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Original Research

Methods of Including Invasive Species Research in Urban Planning – A Case Study on *Ailanthus altissima*

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Abstract

With the increased effects of urbanization, essential aspects such as green spaces or quality of residential areas were often reduced in importance in developing countries. At present green spaces in urban areas are facing problems related to invasive plant species, which have been introduced in order to mitigate potential environmental problems or to increase the landscaping values. The present research started from the existing documents on urban planning at national and local level and their consideration of invasive plant species. Based on these documents, we realized a spatial analysis of the distribution of *Ailanthus altissima* in an urban sample, with data generated from on-field mapping of presence, a data collector and comparison of results with a population survey. In order to collect data for analysis, 100 questionnaires were applied and a total of 1036 trees were mapped using the Survey 123 application. The results provide an overview of the presence and distribution of *Ailanthus altissima* in the different functional areas of the urban sample.

Keywords: cities design, invasive plant species, tree of heaven, functional areas

Introduction

Cities have always been economic centers and also places with a high population density. Even dating back to the first urban settlements, cities were attracting high numbers of people, which led to the exchange of ideas and perceptions about the quality of living [1]. From the oldest of times, urban poles were mostly areas with high economical potential, such as markets, boroughs, and others. In present times, a city can be defined as an urbanized area, highly important and influential from an economical point of view, and also specialized in providing services and communication, attracting high numbers of heterogenous people. The urbanization process, as a result of the development of industry, transport and construction networks, led to the emergence of a large deficit of green spaces [2]. This demographic growth has led to several important changes when it comes to economic diversity, social inequality, segregation, new governance models, and also new futuristic technologies. Therefore, all of these changes have contributed to the globalization [1].

Cities globalization has caused the transformation of society, offering a faster way of transporting both population and supplies, and also a significantly faster lifestyle. However, this also led to many challenges

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for cities and society [3]. Most of the challenges of the contemporary man have economic, social or ecological backgrounds, being faced with several issues like poverty, hunger, air, water and soil pollution, poor infrastructure, lack of resources, pressure on the built areas, invasive species, inefficient urban planning, and others. All these problems are closely related to land use changes, changes that are induced by humans [4].

Invasive species have extended their boundaries once globalization started to happen, because their transportation between states became faster [5]. The growth of terrestrial, aerial and naval traffic has been one of the major causes of the propagation of species between different regions with different geographical and ecological characteristics [6]. Both trade and tourism have been a core factor when it comes to plants, animals and biological material dissemination towards other frontiers [7]. This way, several species have had both positive and negative effects on society. In both cases, the ecosystems suffer major changes.

Invasive species have characteristics and abilities that have a tremendous impact on society [8]. Their annual costs in USA are of 34,7 billion dollars. The most aggressive invasive species worldwide, which caused the decrease of quality of life and high costs, endangering both the human health and indigenous plants, have a dissemination and adjustment rate of roughly 85-90%. The main illnesses caused by the pollen of *Ambrosia artemisifolia* are the allergic rhinitis, conjunctivitis, the hives and dermatitis. One of the species that presents an important impact on both economy and ecology is *Ailanthus altissima.* It has a high rate of dissemination in urban, agricultural and abandoned lands, having important effects on vegetal diversity, infrastructure and ecosystem [9].

Urban planning is a mixture of urban design, architecture, transport infrastructure, building engineering, green areas, and all of the other elements which can be found inside a city. In 19th century, at the time of industrial development, more specifically petroleum industry, urban planning was being debated by the Enlightenment philosopher's critical and rational ideas. This debate led to the redevelopment of cities and the improvement of urban life. But, with the passage of time, there are various inevitable changes in land use patterns [10]. Thus, one of the most important ideas of the 19th century when it comes to urban planning, and that is also present to this day is represented by the importance of green areas [11].

Once urban areas became more and more populated, several major changes started to happen, such as urban landscape deterioration, poor residential infrastructure, traffic and environment issues [12]. Therefore, the expansion of the urban areas towards the outskirts of the city caused the industrial areas to actually be placed in central zones of the city [13]. The inefficient urban planning also led to other issues such as lack of space, soil degradation, excessive air pollution, heat islands and urban landscape deterioration [14]. Urban landscape is also highly affected by the resident's increased interest in exotic plants. Therefore, the introduction of alien species in urban areas as ornamental species caused them to rapidly spread, having a high adaptability rate, especially along corridors such as railways, roads, rivers and canals [15]. Most of the newly introduced exotic plants are in fact invasive species, which are highly resistant in environments that suffered human impact. Therefore, the growth of invasive species in urban areas can be correlated with the decrease of native species in urban areas, in Europe [16].

In order to have a certain balance in urban areas when it comes to invasive species, there are two options. We can either eliminate them, or learn how to live with them [17]. Also, land use change is main reason why the urban biodiversity is decreasing, and coupled with urban expansion and all of the industrial activities, which cause heat islands, air, water and soil pollution, it can be said that the incorporation of invasive species in urban planning is a solution [18]. Considering urban planning, and the rapid expansion of invasive species in urban environments, which are two elements that developed chaotically in the last century, previous studies tried to find a correlation between the use of urban areas and the reproduction of negative species [19].

The main aim of this study is to explore methods of including invasive species research in urban planning, with a case study on *Ailanthus altissima*. The specific objectives are: (i) analyzing relevant planning documents for their approach on invasive plants species; (ii) mapping of *Ailanthus altissima* in an urban area; (iii) analyzing people perception about the advantages and disadvantages of invasive species in urban areas. The chosen area consists of a part of Bucharest which is known for the rapid growth of built areas and infrastructure, and also for the continuous increase of residents, which means that there is a high risk of inefficient and troublesome urban planning. The main purpose of this study is to evaluate the possibility of including invasive species in urban planning documents, considering their main benefits.

Material and Methods

Study Area

Bucharest, the capital of Romania, is a city located in southern Romania, 64 km north from the Danube River, 100 km south from the Eastern Carpathians, and 250 km west from the Black Sea. It is divided in 6 sectors, and this study refers to the south-eastern side of the city, more specifically the 4th sector. Sector 4 is diverse from the point of view of the functional areas. The most common areas are represented by residential areas, both collective and individual, industrial areas, aquatic surfaces, green areas and others. Green areas are mostly located in the central-north area, comprising most of the large parks of the sector: Carol Park, Tineretului Park, Văcărești Natural Park. Tineretului Park, Bellu Cemetery and the neighboring residential area make up the analyzed sample that makes this study's object. Most of the species from the green areas within Bucharest, sector 4 included, are indigenous species, but there are non-native species, too. These latter species were introduced in the green urban areas from sector 4 for decorative purposes [20], their possible future impact being unknown. Therefore, the new species that have been used to improve the urban landscape proved to be invasive species, which has been the case with *Ailanthus altissima.* That is because it is currently considered a troublesome species inside urban area. However, in the past it was used in the planning of green urban areas due to its ornamental qualities [21].

Extracting the Information about the Invasive Species

The more comprehensive study of the occurrence of invasive species started in 21st century, both worldwide and at a national level, in a wide range of official documents such as strategies, plans and urban development programs. For this study have been considered 15 official documents: 7 national documents – 4 strategies, 2 programs and a plan; 5 regional documents (Bucharest) – a strategy, a program, a plan and a project; and 3 local documents (sector 4) – 2 strategies and a plan. From these 15 documents various information regarding invasive species, green areas and especially observations regarding their approach at different scales have been extracted [22]. It is worth mentioning that in this case, when referring to green areas, this term will automatically include the invasive species. In most cases, when exotic or native trees are being planted in order to improve the urban landscape, one of their primary purposes is their resilience to pollutants. Thus, the vegetal layer is important in urban planning, whether it is about indigenous or non-native species, because trees are key organisms when it comes to pollutant retention and other positive benefits on the environment and the human health [18]. The fact that the existence of invasive species in sector 4 is confirmed in relevant documents is helpful for understanding the necessity of urban planning to take into account the non-indigenous plants capacity to disseminate and to settle. The paper „The methodology of municipality assistance in urban development" includes a variety of subjects, among which it is present the introduction of invasive species in central parks from Bucharest. One of the most encountered species is *Ailanthus altissima* [23]. Therefore, to analyze this species, relevant information has been extracted by the means of 4 methods: documentation, mapping, surveys and spatial methods (Fig. 1).

Documentation was used in order to define several terms, to identify the key theoretical aspects related

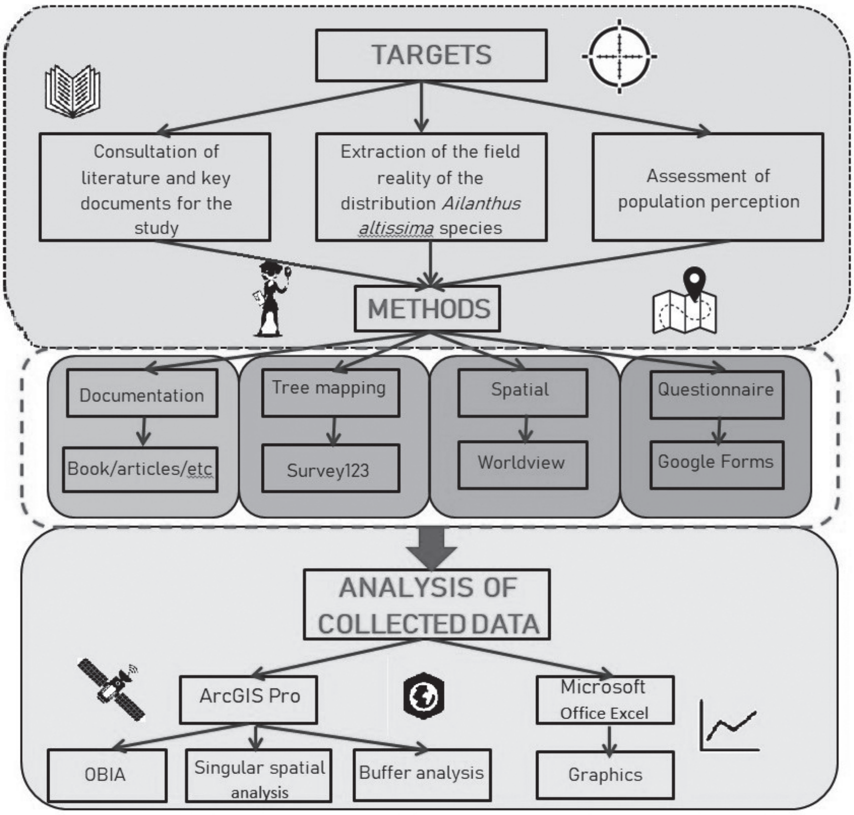

Fig. 1. Detailed methodological flow of the research.

to the essential characteristics of the species, and also the positive and negative effects. Documentation is the justification offered for data and concepts derived from external sources in our research paper. Both original sources and secondary sources are cited as examples of that evidence. After analyzing specialized documents, it has been concluded that the *Ailanthus altissima* species is an invasive allogenic plant, which has a negative impact on economy, ecology and society. In this case, the plant multiplies two ways: asexual [24] and vegetative. This species can disseminate on short distances, in the proximity of the vegetative propagating stem. However, it disseminates asexually on up to 90 m. Also, as it is a dioecious species, the masculine and feminine flowers on different individuals. Usually, the highest production belongs especially to trees aged 12-20.

The mapping of the species has been carried out at the same time with the survey sheet. Mapping of the species was made with the Survey 123 app, and in order to properly locate the geographical coordinates, the mobile phones GPS was used. A full, form-centric solution for creating, sharing, and evaluating surveys is ArcGIS Survey 123. It has been used by us to design forms that support several languages and have skip logic and default settings. Even when you are not connected to the Internet, data can still be acquired via the web or mobile devices. This method of collecting in-field data by using a mobile application can be susceptible to errors when it comes to positioning the point on the map, by a few meters. The physical characteristics of each individual were measured with a Lasermeter. The observation sheet was compiled using ArcGIS Survey 123 and applied by using the mobile phone Huawei P20 Pro and the Survey 123 application. The questions in the observation sheet focused primarily on the physical characteristics of the individuals. The sample in which the species was mapped comprises the following types of functional areas: green areas (park, cemetery, residential gardens) and collective and individual residential areas. The Park that was chosen for this study is Tineretului, which has the largest surface in the sector and the 3rd largest in Bucharest. In its immediate vicinity it is situated the Bellu cemetery, mentioned earlier. It is the most famous and one of the longest running in sector 4 [25]. In total, 1036 individual were mapped in 30 days, between 1-30 September 2019, on a 269-ha surface.

A questionnaire is a type of research tool used to gather data from respondents and consists of a series of questions or other prompts. Typically, a research questionnaire will have both closed-ended and open-ended questions. Long-form, open-ended inquiries provide the reply room to expand on their ideas. Both qualitative and quantitative information can be gathered with a data collecting questionnaire. A survey may or may not include a questionnaire, but a survey always includes a questionnaire [26]. The survey, which was created in Microsoft Word, was transposed in Google Forms in order to be shared with a large number of people living in Bucharest. The survey was applied exclusively online, being posted on social networks such as Facebook, in various groups with a significative number of participants. The survey is comprised of 27 questions, having both closed answer questions and open answer ones, in order to receive a large diversity of answers. In total, 100 participants answered the survey.

The spatial method can only be applied after the other methods have been applied. Therefore, the data obtained after applying the observation sheet, the survey, the mapping and the one from scientific literature could be modelled for graphic and cartographic visualization, but in order to understand these species' purpose in urban planning. Thus, after applying this method, several maps were obtained, such as: spatial distribution maps, density maps and others. Also, in order to estimate each individual's age, the Model Builder was applied starting from the principles of finding the age based on the trees height developed by previous studies [27]. Another method used for data analysis is the Buffer analysis. Furthermore, in order to analyze the spatial distribution of the *Ailanthus altissima* in sector 4, we applied an object based image analysis, more specifically a supervised classification. It was done on a satellite image from Worldview, with a 1 m resolution. This method is based on an older concept, the segmentation, which involves dividing an image into several categories: point-based algorithm, margin-based, region-based, or mixed [28]. There are 8 bands of the satellite image that were used: band 1 – Coastal blue (400-450 nm), band 2 – Blue (450-510 nm), band 3 – Green (510-625 nm), band 4 – Yellow (585-625 nm), band 5 – Red (630-690 nm), band 6 – Red-edge (705-745 nm), band – Near-IR 1 (770-895 nm) and band 8 – Near-IR 2 (860-1040 nm) [29].

The first step applied within the object-based image analysis is the segmentation, which consists in converting a pixel/image type structure into an object type structure, after which these objects/segments will be outlined on the limit of different pixels. Therefore, throughout this step, all of the information within pixels are being transferred in polygons. During this step, the objects are being classified by the means of 3 parameters: scale parameter, shape factor and smoothness. The scale parameter is used to extract objects depending on their size. The other two parameters, shape factor and smoothness, relate to the homogeneity and heterogeneity of the objects and to the association between them [30]. The second step, which is the actual classification, a list with the relevant classes for the analysis was created. The classification algorithm will allocate an object to a certain class, so we will not have to select pixels and allocate them to a class. We will simply select segments which we'll then assign to the classes we created. There is a total of 13 classes, most of them representing different species of trees. Several classes were created for vegetation

Table 1. Details about the documents at national and local scale included in the analysis.

Scale	Documents	Name	Year	Presence /Absence of green spaces	Presence / Absence of invasive species	Observations	
						Positive	Negative
Romania	Strategies	Romania's territorial development strategy	2016	Present	Absent	-	-
		Romania's National Strategy for Sustainable Development Horizons 2013-2020-2030	2008	Present	Present	-	- disruption of natural and semi-natural systems
		Romania's development strategy in the next 20 years	2015	Present	Present	-	- extension of invasive species; - combating invasive species
		Romania's National Strategy for Sustainable Development 2030	2018	Present	Present	-	-
	Programs	Regional Operational Program 2014 - 2020	2015	Present	Absent	-	-
		National Rural Development Program for the period 2014 - 2020	2014	Present	Present	-	- negative impact on native species
	Plans	National Recovery and Resilience Plan	2021	Present	Absent	-	-
Bucharest	Strategies	The integrated urban development strategy of Bucharest and its territory of support and influence	2012	Present	Absent	-	-
	Programs	Bucharest's local government program	2016	Present	Present (indirect mentioning)	-capability to adapt quickly; - decorative value; - pollution resistance	-
	Plans	Integrated urban development plan – Central Area Bucharest	2010	Present	Absent	-	-
	Project	Bucharest ring highway km 0+00 – km 100+900	2020	Absent	Present	-	-installation of invasive species
	Project	Opportunity study on how to delegate the maintenance service for trees and green spaces in Bucharest	2017	Present	Present (indirect mentioning)	- improving the quality of the landscape	
Sector 4	Strategies	Sector 4 development strategy for the period 2020-2024	2020	Present	Absent	-	-
		Sector 4 development strategy for the period 2016-2020	2018	Present	pPresent	- decorative value	- affects native species
	Plans	P.U.Z. Sector 4 Coordinator – Southern Area	2017	Present	Present	- function of the area connectivity	-

in order to separate the *Ailanthus altissima* species from the other ones, which are mostly indigenous species. In the end, it resulted a file which contains polygons [31].

Results and Discussion

Invasive Plant Species in Planning Documents

In order to incorporate the species in national, regional and local planning documents, 15 strategies, plans, programs and projects were analyzed. In Table 1 we mentioned information about the presence or absence of green areas, and also of the invasive species. Alongside mentioning the presence of invasive species, several considerations are being made regarding their positive or negative character.

In Romania, the invasive species are being mentioned in only 3 of the 6 official documents. The main points refer to their negative impact on local species, the high degree of dissemination and the disruption of natural and semi-natural systems. In Bucharest, only 3 of 5 documents offer details about invasive species. Among these 3, the only project that highlights the *Ailanthus altissima* species is the one titled „Bucharest ring highway km 0+00 – km 100+900". The main points regarding the species are positive, more exactly their decorative role and the fact that they are resilient in highly-polluted environments. At national, regional and local scale, the urban planning documents that refer to invasive species are similar. Therefore, in sector 4, among the 3 documents considered for this study, in only 2 of them are being mentioned both negative and positive aspects of invasive species.

Research on Invasive Plant Species

In sector 4, although the *Ailanthus altissima* species is not mentioned in official planning documents, it has been identified and confirmed, together with other invasive species, in scientific articles, official sites, by people that participated in the survey, and by the authors when we applied the observation sheet to each individual in the analysis sample.

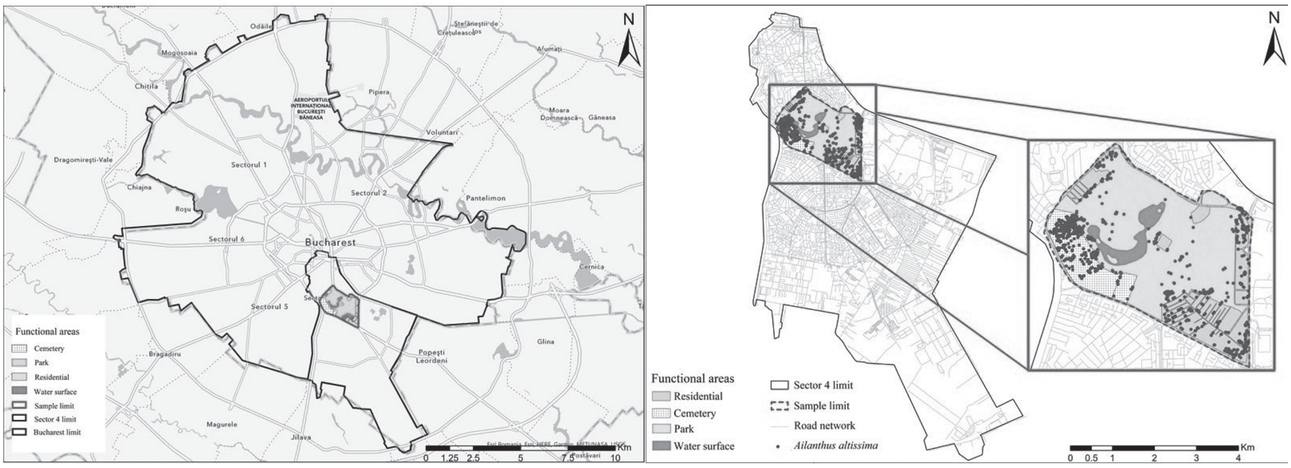

Fig. 2. Location of the detailed case study in Bucharest.

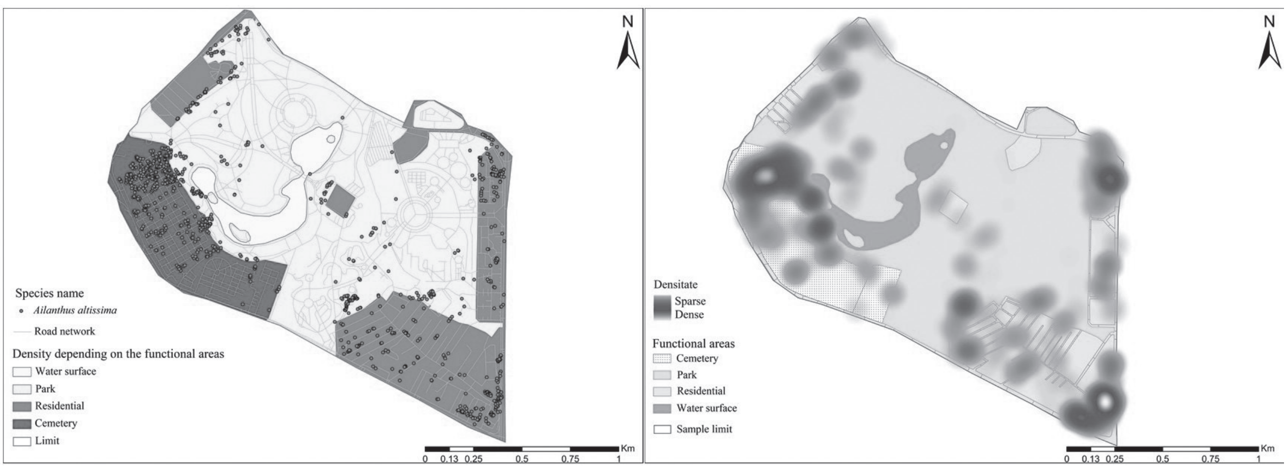

Fig. 3. Distribution of *Ailanthus altissima* according to functional areas.

Mapping

The analysed sample is bordered by the Carol Park and by residential and industrial areas in north-west, by residential areas in north, by Văcărești Natural Park in the east, by residential areas in south and by the Jewish Cemetery in the west (Fig. 2). By analyzing the neighboring areas, it will be concluded that they have a high potential of influencing the distribution of the *Ailanthus altissima* species.

The hot-spots regarding the entering points of the *Ailanthus altissima* species in the study area are primarily represented by the Văcărești Natural Park, the Jewish Cemetery and by the industrial areas (Fig. 3). Regarding Văcărești Natural Park, the current administrator is the National Agency for Natural Protected Areas. It has the responsibility to protect and preserve the park. A natural park is a protected natural area with the aim of landscape conservation.

The exponential epicenters of the *Ailanthus altissima* species are acting excessively in the northern area of the Bellu Cemetery and also in both northern and southern areas of the residential area. The surface located in the southern part of the residential area presents a high number of individuals. This surface is in fact a terrain which is being used by the residents as a parking area, without it being actually designed for this purpose. This area can be treated as an abandoned one because, while it is being used, it is not done so in an official way. Therefore, it facilitates the fast and chaotic dissemination of the *Ailanthus altissima* species. In the case of Tineretului Park and Children's World Park (Parcul Orăşelul Lumea Copiilor), the density of this species is much lower. The constructed environment as well as infrastructure, including alleys, sidewalks, roadways, and fences, can be used to summarize the most notable dysfunctions caused by Ailanthus altissima in the study area. In addition to the cases that have been reported, the invading species' individuals have massively overtaken the places they previously occupied, obstructing the native species.

After analyzing the species distribution depending on the assessed functional areas, it can be seen that the Bellu Cemetery is situated on the first place, displaying an abundance of individuals in the northern side. However, if the local administration would have carefully planned this green area, then the current situation would have been different. The second area with a high concentration of tree of heaven is represented by built areas, followed by Tineretului Park and Children's World Park (Parcul Orăşelul Lumea Copiilor).

After studying the scientific literature and finding out that a young individual of the *Ailanthus altissima* species grows in its first year of life by 4 m on average in the case of vegetative propagation, and 1-2 m when it comes to asexual dissemination, a Model Builder was created in ArcGis PRO (Fig. 4a). More exactly, the model obtains each individual's age by correlating the trees heights and the relation curve from the aforementioned literature. Class 1 comprises young sprouts with heights under 2 m tall, which corresponds to 1 year old trees. Class 2 features trees with heights between 2-5 m, aged 2. Class 3 is made of 5-7 m tall trees, aged 3. Also, the segment between 7-10 m tall comprises trees aged 4 and so on. The model builder in ArcGIS Pro was also used to obtain the tree's gender. The model determines the gender based on the presence of saplings at less than 90 m. It is known from the specific literature that male individuals spread pollen which fertilizes female individuals' flowers, resulting seeds, which means that we'll find juvenile trees at less than 90 m, more specifically aged 1-5.

a) b)

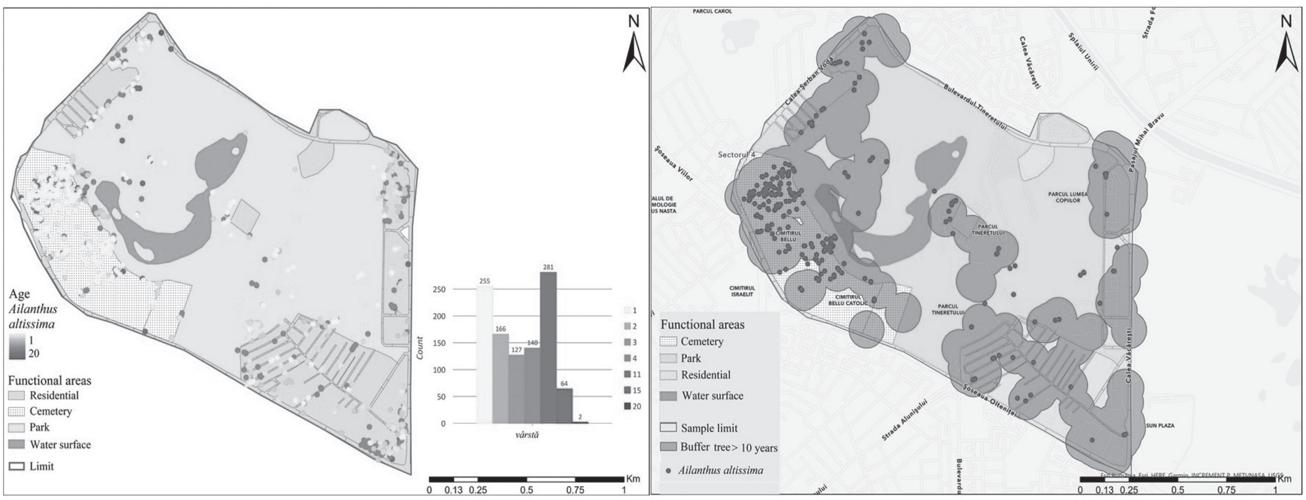

Fig. 4. a) Distribution of individuals according to age resulting from the builder model; b) Distribution of young individuals at a distance of more than 90 m from adult trees).

After applying the model builder, the individuals were grouped in 2 categories: male and female. The presence of both at less than 90 m from each other is important when it comes to dissemination. Inside the assessed sample have resulted 554 female individuals and 484 male individuals. Being a known fact that trees older than 10 produce the highest quantity of seeds, a buffer was created (Fig. 4b) for them, with a 90 m distance. This distance is in fact the maximum one at which a seed can be carried away by the wind and may have a chance of actually developing, becoming a young sprout. When it comes to the red dots from Fig. 4b), they depict trees aged 1-4, in order to have an overall view of the species distribution inside an area. It is crucial to realize that although air currents can distribute seeds up to a distance of 90 meters, anything beyond than that requires the involvement of birds, animals, or humans.

Satellite Analysis

In order to assess the condition of the *Ailanthus altissima* species distribution in both green areas and residential, industrial and commercial areas within sector 4, an object-based image analysis was conducted. The satellite image that was used to obtain the OBIA classification was taken from Worldview 3, and has 8 bands. This way, each band has a different spectral response and also different characteristics. Several areas and species were considered for the analysis, including *Ailanthus altissima*. The spectral response will differentiate each individual class. The resulting supervised classification, together with the spectral answer graph, will better showcase the species positioning inside the sector (Fig. 5).

In order to properly identify the *Ailanthus altissima* species, various band combinations were used. Near-IR 1 is represented by red, Red-edge by green, and

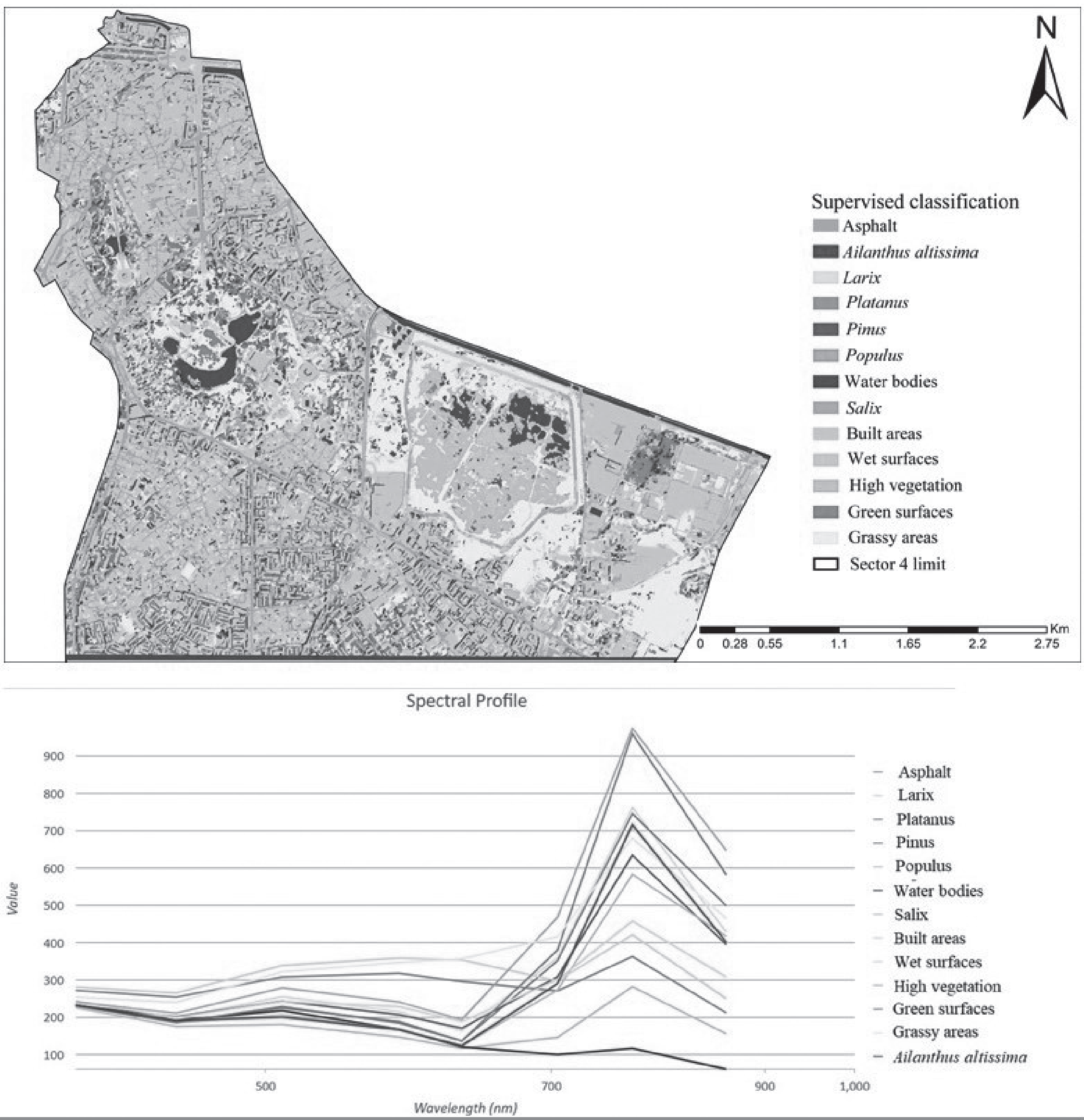

Fig. 5. Supervised classification results and spectral responses of classes.

Green is represented by blue. The *Ailanthus altissima* species is shown in red on the map, so that it can be better distinguished from other species. Beside the tree of heaven, several other species were identified: the larch, pine, poplar, willow; the aim being to help create an accurate supervised classification. After applying the OBIA classification, it can be observed that the *Ailanthus altissima* species is spread all over the analysed area.

The *Ailanthus altissima* species is represented by the red profile, in band 2 – Blue, the spectral answer decreases, because bands 2 and 5 are being absorbed by plants. In band 3 – Green, there is a small peak, because green is being reflected by the chlorophyll. Both the tree of heaven and the other vegetation classes reflect the most in band 7, which is near-infrared 1. *Ailanthus altissima* is not a species that reflects the most in near-infrared, because this band mostly interracts with either palmate leaves, large leaves, or ones facing the Sun. This one however, although its leaf is quite developed, it is not palmate, also having a composed leaf, consisting of 11-30 elongated lanceolate leaflets. This means that although it reflects a lot in Near-IR 1, it does not reflect as much as the *Platanus* whose leaves are much more developed. When it comes to the tree of heaven, there is a small peak in band 3 because of the chlorophyll. However, compared to other classes of vegetation, it reflects almost the least of all of them. This is due to the shade of green. More specifically, its shade is darker, which means that it has less chlorophyll in its leaves, therefore it reflects less.

Public Perception on Invasive Plant Species

In this chapter, the population's opinion referring to invasive plant species, with a focus on *Ailanthus altissima*, will be reviewed and assessed. This survey's purpose is to identify the average level of knowledge of invasive species positive and negative effects on society, the awareness of this species impact on people, and others. Several species have been mentioned by the inhabitants (Fig. 6).

The first question refers to the species known by the participants. More than 30 people mentioned ragweed, followed by *Robinia pseudoacacia* (acacia) (25%), and *Ailanthus altissima*. More than 20 people have mentioned the species, but just like the acacia, most people stated that its purpose was its own aspect, more exactly the fact that it improves the urban landscape, being planted in gardens as an ornamental species with a positive visual impact. Other species were mentioned by groups of 5-10 people, such as: *Hedera helix* – ivy, *Urtica dioica* – nettle, *Taraxacum officinale* – dandelion, *Carduus nutans* – thistle and *Amaranthus* – red root amaranth.

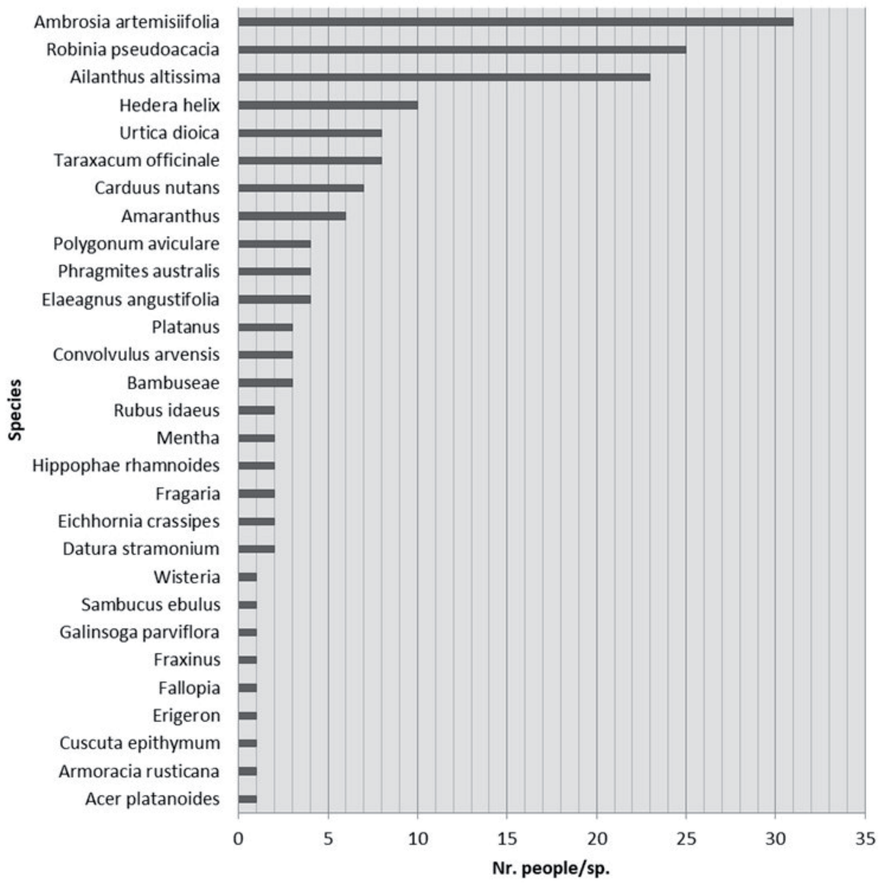

Fig. 6. List of invasive species identified by the population.

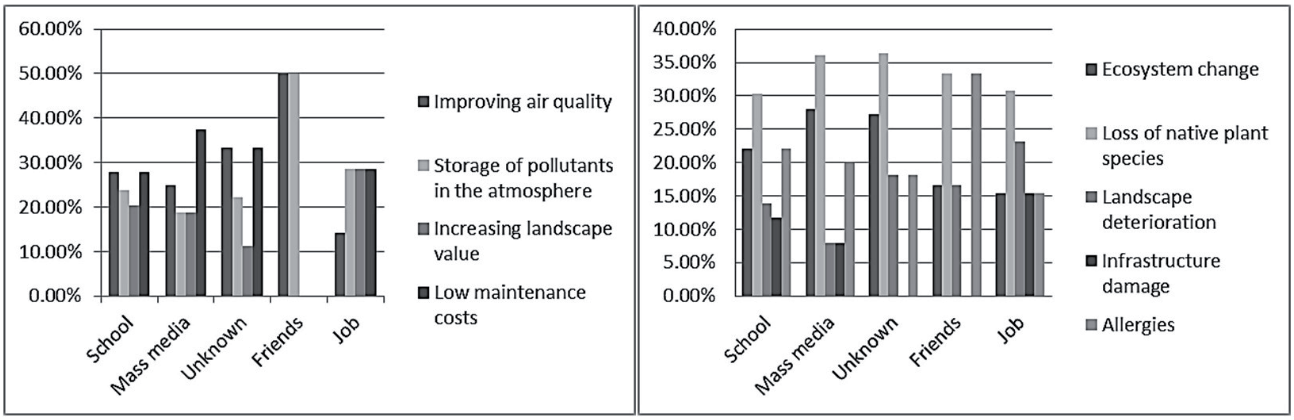

Fig. 7. Perceived positive (left) and negative (right) effects of invasive plant species.

The main positive effects depending on the environment where the respondents heard for the first time about the invasive species term can be divided into 4 categories. The number one positive effects of the invasive species is the „low maintenance cost". Even people who never heard of invasive species, and the ones who know about them from „school", „mass-media" or from their „job" considered that this factor is a positive one. Among people who know about invasive species from an educational institution, roughly 29% mentioned „low maintenance cost" and „improvement of the air quality" as the most important positive effects that these species have on society. Also, 24% of the respondents considered that the „storage of pollutants" is the most important one, while 20% leaned towards „improvement of urban landscape" (Fig. 7).

Furthermore, from the people who heard about invasive species online, 38% of them mentioned „low maintenance cost", 25 % „improvement of air quality" and 19" opted for both variants. Although there are many respondents who found out about this term from more or less official sources, or who don't know about this term at all, most of them opted for „low costs" and „improvement of air quality" as the main positive effects that these species have. Also, 21% of people felt that „storage of pollutants" is the main effects, while 11% considered that „improvement of urban landscape" is the most important one. As for people who know about invasive species from close persons, there were two options: 50% went for „improvement of air quality" and 50% for „storage of pollutants". The last group is comprised of people who found out about this term from their job. As far as they're concerned, 15% considered „improvement of air quality" to be the main positive effect, while 29% opted for the other options.

When it comes to the analysis of the negative aspects, the leading one was the „loss of native species". Therefore, above 30% of individuals from each category mentioned the aforementioned aspect. As for the people who found out about invasive species from an educational institution, from mass-media or even the ones who never heard about this term, more than 20% of them opted for „ecosystem alteration", labeling this option as the second most important negative aspect. Third place is occupied by „allergies", and the least mentioned variants were „landscape degradation" and „infrastructure damage".

The present research has started from evaluating the official documents regarding urban planning, especially the way in which invasive species of plants are integrated in these strategies, plans, programs and projects at different scales [32]. Even though in the majority of the analyzed documents, invasive species are more or less mentioned, in certain strategies, programs a future plans these specific invasive plant species should be included, as well as their documentation and the way they were managed according to the availability of resources.

In the study, several types of methods were applied to help understand the distribution of invasive plant species at the urban level and how they are seen from the point of view of urban planning, taking into account certain indicators. According to Zehlius-Eckert (1998) the ''Indicator: is an attribute of an object, of which the parameter values show a high correlation to parameter values of another attribute (indicandum) of the same or another object. The parameter values of both attributes must be qualitatively or quantitatively correlated as closely and distinctly as possible. Therefore it is advantageous if the causal implications on which the correlation is based are preferably direct and monocausal'' [33]. This definition openly addresses indicators at a descriptive level. Compared to other definitions, where indicators are used to describe, reflect, or represent a problem, this criteria is more stricter. Zehlius-Eckert proposes a direct causal relationship between the indicator and the indicandu [34].

This study aims at the spatial presentation on a sample from sector 4 of the invasive species *Ailanthus altissima*, with both positive and negative parts. The study focused on the implementation of several methods of analysis: documentation, mapping, population perception and satellite analysis. In the documentation part, the situation regarding the integration of invasive plant species at national, regional and local level was evaluated, and then the situation in the field was evaluated, including also restrictions and favors.

The positive and negative impacts and effects of invasive plant species on society and the health of the population are known from the scientific literature [35]. As a result, the potential methods of introducing the invasive species *Ailanthus altissima* into the selected sample as well as the spatial distribution, features linked to multiplication, dissemination, etc. in various kinds of functional areas were examined. The invasive species *Ailanthus altissima* was the topic of this article because, as other studies have noted, it is a species that constantly competes with native flora, having an increasing and significant influence on infrastructure [36]. After examining various strategies, programs, plans, and projects with planning as their main focus, it was concluded that invasive species are handled and introduced in territorial development far too little. Although most invasive plant species have a negative impact on society, they can also bring certain benefits to the ecosystem.

For the existing data set there were used several methods of spatial analysis. The first method applied is called" singular spatial analysis" [37], in which maps were made from the density and distribution of the species, but also maps with some characteristics such as: height or age. The density and distribution of the species should normally be controlled by the local public administration and included in the local urban planning. For example, today Bellu Cemetery has a well-defined purpose, but two centuries ago, it had a completely different function. In the nineteenth century, Bellu Cemetery was the garden of Baron Barbu Bellu, a garden that was full of exotic trees, especially citrus. In the autumn of 1855, the garden was started to be transformed into a cemetery, and in 1856 it became functional [38]. Given the first purposes of the land, it is possible that the invasive species *Ailanthus altissima* was introduced into the garden of the great baron in the nineteenth century. Therefore if in the case of the cemetery there is a possible explanation of the abundance of such individuals, when it comes to the residential area, the main factor may be represented by the uncontrolled dissemination of seeds from the Văcărești Natural Park (V.N.P.). Taking into account the above information, the biodiversity within the V.N.P. does not present interventions, but only protection, allowing the chaotic development and spread of invasive plant species. The probability of *Ailanthus altissima* coming from V.N.P. into residential areas it is big and can be the main dissemination vector outside the conserved space.

In the case of the age of the individuals map, this represents the result of the builder model. As with previous studies, the height of *Ailanthus altissima* and knowledge in the scientific literature were taken into account [26]. Thus, it is assumed that the dispersion of the trees in terms of age on the surface of the evaluated sample is asymmetric, a high density of young trees aged 1-2 years being located in Bellu Cemetery. In addition to the large number of seedlings, there are also a large number of adult or old trees. Over 300,000 seeds are produced year by trees older than 10 years [39], indicating that they have a strong reproductive capacity. As a result, there are many young seedlings at the Bellu Cemetery because there are more mature trees there. However, this significant growth in invasive plant species, *Ailanthus altissima*, is also due to ineffective design of green spaces at the sector and municipal levels. From the scientific literature is known that the invasive species *Ailanthus altissima* multiplies in two ways, asexual and vegetative. The vegetative propagation is carried out immediately near the adult tree, up to a maximum distance of 5 meters, and the asexual propagation, through seeds, thus reaching up to a distance of 90 meters. Based on the information related to the type of reproduction, a buffer was made with a distance of 90 meters for individuals under 4 years of age. Thus, the result includes most of the young seedlings in the created buffer, there are also exceptions of juveniles that did not fit. Other studies mentioned that birds have a major impact in shaping ecological diversity [40], which means that in this paper's study area, birds have played a very important role in seed dispersal, beyond the 90 meters limit specified. Individuals not found in the buffer have had a zoophilic or perhaps human spread. It is very important to understand that although the ability of the seed to be spread by air currents can be carried out up to a maximum distance of 90 meters, o anything above this distance involves birds, animals or maybe humans.

In addition to the singular spatial analyzes we used in this research, we also applied the OBIA supervised classification. The method offers very good results on large areas, when it is desired to make a classification as detailed as possible, used in many studies on land use, but also to be able to visualize aspects related to urban planning. In the case of OBIA, the scale of detail of satellite images is much larger, with a very good spectral resolution, which means that the objects present in the study area cover much more pixels, because OBIA does not classify pixels, it classifies objects. Other authors set out to extract features specific to urban areas from satellite images of Sentinel-2 and Landsat-8. The two researchers used free high-resolution satellite images in their study for best results, where Sentinel 2 has a resolution of 10 m and Landsat 8-15 m. The satellite image used in this study is taken from Worldview, with a resolution of 1 m and dating from 2016. The result obtained is satisfactory, especially since it helped me to have an overview of the distribution of the invasive species *Ailanthus altissima* on more than half of sector 4, in different types of functional areaFollowing the running of the supervised classification by objects, the presence of *Ailanthus altissima* in sector 4 is visible in all functional areas. But it can be seen that depending on the area in which we identify it can be in greater numbers as in the area of the cemetery, the park, but also on an abandoned plot of land, and in the residential area, through the blocks of flats in smaller numbers. The higher or lower density is correlated to the administration that should manage such landscape inequalities. To validate the classification performed, a number of 100 points were taken into account, which were generated randomly (Table 2). The column named p_accuracy represents the errors in the supervised classification by objects, in which the segments, more precisely the pixels, were not classified correctly, for example, as it was in the case of the built areas where they were confused with the asphalt. Accuracy is read in columns, not in rows, and thus reproduces the omitted errors. The total represents the total number of points that were identified for each class. The statistics provided by kappa give us a general assessment of the accuracy of the classification made (ArcGIS Pro).

Following the validation of the data classification, the accuracy of the correctness of class identification by OBIA of 0.71 resulted, means that the statistical parameter kappa indicates a substantial accuracy, being included in the 5th class - in the range of 0.61-0.80 [41]. Thus, all the results obtained from the spatial distribution of the studied sample and the spatial distribution on more than 50% of sector 4 of the invasive species *Ailanthus altissima*, starting from previous studies we could evaluate the relationship species with different types of areas in which it was found in the urban environment [15]. Although there is no introduction of the species in the urban planning of sector 4, it is present in all functional areas and with a visibly high density. For the efficient dissemination of *Ailanthus altissima*, it should first be mentioned in official documents and then practical solutions for community management should be found.

By applying the questionnaire, it was possible to establish depending on the perception of the population what are the main advantages and disadvantages of the presence of *Ailanthus altissima* in Bucharest. Also, by involving the population in making decisions on the integration of invasive plant species in urban planning, there would be no more confusion for their management. Starting from the paper entitled "Between approval and disapproval: Citizens' views on the invasive tree *Ailanthus altissima* and its management" we introduced citizens to the study we conducted to establish the main negative and positive effects of the presence of *Ailanthus altissima* [42]. Although the species leads to the elimination of native species, with the ability to adapt quickly, the main advantage is the low costs for its maintenance. Another invasive species that benefits society is *Robinia Pseudoacacia*. Although it is considered an invasive species, compared to other species, such as *Ambrosia artemisiifolia*, it also brings benefits to society.

This species is planted in disadvantaged environments, to stabilize the slopes, having a fast-

Table 2. The validation of supervised objects classification.

Class	Asphalt	*Ailanthus altissima*	*Platanus*	Water	Built	Wet surfaces	High vegetation	Green surfaces	Grassy areas	Total	U_Accuracy	Kappa
Asphalt	9	0	0	0	3	0	0	0	0	12	0.75	0
Ailanthus altissima	0	4	0	0	0	0	0	0	0	4	1	0
Platanus	0	0	0	0	0	0	0	1	0	1	0	0
Water	2	0	0	2	1	0	0	1	0	6	0.333	0
Built	4	1	0	0	26	0	1	1	0	33	0.787	0
Wet surfaces	0	0	0	0	0	5	0	2	0	7	0.714	0
High vegetation	0	0	0	0	0	0	3	3	0	6	0.5	0
Green surfaces	0	0	0	0	0	0	0	7	0	7	1	0
Grassy areas	0	0	0	0	0	0	0	3	21	24	0.875	0
Total	15	5	0	2	30	5	4	18	21	100	0	0
P_accuracy	0.6	0.8	0	1	0.866	1	0.75	0.388	1	0	0.77	0
Kappa	0	0	0	0	0	0	0	0	0	0	0	0.716

growing power, representing a source of quality wood, appreciated by carpenters. The problems brought on the population are reduced to the allergies induced by the pollen it generates in the floristic season. Like the species *Robinia pseudoacacia*, the species *Ailanthus altissima* also offers societal favors through its high growth and spreading power [43] being a suitable species to be used as green curtains along the belts of large cities or even highways, having the ability to absorb dust in suspension and CO_2 [44]. Although it offers positive effects to society, like any invasive species, it also has a number of negative effects. Even if the rapid growth and spread can be considered qualities, when the species has been out of control, it can easily lead to the loss of native species, soil cover, urban infrastructure, heritage buildings, and also damage the health of the population.

Following the analyzes resulting from mapping, satellite imagery and the application of the questionnaire, it was deduced that although invasive plant species spread chaotically, without planning, they can bring both dysfunctions and benefits to society. Taking into account the main functional areas of Sector 4 and characteristics related to the ecological, economic and social favors and restrictions generated by *Ailanthus altissima* (Table 3).

Given the pros and cons of functional areas that we find in sector 4, but also the growth and spreading skills of *Ailanthus altissima*, it could easily be included in the urban planning documents of the sector. If the sex of the individual were taken into account, male individuals could be planted both in block gardens, parks, street alignments, but also as curtains for the absorption of noise and pollutants. When the data collection started, the first inconvenience was the impossibility to enter certain green spaces, due to their private nature. Another limitation during the study was also represented by the terrain, due to extreme weather conditions (high temperatures or rainfall for long periods of time). Field data collection was also slowed due to the Covid-19 virus, and the application of the questionnaire was done only online, because people were much more reluctant to be around strangers. In the analysis of the data, there were other small situations that made it difficult to obtain a complete and present result. In this case, it is about the lack of recent satellite images and at an even more detailed resolution. Regarding the evaluation of documents, we encountered only one problem, namely the format, some of which were scanned.

Similar to the work "Assessing the impacts of invasive alien plants on urban ecosystem services" [45], which integrates many analysis tools, including document analysis, satellite analysis, and population perpetuation to evaluate the role of urban vegetation, including invasive plant species in general, an area was evaluated by 4 approaches in the current paper (documentation, mapping, population perception and satellite methods). The study of the questionnaire as well as the materials on urban planning revealed that

Table 3. Favorability and restrictions for Ailanthus altissima in urban functional areas.

Classes	Characteristics	FUNCTIONAL AREAS				
		Residential	Industrial	Green spaces	Wet surfaces	Abandoned lands
Ecologic	*Favorability*	Improving air quality	High resistance in heavily polluted areas	Decreasing high temperatures	-	Reducing CO_2 concentrations in the atmosphere
	Restrictions	Infrastructure damage	Damage to the built space	Landscape degradation	Ecosystem change	Changing soil chemistry
Social	*Favorability*	Decorative value	Increasing the attractiveness of the industrial area	Decorative value	Greater diversity of flora	Greater diversity of flora
	Restrictions	They weaken the strength of constructions	Decreased visual appearance of the area	Decreased attractiveness	Allergies	Increasing the number of allergic diseases
Economic	*Favorability*	Low maintenance costs	Resistance to pollutants and compliance with mandatory % of green space	Decorative value	Rising real estate purchase prices due	Reducing CO_2 concentrations in the atmosphere
	Restrictions	Degradation of transport infrastructure	Increasing costs for combating invasive plant species	Decreasing the number of inhabitants in public green spaces and implicitly decreasing the earnings of entrepreneurs	Increasing the risk of extinction of native species	Increasing the costs of restoring abandoned land

one of an invasive plant species' most crucial abilities is the capacity for speedy adaptation. As a result, other authors [46] presented a strategy to lower the cost of invasive species management.

In the future, the aim is to extend the analysis on a European scale of documents related to urban planning, in order to compare it with the situation in Romania. In addition to the documents, we would like to identify how *Ailanthus altissima* is distributed in urban and rural areas and realize larger scale analyses in order to be able to identify aspects that can be introduced later in the urban planning on national level.

Conclusions

Following the analyzes carried out on official documents on urban planning at different scales, it was found out that most strategies, plans, programs and projects do not include plant species, and those that mention them provide few details. Thus, it concludes that although more than half of the analyzed documents do not consider the incorporation of invasive plant species, there are also some that present the benefits they offer to society. By extracting information from the field, it was found out that invasive plant species are abundant. Following the mapping of the species *Ailanthus altissima* in the sample chosen as a case study and the satellite evaluation, it resulted a high density of this species. Thus, as a result of the analysis, it was noticed that the species has a high density in the evaluated urban sample, which means that it has a high resistance and adaptation to the conditions offered by the city of Bucharest.

As such, in terms of population perception, it turned out that although *Ailanthus altissima* is a danger to native plant species, it is economically viable because it does not require exorbitant maintenance costs. Therefore, balancing the disadvantages and advantages of the mentioned species, it was concluded that there is a balance between the two extremes, which should be polished and introduced in future urban planning. Based on the results and discussions presented so far, it has been concluded that the species *Ailanthus altissima* could be integrated in the near future in the urban planning of the sector, taking into account primarily the aspects related to the dissemination of the species, the distance between female and male individuals, as well as the areas in which they are to be used for economic, ecological or social purposes.

Also, starting from the main purpose of this study, namely that of evaluating the possibility of including invasive species in urban planning documents, considering their main benefits, the species *Ailanthus altissima* could be introduced in large cities where the degree of pollution is high, and the native species could not have a considerable lifespan due to the extreme conditions. Thus, a species like *Ailanthus altissima*, which shows a high resistance to disadvantaged environments in terms of unfavorable environmental conditions and would take into account the sex of the planted tree, could solve many problems, especially those of the lack of spaces green and air quality.

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Conflict of Interest

The authors declare no conflict of interest.

References

1. MOOSAVI M.S. The smart city; challenges and opportunities in developing countries. Iranian Online Journal of Urban Research. **3**, 1, **2018**.
2. CETIN, M. Using GIS analysis to assess urban green space in terms of accessibility: case study in Kutahya. International Journal of Sustainable Development & World Ecology. **22**, 420, **2015**.
3. ARONSON M.F.J., LEPCZYK C., EVANS K.L., GODDARD M.A., LERMAN S.B., MACIV J.S., NILCON C.H., VARGO T. Biodiversity in the city: key challenges for urban green space management. Frontiers in Ecology and the Environment. **15**, 189, **2017**.
4. AKSOY T., DABANLI A., CETIN M., KURKCUOGLU S.A.M., CENGIZ E.A., CABUK N.S., AGACSAPAN B., CABUK A. Evaluation of comparing urban area land use change with Urban Atlas and CORINE data. Environmental Science and Pollution Research. **29**, 28995, **2022**.
5. BUERGER A., HOWE K., JACQUART E., CHANDLER M., CULLEY T., EVANS C., KEARNS K., SCHUTZKI R., RIPER L.V. Risk Assessments for invasive plants: A Midwestern U.S. Comparison. Invasive Plant Science Management **9**, 41, **2016**.
6. STOIA L.N., NITA M.R., POPA A.M., IOJA C.I. The green walk – An analysis for evaluating the accessibility of urban green spaces. Urban forestry & urban greening. **75**, 1, **2022**.
7. GAERTNER M., LARSON B.M.H., IRLICH U.M., HOLMES P.M., STAFFORD L., VAN WILGEN B.W., RICHARDSON D.M. Managing invasive species in cities: A framework from Cape Town, South Africa?, Landscape and Urban Planning. **151**, 1, **2016**.
8. PHAM, PHAM THI KIM THOA, VU THI BICH HAU, NGUYEN VAN HIEU. Assessment of the current distribution, dispersal trends and impacts of invasive species in Bana - Nui Chua Nature Reserve, Vietnam. Journal of Science and Technology Issue on Information and Communications Technology, 6, **2021**, doi:10.31130/jst-ud2021-437.

9. KOWARIK, I. Some responses of flora and vegetation to urbanization in Central Europe. Urban Ecology, 45, **1990**.
10. CETIN M., AKSOY T., CABUK N.S., KURKCUOGLU S. A.M., CABUK M. Employing remote sensing technique to monitor the influence of newly established universities in creating an urban development process on the respective cities. Land Use Policy **109**, 1, **2021**.
11. PARDO M., ECHAVARREN J.M. Transportation, mobility, and women in cities of developed countries, Social and Economic Development. Encyclopedia of Life Support Systems, **3**, 168, **2010**.
12. WERNER P. The ecology of urban areas and their functions for species diversity. Landscape and Ecological Engineering. **7**, 231, **2011**.
13. GALLARDO B., BACHER S., BRADLEY B., COMÍN F.A., GALLIEN L., JESCHKE J.M., CASCADE C. J., VILA M. InvasiBES: Understanding and managing the impacts of invasive alien species on biodiversity and ecosystem Services. NeoBiota **50**, 109, **2019**.
14. GAMAYUNOVA O., GUMEROVA E. Solutions to the urban problems by using of underground space. Procedia Engineering. **165**, 1637, **2016**.
15. ŠTAJEROVÁ K., ŠMILAUER P., BRŮNA J., PYŠEK P. Distribution of invasive plants in urban environment is strongly spatially structured. Landscape Ecology. **32**, 681, **2017**.
16. RICHARDSON D.M., PYSEK P., REJMANEK M., BARBOUR M.G., PANETTA F.D., WEST C.J. Naturalization and invasion of alien plants: concepts and definitions. Divers. Distrib. **6**, 93, **2000**.
17. JOHNSON L.R., TRAMMELL T.L.E., BISHOP T.J., BARTH J., DRZYZGA S., JANTZ C. Squeezed from all sides: Urbanization, invasive species, and climate change threaten riparian forest buffers. Sustainability (Switzerland). **12**, 1, **2020**.
18. IOJA C., PATROESCU M., NITA M., ROZYLOWICZ L., VANAU G., IOJA A., ONOSE D. Categories of residential spaces by their accessibility to urban parks - indicator of sustainability in human settlements case study: Bucharest. WSEAS Transactions on Environment and Development. **6**, 307, **2010**.
19. GULEZIAN P.Z., NYBERG D.W. Distribution of invasive plants in a spatially structured urban landscape. Landscape Urban Planning. **95**, 161, **2010**.
20. SIRBU C., MIU I.V., GAVRILIDIS A.A., GRADINARU S.R., NICULAE I.M., PREDA C., OPREA A., URZICEANU M., CAMEN-COMANESCU P., NAGODA E., SIRBU I.M., MEMEDEMIN D., ANASTASIU P. Distribution and pathways of introduction of invasive alien plant species in Romania. Neobita. **75**, 1, **2022**.
21. ANASTASIU P., ROZYLOWICZ L., SKOLKA M., PREDA C., MEMEDEMIN D., COGĂLNICEANU D. Country reports: Alien Species in Romania. ENESIAS Scientific Reports 1. State of the Art of Alien Species in South-Eastern Europe. 75, **2016**.
22. GRADINARU S.R., IOJA C.I., PATRU-STUPARIU I., HERSPERGER A.M. Are spatial planning objectives reflected in the evolution of urban landscape patterns? A framework for the evaluation of spatial planning outcomes. Sustainability (Switzerland). **9**, 1, **2017**.
23. CIUIU G., COBZARU I., GHEORGHE R., ION M., ISAC S., IORDACHE V., MOUNTFORD O.J., ONETE M., NICA M., PAUCA-COMANESCU M., RADU A. Metodologia de asistare a municipalitatii in planificarea urbana. **2010**.
24. BURNS R.M., HONKALA B.H. Silvics of North America: Volume 2. Hardwoods. Agriculture Handbook 654 vol. **2**, **1990**.
25. NITA M., IOJA C., ROZYLOWICZ L., ONOSE D.A., TUDOR A.C. Land use consequences of the evolution of cemeteries in the Bucharest Metropolitan Area, Journal of Environmental Planning and Management, 37, **2013**.
26. ROOPA S., RANI M.S. Questionnaire designing for a survey. The journal of indian orthodontic society **4**, 273, **2012**.
27. PANAYOTOV P., KALMUKOV K., PANAYOTOV M. Biological and wood properties of *Ailanthus altissima* (Mill.) Swingle. Forestry Ideas. **17**, 122, **2011**.
28. KHADANGA G., JAIN K., MERUGU S. Use of OBIA for extraction of cadastral parcels. 2226, **2016**, doi:10.1109/ICACCI.2016.7732382.
29. LABIB S.M., HARRIS A. The potentials of Sentinel-2 and LandSat-8 data in green infrastructure extraction, using object based image analysis (OBIA) method. European Journal of Remote Sensing. **51**, 231, **2018**.
30. JOHNSON B.A., MA L. Image segmentation and object-based image analysis for environmental monitoring: Recent areas of interest, researchers' views on the future priorities. Remote Sensing. **12**, 1, **2020**.
31. WHITESIDE T.G., BOGGS G.S., MAIER S.W. Comparing object-based and pixel-based classifications for mapping savannas. International Journal of Applied Earth Observation and Geoinformation. **13**, 884, **2011**.
32. DINGMAN S., ABELLA S.R., FREY M., BUDDE P., HOGAN T. Invasive plant management planning: Technical Considerations, **2018**.
33. ZEHLIUS-ECKERT W. Arten als Indikatoren in der Naturschutz- und Landschaftsplanung. Zielarten - Leitarten - Indikatorarten Aussagekraft und Relevanz für die praktische Naturschutzarbeit. Munchen : Bayerische Akademie für Naturschutz und Landschaftspflege (ANL), **1998**.
34. HEINK U., KOWARIK I. What are indicators? On the definition of indicators in ecology and environmental planning. Heink, Ulrich and Kowarik, Ingo. 2010. Berlin: Ecological indicators. **10**, 584, **2010**.
35. KAPITZA K., ZIMMERMANN H., MARTÍN-LÓPEZ B., WEHRDEN H. VON. Research on the social perception of invasive species: A systematic literature review. NeoBiota **43**, 47, **2019**.
36. SWINGLE M. Rick assessment *Ailanthus altissima*. Natural biodiversity center. **2013**.
37. HAIDU I., HAIDU C., S.I.G. Analiza spatiala, **1998**.
38. BEZVICON G. Necropola capitalei. Daco Romanica, **1972**.
39. CSETE Á., TANÁCS E., GULYÁS Á. Assessment of tree of heaven (Ailanthus Altissima) Spread Dynamics on Example of Szeged (Hungary). Acta Climatologica Et Chorologica. **49-50**, 9, **2016**.
40. KARUBIAN J., BROWNE L., BOSQUE C., CARLO T., GALETTI M., LOISELLE B.A., BLAKE J. G., CABRERA D., DURAES R., LABECCA F.M., HOLBROOK K.M., HOLLAND R., JETZ W., KUMMETH F., OLIVO J., OTTEWELL K., PAPADAKIS G., RIVAS G., STEIGER, S., VOIRIN B., WIKELSKI M. Seed dispersal by neotropical birds: Emerging patterns and underlying processes. Ornitología Neotropical. **23**, 9, **2012**.
41. RWANGA S.S., NDAMBUKI J.M. Accuracy assessment of land use/land cover classification using remote sensing and GIS. Int. J. Geosci. **08**, 611, **2017**.

42. KOWARIK I., STRAKA T.M., LEHMANN M., STUDNITZKY R., FISCHER L.K. Between approval and disapproval: Citizens' views on the invasive tree *Ailanthus altissima* and its management. NeoBiota **65**, 1, **2021**.
43. HU S., JIAO J., KOU M., WANG N., GARCIA-FAYOS P., LIU, S. Quantifying the effects of *Robinia pseudoacacia* afforestation on plant community structure from a functional perspective: New prospects for management practices on the hilly and gullied Loess Plateau, China. Science of the Total Environment. **773**, 1, **2021**.
44. WINNER W.E., ATKINSON C.J. Absorption of air pollution by plants, and consequences for growth. Trends in Ecology and Evolution. **1**, 5, **1986**.
45. POTGIETER L.J. Assessing the impacts of invasive alien plants on urban ecosystem services. (Stellenbosch University, **2019**).
46. CUSACK C., HARTE M., CHAN S. The Economics of Invasive Species. **2009**.