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EVALUATING URBAN FORESTS CONNECTIVITY IN RELATION TO URBAN FUNCTIONS IN ROMANIAN CITIES

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Abstract: Urban forests are important elements of the green infrastructure network. Cities are changing under economic development and the planning of open spaces is increasing in their complexity, with a wide range of land uses which need to be managed together. Urban forests are seen as strategic areas providing multiple benefits for the community and enhancing the quality of life. The present study evaluates the relation between structural connectivity of urban forests and urban planning, using seven Romanian cities as case studies. Spatial analysis allowed the evaluation of urban functions planned in the proximity of urban forests. We used data extracted from the master plans of cities, from their graphical and regulatory parts. In addition, we assessed structural connectivity by using landscape metrics such as the Proximity Index, Euclidean Nearest Neighbor and Percentage of the Landscape. We tested for differences in patch metrics values on groups of cities based on the Romanian urban hierarchy. Results highlighted two types of urban planning patterns in the proximity of urban forests: one with high percentages of built up space, especially residential areas (27.68% of the study area) and one characterized by open spaces where agricultural land (19.19%) is the most common type of land use. The assessment of structural connectivity revealed a statistically significant effect on the Proximity Index values by city rank. The group mean is higher for urban forests patches in cities having rank 0 and 2. Understanding the complex connections derived from the spatial configuration of urban functions, useful information in promoting the sustainable management of urban forests as part of the green infrastructure network is provided. Integration of urban forests management in urban planning remains an essential objective for achieving urban sustainability in Romania.

Keywords: urban green infrastructures, structural connectivity, urban planning, forest patch.

1. INTRODUCTION

Urban forests are important elements of the green infrastructure network in the urban landscape (Riitters et al., 2012). Even though there is no unanimously accepted definition at European level for urban forests (Ostoic & Koninendijk 2015; Konijnendijk et al., 2006), they are now seen as strategic areas providing multiple benefits for the community: social, aesthetic and architectural benefits, climatic and physical benefits, ecological benefits, economic benefits (Konijnendijk et al., 2005), together with numerous co-benefits enhancing the quality of the urban life (Emborg et al., 2012).

The spatial and functional patterns of cities are topics of interest in urban studies because they provide useful information for urban planning to solve the problems affecting the urban community (Wu 2010). Many of the theories used in urban planning consider the city a mixture of areas with different functionalities (Tian et al., 2010). One of those functions required for a good quality of life is being connected to the green infrastructures within a city (James et al., 2009). Part of the urban landscape, urban forests are exposed to the transformations determined by the intense urbanization processes (Dobbs et al., 2014, Gong et al., 2013) as a result of driving forces such as socio-economic development, policy and technology advancements (Pirnat & Hladnik 2016).

Urban areas are faced with major challenges, and the habitat fragmentation of forests is considered one of them at European level (EEA 2006). This can result in barriers for species movement, loss of biodiversity (Miller, 2012) and a weak provision of other types of ecosystem services (Pirnat & Hladnik 2016). The construction of roads and the expansion of low-density built spaces are disturbing the balance between the compact city and natural areas, reducing their ecological and recreational value (Konijnendijk et al., 2005).

One of the main characteristic of the green infrastructure network is connectivity. From an ecological landscape perspective, connectivity defines the spatial continuity of a habit or a land use/cover type (Turner et al., 2001) and also the capacity of a landscape to allow the movement of individuals (Diekotter et al., 2008, Uezu et al., 2005). It is also a multi-scalar concept used to support decision processes in conservation plans (Luque et al., 2012) and sustainable urban development (Yu et al., 2014). Structural connectivity is related to the spatial configuration of patches in the landscape (Iojă et al., 2014) and can be evaluated by measuring landscape patterns using distances between patches and area indicators (Dobbs et al., 2014, Uezu et al., 2005).

The study of urban forests connectivity is a topic of interest not only in current scientific research but also in general planning at territorial, urban or local scale (Pascual-Hortal & Saura, 2008), mostly in conservation planning (Minor & Urban, 2008) and recently as a response to global problems such as climate change (Nuñez et al., 2013). Frequently, the applied methods link the connectivity of urban forests with human activities using gradients (Ren et al., 2014), at the same time assessing the functional connectivity of urban forests using graph theory (Pirnat & Hladnik 2016) or focusing on quantifying the provision of ecosystem services and disservices (Dobbs et al., 2014).

Urban forestry as a field of study presents several main approaches, one of them focusing on the biodiversity and green infrastructures including an assessment of urban forests connectivity. The urban planning approach considers urban forest as part of the urban fabric and an essential element to achieve sustainable cities (Ostoic & Koninendijk 2015). Nevertheless, there is still a gap in addressing and integrating the management of urban forests as part of the urban planning policies. Romania has a long tradition in the forestry domain (Stancioiu et al., 2010) being one of the richest European countries in forest resources (Walentowski et al., 2013, Gurung et al., 2009). These forests can have a public or private ownership status and they are all managed under the Forestry Code Law (R.P. 2008).

Forests have always been regarded as vital resources not only for their wood (Bouriaud et al., 2013), but also for their services provision to the quality of life (Nowak & Dwyer, 2007). Their proximity has determined areas to be attractive for cities to expand and thus more buildings to be developed close to the forests edges leading to problems such as pollution, wildlife encounters, fires etc (Escobedo et al., 2011). All these environmental and social problems underline the fact that there is a lack of colaboration between urban planning and forestry.

The aim of urban planning is to organize and plan space according to economic, social and environmental constraints. Over the years, theories were conceived to explain the patterns of urban land use: Burgess's concentric theory 1925, Hoyt's sector theory 1939, CBD multiple nuclei underlining the interest in a better understanding of the urban spatial structure (Tian et al., 2010). The functional zonation of an urban area is based on urban planning documents and strategies (L350, 2001). This specifies the present and future functionality of a certain area, for example: residential use, green urban space, industrial areas.

Because cities are the most dynamic and heterogeneous landscapes in terms of development patterns, urban sustainability is a necessity (Wu, 2010). Carefully planned functional areas can make cities more resilient (Banica & Muntele, 2015) by using the green infrastructure network (Meerow & Newell, 2017). After the abrogation of comunist regulations on cities development in 1990, urban planning in Romania has experienced a period of confusion and lack of public policies. This allowed the expansion of built-up areas and transformation of cities limits (Iatu & Eva 2016), generating the urban sprawl phenomena in most of the large cities (Suditu et al., 2010).

At national level, Urban and Land planning Law no. 350/2001 (R.P. 2001), and the Urban Green Spaces Law no. 24/2007 (R.P. 2007) are the main regulatory documents influencing the planning of urban forests. Equally important is the Forestry Code (2008) that aplies to all forests. One of the designated urban green areas for a city are recreational forests, defined as forests with a specific infrastructure for recreational activities (R.P. 2007). One can also find forests planned for sanitary protection or for climate improvement purposes. Urban forest connectivity on the other hand is a topic missing from the urban planning process, while only elements of urban green infrastructures such as parks are sometimes designed to create a network and to connect with other areas.

Because there is no integrative approach between urban planning and forestry, understanding the connections between urban forests and the city can provide useful information for policy makers, local authorities and practitioners in the field of green infrastructure by helping to promote a sustainable development of urban areas (Baptiste et al., 2015). Therefore we chose to focus on the spatial configuration of urban functions in the proximity of urban forests.

This study aims to assess the connectivity of urban forests in relation to the urban planning patterns in Romania. The objectives of the paper are:
(i) To evaluate the urban planning patterns in the proximity of urban forests;
(ii) To assess the urban forests structural connectivity between cities.

2. DATA AND METHODS

2.1. Study area

Our study is conducted on seven Romanian cities: Bucharest (rank 0), Brasov and Iasi (rank 1), Sibiu and Giurgiu (rank 2), Cernavoda and Rupea (rank 3). The selection of the case studies was made by informed choice based on an analysis of master plans for 87 cities in Romania. The criteria used to select the cities were: to cover all the levels in the Romanian urban network hierarchy, each city selected having to have had urban forests inside its administrative limit and spatial data availability.

For spatial analysis purposes we considered that an urban forest comprises all the forest areas inside a city's administrative boundary. The cities are spread across Romania; they are localized in plain (Bucuresti, Cernavoda, Giurgiu), hilly (Iasi) and mountain (Sibiu, Brasov, Rupea) areas (Fig. 1).

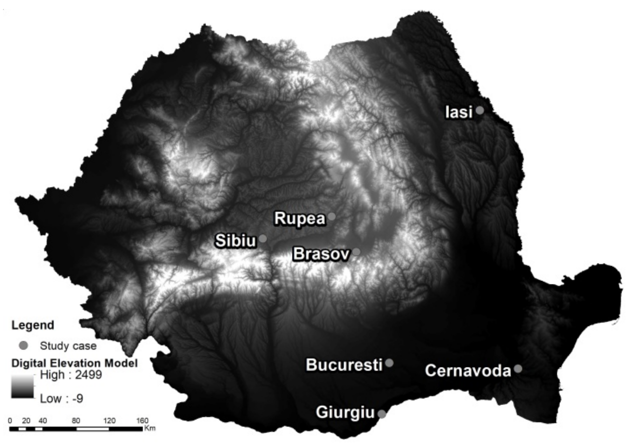

Figure 1. Map of selected case studies

All cities experienced landscape transformations in the decades following the fall of the communist period, which are translated into the expansion of built up areas, fragmentation of land uses/covers and loss of natural areas. Regarding the urban population, all cities subscribe to the national trend, the number of inhabitants decreasing in the recent years.

Bucharest is the city capital of Romania. Its largest part of the urban forest, Baneasa forest, is located in the north part. Brasov, Iasi, Sibiu and Giurgiu are important cities in the Romanian urban network playing a fundamental role at regional and county level. Brasov is located in the Carpathian Mountains and it is a very popular touristic destination for its cultural and historical heritage. Also the variety of landscapes offers the possibility to practice a wide range of recreational activities including winter sports, mountain biking, hiking etc.

The south part of the city, the mountain part, is occupied by forests and also includes an urban IUCN protected area – Tampa Mountain. Iasi is a county capital and a cultural and university center in Romania. Both Brasov and Iasi are fundamental transportation poles at national level. Sibiu was the European Cultural Capital in 2007 and it also has a touristic value due to the historical heritage. Giurgiu is a port located on the left bank of Danube River. Cernavoda and Rupea are small towns; the first one hosts the Cernavoda Nuclear Power Plant.

2.2. Data analysis

The main data source consisted in valid master plans of the cities. Besides Bucharest, all the other cities have had their master plans updated after 2009. According to Law no. 350/ 2001 (R.P. 2001) for the spatial planning in Romania a master plan has a validity of 5 to 10 years. Information regarding urban statistics was obtained from the National Institute of Statistics based on the 2011 Census.

The graphical part of the master plans was digitized and a GIS database was created using Arc Map 10 software. The urban land uses were aggregated into 8 classes of urban uses: residential area (individual and collective residential areas), mixt areas uses (services, cultural and educational institutions), industrial areas, agricultural areas, urban green spaces (other than urban forests), urban forests, transportation areas (roads, railroads, airports, naval areas), other urban land uses (special planning purposes, town management and cemeteries).

The local planning regulations, which are part of the master plan, were analyzed in order to see which land use categories were assigned for urban forests and what planning objectives were set for these areas. We focused on both spatial and regulation aspects by analyzing the GIS database and studying the Local Urban Planning Regulations.

To analyze the urban planning patterns in the proximity of urban forest we conducted a spatial analysis (Fig. 2). For every urban forest patch a buffer of 500 m was applied. The distance represents a 10 min walking area and it is oftenly recommended as an indicator for developing new urban green areas (Iojă et al., 2014, Kienast et al., 2012, Sander et al., 2010, Diaz-Varela et al., 2009, Barbosa et al., 2007). We calculated the percentages occupied by each of the urban land uses considered. We analyzed the differences obtained between cities and underlined the landscape patterns using correlations.

The second part of the analysis consisted in computing several landscape metrics for the assessment of urban forests structural connectivity. We selected the Proximity Index, Euclidean Nearest Neighbor and Patch Area metrics, which were calculated at patch level (Table 1). The search radius considered for the Proximity Index was 500 m, same as the buffer analysis. The selected landscape metrics are commonly use indicators for structural connectivity.

We converted the vector type data into raster data of 5 m cell. The connectivity metrics were computed using Fragstats 4.2 (McGarigal 2015). The resulted data was organized into continuous variables. We have used an analysis of variance (ANOVA) to test whether the rank of the city has had an effect on the structural connectivity of urban forests. Four groups were created according to the possible ranks in the Romania's urban hierarchy. We also tested for differences between cities.

We applied a log-transformation on the selected data and used Shapiro-Wilk test to assess the normality assumption and the Levene Test for the homogeneity of variances between groups. The statistical analysis was conducted using R 3.3.1 software.

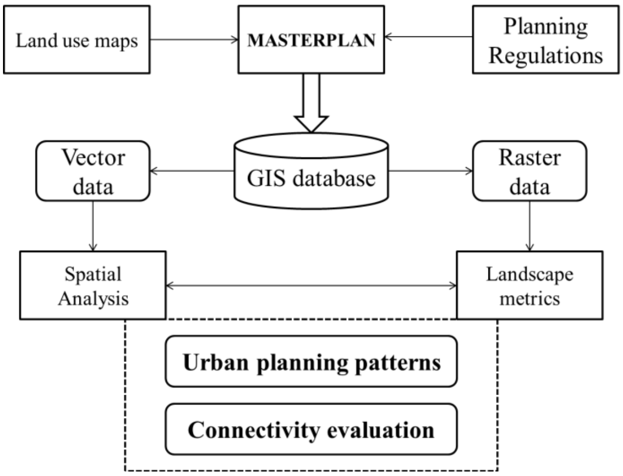

Figure 2. Methodological process

3. RESULTS

3.1. Evaluation of urban planning patterns in the proximity of urban forests

The analysis of planning documents and regulations established by the master plan revealed that urban forests are acknowledged in the urban planning process, being included in the wide category of green urban spaces (R.P. 2007).

Table 1. Landscape metrics selected for the assessment of structural connectivity of urban forests

Landscape metric	Explanation	Usage	Effect on connectivity
Percentage of Landscape (PLAND) 0< PLAND ≤100	PLAND measures the percentage of the landscape that corresponds to a certain class type of patches (McGarigal, 2015).	It is considered a fundamental metric to characterize landscape composition (Diaz-Varela et al., 2009, Sun et al., 2007).	+
Euclidean nearest-neighbor (ENN) 0< ENN	ENN is a measure of patch isolation and it represents the shortest Euclidean distance based on the edge-to-edge distance from the focal patch to the closest same class type patch (McGarigal, 2015).	It is considered a structural connectivity metric (Ioja et al., 2014, Magle et al., 2009).	-
Proximity Index (PROX) 0≤ PROX	The index is calculated as the sum of patch area divided by the square of the distance to the focal patch. High values are recorded when the search radius is occupied by same type patches which are closer and contiguous in distribution (Iojă et al., 2014).	It is used in characterizing the connectivity of landscapes with woody vegetation (Diekotter et al., 2008).	+

Nevertheless, the documentation review showed that there are no regulations taking into account the local specific conditions in the management of these areas. Most of the rules imposed are based on the national legislation with no input of the local authorities or experts. We also noticed differences in how urban forests are defined at a city level. One can find different types of land use classification such as *recreational forests* (Bucharest, Brasov, Iasi), *forests for sanitary purposes* (Bucharest, Brasov, Sibiu), protected areas (Brasov, Giurgiu) or simply just *forests* (Giurgiu, Sibiu, Cernavoda, Rupea).

The master plan imposes restrictions on cutting the trees or building, but at the same time there are no indicators concerning the urban forests environmental quality besides physical aspects such as surface.

Although their importance is generally acknowledged, there are still elements missing in quantifying their benefits. Looking at the spatial configuration of urban functions in the proximity of urban forests, we highlighted two patterns. The most encountered urban land use in the buffer area is the residential one, occupying in average 27.68% of it followed by agricultural areas with 19.19% (Table 2). At city level almost 30 % of the residential areas are planned within 500 m from the forests. These values are ranging from 30% (Brasov) to 70% (Cernavoda) from the total residential areas per city.

Table 2. Urban land uses percentages

Urban functions	Mean	Median	Std
Residential	27.68	31.92	22.09
Mixt uses	11.03	9.26	8.71
Industrial	7.01	7.04	3.02
Green spaces	16.00	9.44	19.91
Agricultural	19.19	10.00	26.33
Transportation	8.57	7.24	5.78
Other urban function	10.23	7.24	9.47

In the study area, the planning of open spaces (green spaces, agricultural areas) near forests is related to residential function occupying smaller percentages from the total residential areas of the city (lower than 7 % - Giurgiu, Sibiu). Industrial areas have the lowest mean percentage of surface occupied in the buffer area considered. Besides the city of Cernavoda (79%), the rest of the cities are reflecting small percentages (under 25%) of the total industrial areas which are planned within 500 m from the forests edge.

The spatial analysis showed that the percentage of residential areas planned within the buffer area positively correlates with the mixt uses areas (r =.48) and with transportation (r=.51).

Also urban green areas positively correlate with industrial areas (r=.51). Agricultural areas negatively correlate with the built up environment and urban green spaces with residential areas (r = -.52).

3.2. Assessment of urban forests connectivity

The connectivity indicators were computed for urban forests patches across the seven cities analyzed. The Proximity Index (PROX), W= 0.2832, p<.001, Euclidean nearest neighbor (ENN), W= 0.22554, p <.001, Patch Area (PA), W=0.1047, p<.001 were significantly non-normal. Regarding the homogeneity of variance, all three indicators showed similar variances between groups (Table 3).

Table 3. Homogeneity of variances between groups for each connectivity indicator

Connectivity Indicator	**Levene Test**
Proximity Index	F=0.4845, p=.69
Euclidean Nearest Neighbor	F=0.5693, p=.63
Patch Area	F=2071, p=.89

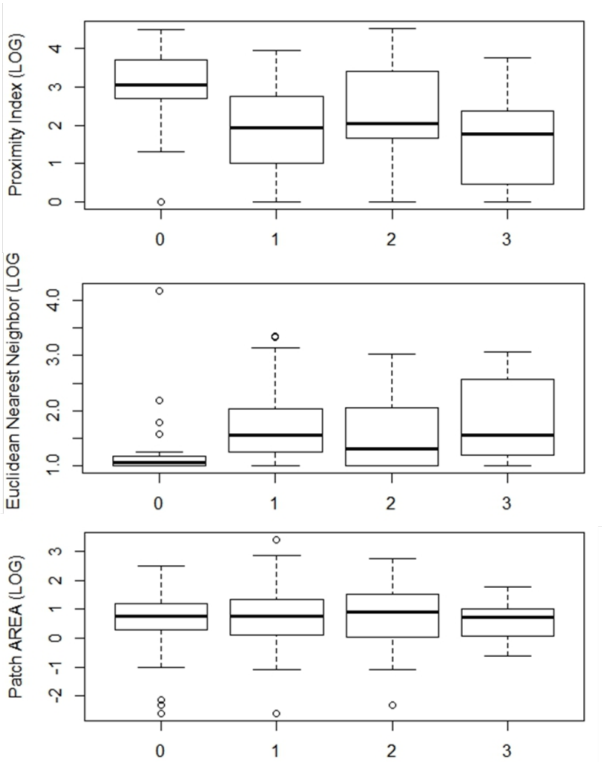

Figure 3. Boxplots: landscape metrics by city’s rank

The analysis of variance showed that there was a significant effect of the city’s rank on the Proximity Index values F (1,196) = 7.232, p<.01. The means values of this metric are higher in 2[nd] rank cities. For the ENN and PA values there were no statistical significant differences in relation to the city's rank (Fig. 3). At city level, there were significant differences for both of the metrics. Proximity Index values $F(6,191) = 5.753$, $p<.01$ and ENN $F(6,191) = 3.274$, $p<.01$.

4. DISCUSSIONS

4.1. Urban land use patterns in the proximity of urban forests

The master plan is a required planning document for the development of urban areas and it provides useful information for the study of urban landscapes. According to the Local Urban Planning Regulations within the cities master plan, most urban forests are regulated as recreational forests, forest plantations and forests for sanitary purposes. In contrast with other urban green areas (parks, public gardens, and water protection corridors) the master plan does not impose thresholds such as a percentage of occupancy by buildings (CUT) or a coefficient for land usage (POT), which are common planning indicators, and it does not specify a clear range of activities allowed in these areas. Our analysis highlights the ambiguity of planning documents regarding urban forests management as part of the urban landscape.

The analysis of urban functions planned in the proximity of urban forests underlined two types of urban landscape patterns. On one side, there is a planning pattern that is characterized by large areas of built up spaces. This pattern often includes high percentage of residential areas and also mixed use areas (Gavrilidis et al., 2015). Inside the buffer area of urban forests the residential percentage mean was 26.78 with some study cases above average (Bucharest, Brasov, Iasi, Rupea).

The second pattern comprises a higher percentage of open space which characterizes cities with large agricultural fields at the edge of the city. The differences between these two urban landscape patterns is closely linked with the spatial configuration of the built up limit and how the urban forests are configured in the landscape structure, both inside and outside this limit. The closer the city center they are, the higher the percentage of built up spaces around them is.

The correlation analysis revealed that urban green spaces correlate positively with industrial areas. This aspect shows the benefits of urban green areas for the purpose of improving the environmental quality around industrial sites by mitigating air pollution and noise.

The results highlight the spatial relationship established between urban forests and the rest of the city, presenting areas with a high complexity in terms of urban functions. Besides Bucharest and Brașov, which do not have agricultural areas specified in their master plan, all the other cities present all the categories of urban functions in the buffer area around urban forest. The implications of this spatial mosaic can be observed in the property value market or the land prices (Konijnendijk et al., 2005).

4.2. Analysis of urban forests connectivity

The results of ANOVA showed that for Euclidean nearest neighbor (ENN) and percentage of landscape (PLAND) indicators, there are no statistically significant differences linked to the urban hierarchy, the city rank. This underlines the fact that not all landscape metrics can be used as indicators to compare different planning situations and to formulated strategies higher than at local level.

Regarding the Proximity Index, the ANOVA analysis underlines that there are statistically significant differences between indicators values for the forests patches of cities with different ranks in the Romania's urban hierarchy. A city's rank is specified by the National Plan for Territorial Planning – Urban Planning section. The criteria for this establishment are based on city's importance in relation with other cities and also its level of urban development and population (Petrișor et al., 2010).

These findings correspond to other studies that have underlined a connection between cities importance and the surfaces of urban green infrastructures which include urban forests (Badiu et al., 2016). These differences on Proximity index values persist at city level but by comparing the F values obtained in the analysis of variances we noticed that the rank of the city has a greater effect than the city itself.

One of the main results of this paper is the spatial analysis of the urban planning in relation to urban forests location within a city. This comes to reinforce the importance of green infrastructures and the accessibility of it (Kolcsar & Szilassi, 2018), to be more precise in the case of the urban forests, as vital elements of urban landscapes for their positive externalities (Sanders et al., 2010).

The urban planning approach regarding the study of urban forest is based on an integrated perspective, including a strategic planning of forest areas in cities (Ostoic et al., 2015).

Our analysis seeks to evaluate the planning patterns in relation to urban forests from a spatial perspective. Because we have quantified only spatial indicators, the study is limited to this dimension and additional local urban data regarding population (density, profiles) would be recommended to be used for future approaches. The connections between urban forests and other urban land uses are more complex, the spatial perspective being just one component (Niță et al., 2015, Poenaru et al., 2015). There are other important aspects which need further research to better evaluate this relationship, such as the negative impacts of human activities on forests (MacDonald & Rudel 2005, Konijnendijk et al., 2005), socioeconomics drivers towards urban forests management (Gong et al. 2013), ecosystem services provision for different types of urban functions (Dobbs et al., 2014), and conflict resolutions between different land uses (Ianos et al., 2012). For better insights on urban planning, one must integrate multiple dimensions (socio-economic, ecologic and decision making) with different types of data: field measurements, social surveys.

5. CONCLUSIONS

In Romania there are different urban planning patterns in the proximity of urban forests, which underline the need for integration of their management into the planning process. Being part of the green infrastructures, urban forests must be connected to support sustainable development of urban areas. Our analysis revealed that the city's rank has had an effect on urban forests connectivity indicators.

The study is limited in terms of the spatial perspective's relation between urban forests and urban planning. The master plan proved to be a useful data source in terms of landscape assessment. Further research should consider other aspects for the analysis: social, economic and ecological ones. Planning the areas which are situated in the proximity of urban forests is a difficult task because it has to align the socioeconomic interests with the ecological ones. The planning process in their proximity must be made precocious without wielding too much pressure on the forest resources that can result in a depletion of benefits.

A particular focus should be orientated towards the urban planning process at different scales, as this can result in types of actions and strategies for maintaining the connectivity of urban forests in the urban landscape.

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