontrolled urban sprawl, the assessment must integrate human pressures and activities into a broader perspective. Our methods primarily target the current

environmental state; however, the identified impacts will be correlated with existing urban trends seen in the area's development. Predictions will also be issued about the evolution of the state of the environment in the peri-urban area of Cluj-Napoca.

The present study assessed the environmental resilience of the area studied and found that it is good. However, the expansion of built-up space poses a significant threat to the condition and integrity of the forest. While various activities contribute to environmental fragility and changes in the quality of certain environmental factors, the current and future consequences of urbanization are of particular concern. In this context, the consumption of space is of paramount importance. Therefore, the study emphasizes the urgent need to address the issue of urbanization and its impact on the environment. Given the heterogeneous nature of the study area such as landscape and human activities, it follows that environmental impacts will have anisotropic features.

Consequently, to ensure a comprehensive evaluation of the environmental impacts, assessment methods were applied to 30 evaluation points, strategically chosen for the following reasons: to be extended on the entire surface area of the study location; to allow all observed anthropogenic interventions and activities; to vary the density of points in an area according to the spatial distribution of anthropogenic interventions; to include "control" points in natural areas for comparative analysis of the environmental conditions between developed and undeveloped areas.

The selected method for evaluation encompasses a series of aspects, methods, and techniques, which are as follows:

1. The application of a legislatively regulated and officially developed checklist (according to Ministerial Order MO No. 304/2018) to find anthropogenic activities that have an impact on the environment.

2. Implementing a Rapid Impact Assessment Matrix (RIAM) on each point to evaluate the effect of the identified activities on the various environmental components. RIAM provides an evaluation score for each established point.

3. The creation of thematic maps through the interpolation of the resulting scores with the Inverse Distance Weighting (IDW) method, and the overlaying of these scores with other spatial elements of interest (QGIS software).

This mixed methodology offers a comprehensive framework for the evaluation of environmental impacts. Utilizing a legislatively regulated checklist ensures that all relevant anthropogenic activities are found. RIAM provides a systematic approach to assessing the impact of these activities on the various environmental components, resulting in an evaluation score for each established point. The thematic maps, which are created by overlaying the scores with other spatial elements of interest, provide a visual representation of the evaluation results.

2. Results

a. Checklists

In the current investigation, a checklist including the key activities that have the potential to affect the environment in the study area is used to evaluate the assessment points. These activities are primarily chosen from the inventory of anthropogenic activities and natural processes, which show current pressures and future threats mentioned in Ministerial Order M.O No. 304/2018, which approves the Guidelines for developing management plans for protected natural areas at the national level. However, in specific cases, the activities are regrouped and reinterpreted to enable a specialized evaluation of uncontrolled urban expansion. Table 1 includes a checklist of existing human activities that have the potential to cause environmental impacts in the area.

Using a checklist of activities that could generate impacts can help to apply the Rapid Impact Assessment Matrix (RIAM) consistently to evaluation points. This approach can systematize judgments about impact characteristics, leading to better alignment between the evaluation scores of each point of interest. However, the checklist alone may not provide a clear and direct view of impact assessment, as activities are linked to impacts of varying magnitudes, and the same pressure may have different intensities at different points.

Table 1. Checklist of existing anthropogenic activities and their environmental impacts (Făgetul Clujului Peri-urban Forest – study area)

Main codes according to MO 304/2018	Specific codes according to MO 304/2018	Anthropogenic activity or natural process - pressures/threats	Impact description
A - Agriculture	A04; A05; B06	Grazing and animal husbandry, grazing in a forested area, wildfires	Grazing threatens grassland biodiversity and can affect habitats by preventing the vertical growth of plants, with negative effects on populations of insects, small mammals, and birds.
B - Forestry	B.02.02; B.02.03; B.02.04	Forest clearance, removal of saplings and dry or drying trees, wildfires	Forest management, conducted mainly in the interest of preserving wood resources, has the potential to interrupt essential ecological cycles and, implicitly, to affect biodiversity.
	B.02.05	Non-intensive wood production (leaving dead wood and old trees)	The exploitation of the natural forest also brings with it changes associated with access to the forest, the transport of logs, and noise pollution.
	B.02.01	Planting and re-planting the forest	Modification of the type and structure of the stands, and modification of the forest ecosystem.
C - Mining and material extraction		Mining (sand, gravel, soil, clay)	Illegal small-scale extraction of aggregates for local or household use destroys the soil profile and associated habitats and allows erosion, thus destabilizing the substrate of the entire area, with a related impact on the landscape.
D - Communications Networks	D01	Roads, paths, routes	Roads fragment habitats and create the possibility of wildlife death by impact with cars. Also, their construction has a considerable environmental impact.
	D02	Utility lines and services	Power lines and pipelines mechanically intervene in ecological corridors and are a disruptive element of the landscape.
	D05	Improvement of access to the area	The development of the Făget 1.0 forest park type space (increasing accessibility and the appearance of recreational activities), positive socio-cultural impact by reporting to ecosystem services versus negative impact on species and habitats generated by citizen access and recreational and sports activities).
E - Urbanization, residential and commercial development	E01	Inhabited areas, the expansion of human habitation	The expansion of urban space comes with a wide range of impacts, but the most important at this point is the fragmentation of the green space and its reduction in surface area.
	G.05.09	Fences, enclosures, yards	Physical obstacles fragment habitats, alter the landscape, and lead to other human interventions in the environment (yards).
	E.03.01; E.03.03; E.03.04	Storage of inert waste from construction and other materials	Any storage on the ground is physical-mechanical pollution and an undesirable element in the landscape. Exposure of improperly stored waste to environmental factors leads to their linear or spatial dispersion, affecting flora and fauna.
	E.04	Infrastructures and constructions in the landscape	The fragmentation of the natural landscape, the modification of the landscape aesthetics, and the acceleration of the occupation of the existing natural space.
G - Human intrusions and imbalances	G.01.02	Walking and cycling, recreational activities	The irresponsible exploitation of the social-cultural potential of the green space (visiting in high volume/frequency for picnics, barbecues, and sports) exerts pressures, the size of which can be controlled by arranging specially dedicated areas.
	G.01.03	Motor vehicles & off-road driving	The intense use of off-roading routes can trigger erosion processes (e.g., gullies, ravines) and affect the morphology of non-permanent flow systems.
	G.02.08	Camping pitches and caravan parking areas	Disturbing the grassland ecosystem, easing other disruptive human activities (wastewater, fires, and recreational activities).

Main codes according to MO 304/2018	Specific codes according to MO 304/2018	Anthropogenic activity or natural process - pressures/threats	Impact description
H - Pollution	H.06.01	Noise pollution and light pollution	Affecting bird and mammal species through disturbance of ecological niches and stress on their way of life
I - Invasive species	I	Invasive species	Known invasive species such as American maple, ash, or acacia together with other species planted for decorative purposes can take advantage of the vulnerability created by forest fragmentation and threaten natural biodiversity.
J - Modifications of the natural system	J.02.07	Groundwater capture	Modification of the hydrogeological regime and drying of springs.
K - Natural Biotic and Abiotic Processes	K.01	Erosion, clogging, drought	There is a wide range of natural hydrological and geological processes that can functionally affect the green space (rivers, gullies, ravines, torrents, shallow and active landslides, stabilized landslides, coastal springs, and lands with excess moisture).
	K.03.06	Antagonism with domestic animals	The populations of small mammals and birds are strongly affected by the presence of dogs and cats in the vicinity of residential areas.
L - Geological events and natural disasters	L.05	Landslides	Landslides affect wooded and sloping surfaces; they are superficial and active (with implications for buildings and access roads) or deep, old, and stabilized (forested or anthropically managed - e.g., the Făget 1.0 forest park is found on such a massive landslide, stabilized with tree plantations).

b. Matrix method - Rapid Impact Assessment Matrix (RIAM)

The Rapid Impact Assessment Matrix (RIAM) was introduced in 1998 by Pastakia and Jenssen to address two primary issues with current environmental impact assessment methods. Firstly, there was a lack of consistency in the results generated by different methods, and secondly, there was a lack of objectivity and transparency in the judgments made during these evaluations (Ijäs et al., 2010).

The key principles of RIAM are as follows (Pastakia and Jenssen, 1998). Firstly, the evaluation criteria should be clearly defined to enable expert judgments on the significance of the impact. Secondly, the criteria should be included in a formula to generate an evaluation score for each environmental element. Thirdly, score ranges should be set up to group each impact score into a specific impact category. Finally, environmental components should be separated into four categories: (a). physical & chemical, (b). biological-ecological, (c) socio-cultural, and (d) economic-operational. These principles of RIAM facilitate a standardized and objective approach to environmental impact assessment, which can ensure consistent and transparent results.

In the present study, the matrix is applied to the surrounding environment of each assessment point within an approximate field-of-view radius, with a focus on relevant environmental components. Each component's impact is quantified and scored, and the scores will be categorized based on the level of impact. The sum of the scores for each part provides the total environmental score for each assessment point. This approach enables a comprehensive evaluation of the project's environmental impact and its potential consequences on the affected areas.

RIAM was adapted for the present context, and it has the following defining characteristics: the evaluation of environmental impact is primarily categorized into two types: abiotic and biotic/ecological; to assess the impact of various activities on a particular environmental factor, all actions that affect the factor are considered. The resulting environmental score can be interpreted as an estimate of the total pressure or threat on the environmental factor in question.

The A1 qualifier, which initially measured the importance of environmental change, has been changed to measure the spatial scale at which the environmental change occurs. This modification was necessary due to challenges in assessing the importance of environmental change for human society, given the multitude of activities that

generate an impact on the environmental element. Both criteria assess the spatial scale, and the unit of measure stays unchanged. Then, score ranges for different impact categories were adjusted based on incremental changes.

The assessment criteria are grouped into two categories (Table 2):

1. Category A (A1 and A2) - criteria of major importance in characterizing the impact and which must be able to fundamentally change the evaluation score. The A category score is obtained by multiplying their marks, ensuring everyone's weight is considered. These are (A1) Spatial scales at which environmental change is manifested. (A2) Magnitude in environmental change, which measures the size of environmental benefits or harms.

2. Category B (B1, B2, and B3) - value criteria in the description of the situation, but which should not be able to influence the evaluation score individually. The three grades are added together to obtain the category B score. They are (B1) Permanence - defines the temporary or permanent character of the impact-generating agents. (B2) Reversibility - notes the extent to which it is possible to return to pre-impact conditions. (B3) Cumulativeness - measures the potential of impact-generating agents to generate cumulative impacts over time or the potential of impacts to act synergistically with other effects.

The formula for calculating the evaluation score for an environmental component is as follows:

$$A1 \times A2 = At \quad (1)$$

$$B1 + B2 + B3 = Bt \quad (2)$$

$$At \times Bt = SE \quad (3)$$

Where: At is the total score for category A; Bt is the total score for category B; SE is the evaluation score for the environmental components. If the value of B1, B2, and B3 is 0, for arithmetic reasons, the criterion Bt will receive the value 1.

Table 2. Impact assessment criteria and scores applied in RIAM

Assessment criteria	Assessment Score (AS)	Class of Impact (CI)
A1 - Spatial scale at which environmental change is manifested	3	Modification at the level of the entire study area
	2	Change on a local scale
	1	Modification at the point/individual level
	0	Without importance
A2 - Magnitude in environmental change	+3	Significant and extensive benefits to the environment
	+2	Noticeable improvement
	+1	Minor improvement
	0	Lack of change
	-1	Minor negative change
	-2	Noticeable negative change
	-3	Significant and extensive damage to the environment
B1 - Permanence	0	Very short-term/ not applicable
	1	Temporary
	2	Permanently or long-term
B2 - Reversibility	0	Very easily reversible/ not applicable
	1	Reversible
	2	Irreversible or with particularly slow recovery
B3 - Cumulativeness	0	No change/not applicable
	1	Easily cumulative or synergistic
	2	With high cumulative or synergistic potential

The scoring grid proposed in the present method is different from Pastakia's and Jenssen (1998) original version. While the original grid had the largest score of ± 108 , the new one had a lower sensitivity, with the highest possible score being ± 56 . However, the new grid emphasizes the criteria in category B, which helps the current study. In the original matrix, hypothetical impact scores were used to create a boundary

between categories. We believe this approach would not be suitable for the modified RIAM used in the present situation due to the diverse range of activities and the possibility of several activities affecting the same environmental factor. Using clearly defined thresholds could compromise the objectivity of the assessment.

We divided the score range semi-arbitrarily, with smaller increments at the bottom and larger increments at the top (Table 3). We aimed to make use of the sensitivity provided by the higher weighting of group B criteria to distinguish small size impacts better. We believe these ranges will allow us to make more correct judgments on the side of major impacts, which are difficult to estimate using our chosen method. The higher categories are broader and thus provide greater confidence in our judgments about major impacts.

Table 3. Conversion of obtained assessment score (AS) into impact categories (IC) and description of these categories.

Assessment score (AS)	Impact category (IC)	Impact category (IC) description
+39 to +54	+E	Major positive impacts
+27 to +38	+D	Significant positive impacts
+15 to +26	+C	Moderate positive impacts
+7 to +14	+B	Minor positive impacts
+1 to +6	+A	Slightly positive impacts
0	N	No changes in environmental status
-6 to -1	-A	Slightly negative impacts
-14 to -7	-B	Minor negative impacts
-26 to -15	-C	Moderate negative impacts
-38 to -27	-D	Significant negative impacts
-54 to -39	-E	Major negative impacts

Given the heterogeneity of the study area, the evaluation matrix encompasses general environmental components, as depicted as an example in Table 4. This approach mitigates the risk of overlap or redundancy among the components, thus ensuring consistent evaluations across multiple components. However, this needs a trade-off between comprehensiveness and specificity, and capturing aspects in the matrix could prove challenging. For example, were we to have included different forest habitats or geological processes, the evaluation process would have been more intricate. Hence, while the current approach may not account for all the intricacies of the study area, it provides a robust, standardized framework for evaluating the environmental components of interest. Table 4 presents the evaluation matrix of the anthropogenic impact on Point 13 (a peri-urbanized wooded area), situated at the intersection of Făgetului Street and Petre Dulfu Street, which is representative of the developed real estate area.

Table 4. Human impact assessment matrix on Făgetul Clujului wooded area (for example Point 13, considered representative of the real estate area developed here).

Environmental components	A1	A2	B1	B2	B3	AS	IC	Sources of impact (types of activities coded and inventoried)
ABIOTIC (PHYSICAL & CHEMICAL NATURAL) COMPONENTS								
Geological substrate and mineral resources	0	0	0	0	0	0	N	Excavation, exploitation
Soils	3	-1	2	1	2	-15	C-	Burning, covering with constructions, and inert materials
Initial terrain morphology	1	-1	2	1	0	-3	A-	Excavation, leveling, and terraces.
Groundwater, lakes, and springs (changes)	2	-1	1	0	1	-4	A-	Capture, abandon, and modification of surface runoff regime.
Water quality	0	0	0	0	0	0	N	Spillage and pollution.

Environmental components	A1	A2	B1	B2	B3	AS	IC	Sources of impact (types of activities coded and inventoried)
Air quality	2	-1	1	0	0	-2	A-	Emissions from fixed and mobile sources.
Topoclimate (changes)	2	-1	1	0	1	-4	A-	Removal of vegetation and covering the land with construction.
Torrent/Linear Erosion (Enhancement)	2	-1	2	1	0	-6	A-	Acceleration by removing the vegetal carpet.
Sedimentation/clogging /subsidence	0	0	0	0	0	0	N	Storage of inert materials.
Terrain stability (landslides)	0	0	0	0	0	0	N	Acceleration through interventions in the geological substratum or water drainage.
Assessment score (AS)						-34		
BIOTIC COMPONENTS (BIOLOGICAL AND ECOLOGICAL)								
Forest habitats found in the Management Plan of ROSCI 0074 (Făgetul Clujului-Valea Morii)	3	-2	2	1	2	-30	D-	General forestry management, wildfires, and fragmentation of habitats.
Other wooded areas, shrubs, and bushes	2	-2	1	1	2	-16	C-	Fragmentation of habitats through the fencing of privately owned lands.
Herbaceous vegetation (rare herbaceous plants found in the Management Plan of ROSCI0074 Făgetul Clujului-Valea Morii)	1	-1	2	1	2	-5	A-	Burning, grazing, and harvesting.
Pastures	2	-2	2	1	2	-20	C-	Stripping, erosion, burning, and grazing.
Bird fauna	2	-1	1	1	0	-4	A-	Disturbance, noise, light, hunting, wildfire, and poaching.
Amphibians & Reptiles	1	-2	2	1	0	-6	A-	Affecting ecological functions, harvesting.
Species of invertebrates	2	-1	1	1	1	-6	A-	Affecting ecological functions, harvesting.
Assessment score (AS)						-87		
Total assessment score (in assessment point no. 13)						-121		

c. Interpolation of impact assessment scores through the IDW method and GIS technique

The assessment scores' values were interpolated using the IDW (Inverse Distance Weighting) method from the QGIS technique. This is a software technique that sets up the value of a parameter across a surface based on known values from a set of points. The algorithm calculates a spatially scaled weighted average of the known points, and an unknown point is assigned a value closer to the values of the known points that are closer to it than those further away (QGIS 3.34, 2022).

The IDW method was used to generate geographical information based on the impact assessment's results. This information can be analyzed by experts or decision-makers. The evaluation scores for each point are interpolated to create a hypothetical evaluation score image for the entire study area. This image is then overlaid on a base map that displays other spatial elements related to the natural and anthropogenic environment. Thus, we can interpret the geographical distribution and the surface of the areas affected by the anthropogenic impact.

4. Discussion

To assess the environmental impact on the Făgetul Clujului wooded peri-urban area, a mixed method was applied. This involved using a checklist to figure out the various

anthropogenic activities and natural processes seen in the area and associated with recently uncontrolled urban sprawl (Table 5). Then, the Rapid Impact Assessment Matrix (RIAM) was applied to each key point to assess its impact on the environment, and a total score for each element was obtained. The results of this assessment are shown in a checklist (Table 6).

It was found that certain activities like walking, cycling, and trekking on roads and paths were widely prevalent, while others such as grazing and harvesting of plant species were seen only in a few points. About half of the points analyzed showed activities related to rapid real estate development, which showed uncontrolled urban expansion. These activities often occurred together, and by analyzing them, it was possible to find a range of impact-generating activities specific to points with significant anthropogenic interventions.

The anthropogenic activities that have been found may seem small in spatial extent at an individual level, but they have a high potential for cumulative impact. For instance, the improper storage of diverse types of waste was seen in multiple locations, resulting in a two-dimensional manifestation due to the linear or areal spread of household waste and the presence of multiple discharge points for construction waste. However, other activities (e.g., access and traffic on roads and paths, noise, and light pollution) manifest themselves with quite different magnitudes from one point to another. This aspect was assumed a priori and justifies the advisory role of the checklist in the used methodology.

As the assessment's focus is on uncontrolled urban sprawl, certain activities such as organized forestry practices were not considered as they are not related to the phenomenon under study. Similarly, no importance was given to the activities performed in the area occupied by Făget 1.0 forest park and their impact as they are not directly associated with the study's purpose. These limitations made it challenging to evaluate the effect of certain impacts on environmental components as it was necessary to distinguish between the impacts of interest and those related to other socioeconomic and natural processes.

After evaluating the natural abiotic and biotic environmental components, the matrix method shows that there were only negative impacts. The points least affected by uncontrolled urban expansion were those with scores close to zero. Amphibians, reptiles, and certain species of invertebrates recorded positive impacts in certain points due to human activities such as filling for road construction, creating paths, and building roads through the forest for motorized sports, and ponds, which had the side effect of creating suitable secondary habitats for these species. However, the Management Plan of ROSCI0074 Făgetul Clujului-Valea Morii (2016) did not mention these positive impacts on the specific ones of community interest.

The synthetic matrix displays the environmental components that have been mainly affected by real estate development over the past decade. According to the theoretical aspects addressed in the paper, soils, forest habitats, and pastures have been most significantly affected. These impacts are particularly complex in both time and space.

In terms of the time scale, historical analyses using Google Earth images have revealed the expanding trends of built-up areas, which have fundamentally affected these components by replacing them. It has been revealed that the current state of the real estate market is leading to expansion in the peri-urban area of Cluj-Napoca, despite the administrative, legislative, conservative, and natural constraints.

Additionally, the presence of human-made elements, and their correlation with specific activities, can have diverse impacts on the environment at a point-in-time level. These are just examples of the considerations that have been used to assess the significance of anthropogenic impacts on soils, pastures, and forest habitats.

After analyzing the results, we can conclude that the changes made to the original RIAM had the intended effects. The total scores have been distributed well, with assessment points showing minimal impact, some having moderate impact, and some revealing major environmental changes caused by uncontrolled urban sprawl.

Points found within forested areas showed neutral values, which was expected since uncontrolled urban sprawl does not directly affect natural protected areas. These points and their scores were instrumental in setting up benchmark values and controlling the size of impacts, especially in terms of graphic and cartographic representation.

Table 5. Checklist of anthropogenic activities at predetermined assessment points

Main codes ¹	Specific codes ²	Anthropogenic activity or natural process - pressures/threats	Total	P 1	P 2	P 3	P 4	P 5	P 6	P 7	P 8	P 9	P 10	P 11	P 12	P 13	P 14	P 15	P 16	P 17	P 18	P 19	P 20	P 21	P 22	P 23	P 24	P 25	P 26	P 27	P 28	P 29	P 30
A - Agriculture	A04; A05; B06	Grazing and animal husbandry, grazing in a forested area, wildfires	5					*							*							*		*									
B - Forestry	B.02.02; B.02.03; B.02.04	Forest clearance, removal of saplings and dry or drying trees, wildfires	12		*			*			*	*	*		*	*			*			*	*				*						*
	B.02.05	Non-intensive wood production (leaving dead wood and old trees)	3					*							*			*															
	B.02.01	Planting and re-planting the forest	1			*																											
C - Mining and material extraction		Mining (sand, gravel, soil, clay)	2										*								*												
D - Communications Networks	D01	Roads, paths, routes	25	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	D02	Utility lines and services	11			*	*			*	*		*	*						*	*	*	*			*							
	D05	Improvement of access to the area	6	*														*	*	*						*							*
E - Urbanization, residential and commercial development	E01	Inhabited areas, the expansion of human habitation	16	*		*	*		*	*	*	*	*		*	*	*		*	*	*		*			*							
	G.05.09	Fences, enclosures, yards	16	*		*	*		*	*	*	*	*		*	*	*		*	*	*		*			*							
	E.03.01; E.03.03; E.03.04	Storage of inert waste from construction and other materials	10	*			*				*		*			*			*	*			*			*							*
	E.04	Infrastructures and constructions in the landscape	9	*		*	*		*		*	*				*				*				*									
G - Human intrusions and imbalances	G.01.02	Walking and cycling, recreational activities	8	*	*							*						*					*			*	*						*
	G.01.03	Motor vehicles & off-road driving	5		*													*					*			*							*
	G.02.08	Camping pitches and caravan parking areas	2		*																												*
H - Pollution	H.06.01	Noise pollution and light pollution	12	*		*	*		*	*	*	*				*				*	*		*			*							
I - Invasive species	I	Invasive species	8								*	*				*			*	*	*		*			*							

Main codes ¹	Specific codes ²	Anthropogenic activity or natural process - pressures/threats	Total	P 1	P 2	P 3	P 4	P 5	P 6	P 7	P 8	P 9	P 10	P 11	P 12	P 13	P 14	P 15	P 16	P 17	P 18	P 19	P 20	P 21	P 22	P 23	P 24	P 25	P 26	P 27	P 28	P 29	P 30
J - Modifications of the natural system	J.02.07	Groundwater capture	12				*				*	*	*		*	*	*		*	*	*		*			*							
K - Natural Biotic and Abiotic Processes	K.01	Erosion, clogging, drought	11		*	*	*	*									*		*		*	*		*					*				*
	K.03.06	Antagonism with domestic animals	10						*		*	*	*		*	*				*	*		*			*							
L - Geological events and natural disasters	L.05	Landslides	4																	*	*					*	*						

¹Main codes according to MO 304/2018; ²Specific codes according to MO 304/2018; ³Total no. of points

Table 6. The synthetic matrix of the impact categories on each component, respectively of the total scores for each point of interest

Class	Environmental components	P 1	P 2	P 3	P 4	P 5	P 6	P 7	P 8	P 9	P 10	P 11	P 12	P 13	P 14	P 15	P 16	P 17	P 18	P 19	P 20	P 21	P 22	P 23	P 24	P 25	P 26	P 27	P 28	P 29	P 30	
ABIOTIC	Geological substrate and mineral resources	N	N	N	N	N	N	N	N	N	A-	N	N	N	N	N	N	N	N	N	N	A-	N	N	A-	N	N	N	N	N	N	N
	Soils	C-	B-	C-	A-	B-	A-	B-	B-	D-	C-	A-	C-	C-	A-	N	C-	C-	B-	A-	A-	A-	A-	C-	A-	A-	N	N	N	N	B-	
	Initial terrain morphology	B-	N	N	A-	N	N	B-	B-	A-	B-	N	N	A-	N	N	N	N	A-	N	N	A-	A-	A-	A-	N	A-	N	N	N	N	A-
	Groundwater, lakes, and springs (changes)	N	N	A-	A-	N	N	N	N	A-	A-	N	A-	A-	N	N	N	A-	A-	N	A-	N	N	A-	N	N	N	N	N	N	N	N
	Water quality	A-	N	N	A-	N	N	N	N	A-	N	N	A-	N	N	N	N	N	N	N	N	A-	A-	N	A-	N	N	N	N	N	N	A-
	Air quality	B-	N	A-	A-	N	A-	A-	A-	N	A-	N	N	A-	N	N	N	N	N	N	N	N	N	N	A-	N	N	N	N	N	N	A-
	Topoclimate (changes)	B-	N	N	N	N	B-	A-	A-	N	A-	N	N	A-	N	N	N	A-	N	N	N	N	N	A-	N	N	N	N	N	N	A-	
	Torrent/Linear Erosion (Enhacement)	A-	A-	C-	B-	C-	N	A-	B-	B-	C-	B-	C-	A-	A-	B-	A-	A-	A-	B-	A-	A-	A-	B-	A-	A-	N	A-	A-	A-	B-	
	Sedimentation/clogging/sub sidence	A-	N	A-	A-	N	N	N	N	N	A-	A-	A-	N	N	A-	N	N	N	N	N	A-	N	A-	A-	A-	A-	N	N	N	N	A-
Terrain stability (landslides)	N	A-	N	N	N	N	N	N	B-	A-	N	N	N	N	N	N	N	N	B-	N	N	N	N	B-	N	N	N	N	N	N	A-	
BIOTIC	Forest habitat	B-	B-	A-	N	A-	A-	A-	C-	N	N	C-	B-	D-	B-	C-	C-	C-	B-	N	A-	A-	A-	D-	N	A-	N	N	N	N	N	B-
	Other wooded areas, shrubs and bushes	A-	A-	B-	B-	N	A-	N	B-	D-	C-	N	B-	C-	N	N	A-	B-	A-	N	A-	N	N	A-	N	N	N	N	N	N	N	B-
	Herbaceous vegetation	N	B-	A-	A-	A-	N	A-	A-	C-	B-	N	A-	A-	A-	B-	N	A-	A-	N	N	A-	N	A-	N	N	N	N	N	N	A-	A-
	Pastures	N	B-	C-	C-	N	N	C-	C-	C-	C-	N	C-	C-	C-	N	C-	C-	C-	A-	A-	A-	N	C-	N	N	N	N	N	N	N	B-
	Bird fauna	B-	A-	A-	A-	N	B-	A-	C-	A-	A-	A-	A-	A-	A-	A-	A-	A-	A-	N	A-	N	A-	A-	A-	A-	A-	A-	A-	A-	A-	A-
	Amphibians & Reptiles	N	N	A-	A+	B+	N	N	N	N	N	N	B+	A-	A-	N	B+	N	A+	B+	N	N	B+	A+	B-	A+	A+	N	N	N	A-	N
	Species of invertebrates	N	B-	B-	A-	A-	N	A-	B-	C-	B-	C-	A+	A-	A-	A-	A+	B-	B-	A-	N	B-	A+	A+	B-	A+	A+	N	N	N	A-	B-
	Total scores	-90	-62	-104	-60	-25	-37	-65	-148	-146	-136	-14	-102	-121	-43	-10	-94	-105	-66	-16	-34	-7	-4	-137	-6	-16	-2	-5	-5	-13	-91	

Based on the total points evaluation scores, a thematic map of the impacts (Figure 3) was made in the QGIS program using the IDW method. In the calculation parameters, the distance coefficient P (which dictates the weight of each known value next to the pixel to be calculated) was given the value 3, a larger value than usual.

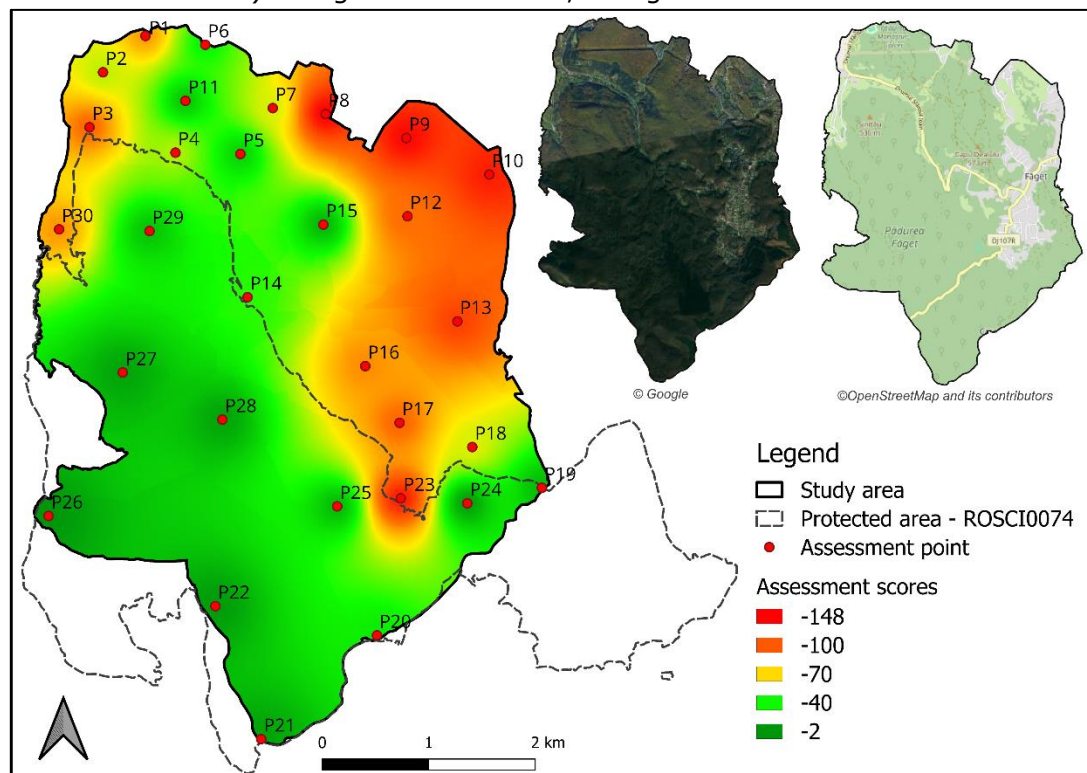


Figure 3. The map of the environmental impact of uncontrolled urban sprawl in Făgetul Clujului, a peri-urban wooded area of Cluj-Napoca Municipality, Romania.

This decision was made on the one hand to compensate for missing data in forested areas (a small P-coefficient causes distant points to have a large weight on the pixel to be calculated, which causes forested areas between well-scoring points to receive considerable scores weaker than these), and on the other hand to limit the influence in the area of the significant scores recorded by the areas where impact is generated, in order not to give rise to aberrant inferences on areas that could not suffer from impacts of such magnitudes.

It was decided not to classify total scores into impact categories as it would have been difficult to justify the thresholds for such categories. This is because it would have been challenging to compare the importance of different environmental components, and it could have been based on subjective judgments or unfounded assumptions. The appearance of the map also suggests that the advantages of such a classification would have been minimal in the current context, and the categories would not have had any practical significance for presentation and interpretation.

The thematic map effectively shows the negative impact of uncontrolled urban growth on the Făgetul Clujului peri-urban area. Based on the method used, it is assumed that the forest fragments without special protection, particularly those in the northeastern quarter of the studied area, are the most affected by this unchecked expansion. Furthermore, the visual analysis and in situ observation highlight the boundary impact on the site of community importance, which is also discussed in the Management Plan of Făgetul Clujului-Valea Morii ROSCI0074.

5. Conclusions

Peri-urban forests and wooded areas can suffer from various environmental impacts, depending on how they are managed and used. However, they also have diverse benefits, including providing ecosystem services like air purification, water regulation,

soil conservation, local climate improvement, and biodiversity conservation. They can also offer cultural and recreational opportunities for urban residents, such as hiking, biking, birdwatching, education, and spiritual values. Moreover, they can support local livelihoods and food security by providing wood, fuel, food, medicine, and other natural products. However, peri-urban areas are vulnerable to natural hazards like fires, pests, diseases, and storms, which can be worsened by climate change. Therefore, it's crucial to use integrated, interdisciplinary, participatory, and strategic approaches to planning and managing peri-urban forests. This will help to maximize their benefits and minimize their negative impacts.

Assessing the scale, intensity, and nature of human-made effects that arise from the uncontrolled growth of cities poses a considerable challenge for Environmental Impact Assessment (EIA). The complexity of this matter requires a thorough comprehension of a range of factors implicated, such as urbanization procedures, land prices, land ownership regime, local terrain exploitation models, and their associated environmental and socio-economic outcomes and restrictions.

Our methodology is important for an extended understanding of the effects of uncontrolled urban expansion on the study area. We use a combination of checklists, matrices, and GIS techniques to assess the local environmental system holistically. The checklists record both anthropogenic activities and natural processes, while matrices measure their impact on the environment. GIS and IDW are used to map the environmental impact of uncontrolled urban sprawl in the study area.

This analytical approach provides a simplified and transparent network that considers multiple environmental elements and territorial relationships. By evaluating the impact recipients (e.g., environmental components), we can draw semi-quantitative conclusions on the state of the local environment without the need to measure and describe individual impacts.

Despite the strengths and weaknesses of the applied method, we consider that the method is appropriately designed and applied for the study's purpose, scale, and available resources. This assessment presents easily understandable and verifiable information about the effects of uncontrolled urban expansion in this peri-urban wooded area. It also offers credible insights into the current state of the local peri-urban environment. Despite our best efforts, we met some limitations in the methodology used to gather and verify existing environmental data. These limitations were the result of a partial lack of credible sources to supplement the data collected both in the office and in the field.

Based on the study conducted, it can be concluded that the environmental state of the area is currently acceptable. However, there are clear indications of fragility and slow degradation that are a result of human activities, both existing and potential. The biggest threat to the wooded peri-urban area is the uncontrolled expansion of inhabited areas, which causes the elimination of vegetation and soil. Additionally, the interaction between the Făgetul Clujului forest and the urban sprawl of Cluj-Napoca Municipality has significantly negative impacts on natural habitats and species. This could lead to the emergence of secondary biocenoses with smaller biodiversity and an increase in the presence of non-native species.

We believe that implementing proper administrative and environmental monitoring measures can help mitigate the negative impacts on the Făgetul Clujului peri-urban area and manage the threats to its ecological state, quality, and integrity. At the same time, a modern and initiative-taking vision of the local authorities can help sustainably exploit the ecosystem services offered by the area. As mentioned earlier in the paper, the Făget Forest's proximity to populated areas and good conservation status offer an opportunity to integrate the forest as a key element in the current and future green-blue infrastructure of the Cluj-Napoca Municipality.

To improve the depth and quality of future studies like this, we recommend the following: Firstly, public information should be made available about the real estate development in the areas surrounding Cluj-Napoca Municipality, as well as the related infrastructure and utility networks. Secondly, a multidisciplinary team, including representatives from the local administration, should be involved. Thirdly, the method

used for impact assessment should be calibrated, improved, and developed by evaluating it alongside other assessment methods and techniques. Lastly, ecological studies should be conducted to examine the impact of inhabited areas on species and habitats of conservation interest.

Local and national administrations need to take the lead in controlling uncontrolled urban sprawl and managing peri-urban forests. This can be achieved through administrative and political measures, such as implementing more rigid urban plans to regulate suburban development and better monitoring of their compliance. Another approach is to guide suburban development with the help of experts and adopt best practice models from countries with a tradition in peri-urban forest management. Moreover, developing suburban areas in the form of projects that ensure the development of environmental studies to issue regulatory acts can be helpful. Finally, promoting the principles of green infrastructure connecting green spaces and making them more accessible to ecosystem services can be another effective measure.

To make the most of the methodology and information provided by this study, it is necessary to scrutinize the significant aspects and impacts revealed in the study area. It's important to mention that the presence, intensity, and magnitude of activities that cause an impact may vary over time. Additionally, the local biodiversity in the area might meet positive or negative changes due to administrative and environmental measures taken to limit uncontrolled urban expansion.

We have concluded that conducting this study is one of the necessary steps towards achieving sustainable management of the peri-urban area of Cluj-Napoca Municipality. The methodology's integrated framework helped us find, assess, estimate, map, and interpret the impact caused by uncontrolled urban expansion. We hope that our methodology is easy to understand, practical, and suitable for authorities, experts, and other stakeholders.

Author contributions: Muntean O.L. - concept & theory, design, acquisition of data, data interpretation, and writing the manuscript. Osiescu T. - concept & theory, acquisition of data, data interpretation, spatial analysis, and writing the manuscript. Baciu N. - design and writing the manuscript; Roșian Gh. - mapping and acquisition of data; Măcicășan V. - design and writing the manuscript; Arghiuș V. - design and interpretation of data.

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