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THE INFLUENCE OF INDOOR PLANTS ON HUMAN HEALTH IN CITIES

Ioan-Cristian IOJA, Mihai-Razvan NIȚĂ, Diana-Andreea ONOSE and Ana-Maria POPA

University of Bucharest, Department of Regional Geography and Environment, Bucharest, Romania
Centre for Environmental Research and Impact Studies, Bucharest, Romania
*Corresponding author: Ana-Maria Popa, anamaria.popa@geo.unibuc.ro

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Introduction. Indoor plant species represent a component of urban housing consumption patterns, which influence the human health. They can reduce stress, depression, increase the ability to pay attention, and reduce anxiety.

Materials and methods. Bucharest city was chosen for assessing specific indicators related to the indoor plants in residential areas. 298 valid questionnaires were applied to collect details about indoor plants. Survey invitations were addressed face-to-face or via email to each person using snowball sampling.

Results. 28.9% of the analyzed households do not have plants. The most common species are from the genus Ficus, Hibiscus, Cactus, Saintpaulia, Orchidae, Dracena, Yucca and Aloe. All respondents recognize the importance of indoor plants for physical and mental health, aesthetics, and air quality improvements.

Discussions. Analysis indicates a moderate presence of indoor plants. The results are close to other global study, but different from those in Netherlands. The most frequently mentioned species in Bucharest indoor households are different compared with the global situation. These could be explained through the species availability on the market, former experience in gardening, and specific indoor conditions.

Conclusions. The results are essential for urban planners and health experts, who must better understand the connection between urban nature and residents.

Keywords: indoor plants, households, Bucharest.

INTRODUCTION

Cities are complex adaptive systems that integrate ecological, human, built, and hybrid networks[1,2]. They face global and regional societal challenges[3,4] which affect their search for sustainability and resilience[5,6]. Therefore, cities are in a continuous search of innovative solutions oriented to: (i) the valorization of opportunities associated with societal challenges[7], (ii) reduce their substantial ecological footprint[8] and (iii) create an attractive environment for different users and stakeholders[9]. Improving air quality, considering climate change adaptation and mitigation measures, enhancing water management, and embedding urban circularity and sustainability principles are relevant steps through urban transformations[10–12]. The urban nature is often considered part of planned and/or implemented solutions for enhancing cities' sustainability and resilience[9,13].

Urban nature includes species that occur in the urban matrix but also the urban places where (i) plants and animals occur, (ii) ecological processes are active, and (iii) interactions exist between ecological, human, built, and hybrid urban networks[14]. Considering[2,13,15], urban nature includes (1) *remains of natural ecosystems* (*e.g.*, natural forests, meadows, wetlands), (2) *production ecosystems* (*e.g.* agroecosystems, planted forests, fish farms), (3) *designed ecosystems* (*e.g.* green areas, urban waters), (4) *restored ecosystems* (*e.g.* abandoned industrial or transport areas), (5) *hybrid ecosystems* (*e.g.* private gardens, experimental gardens), and (6) *indoor plant and animal species*. Regardless if we talk about indoor plants or animals, most of them depend on human maintenance, providing shelter, food, water, minerals, medical care, and/or effectiveness.

Indoor plant and animal species can be classified using different criteria (Table 1).

However, some of them are primarily spread worldwide: (i) dogs (471 million), cats (373 million), fish, and birds among indoor animals, and (ii) snake plant (*Dracaena trifasciata*), pothos (*Epipremnum aureum*), ZZ plant (*Zamioculcas zamiifolia*), spider plant (*Chlorophytum comosum*), lucky bamboo (*Dracaena sanderiana*), cast iron plant (*Aspidistra elatior*), staghorn fern (*Platycerium bifurcatum*), peace lily (*Spathiphyllum wallisii*), philodendron (*Philodendron* spp.), English ivy (*Hedera helix*), Jade plant (*Crassula ovata*) and African violet (*Saintpaulia ionantha*) among indoor plants[16].

Although very diverse, plants are the most representative symbol of urban nature[17]. They are present both in outdoor and indoor urban environments, having a high impact on human health and wellbeing[18]. In an indoor environment, plants become an emerging part of the residential consumption pattern[19], contributing to the improvement of the living conditions (*e.g.*, air quality, microclimate), which influence stress control and pain tolerance[20], enhancing individual performance[21], people's comfort, satisfaction, happiness, and mental health[22], increasing positive emotions and reducing negative feelings[23]. Although the positive impacts are dominant, the indoor plants could also lead to (i) the development of pests or unexpected organisms (including mold), (ii) high water consumption, (iii) increasing air humidity, (iv) risk of allergies, or (v) risk of ingesting or inhaling poisons substances[24].

Table 1

Categories of Indoor Urban Species

No.	Criteria for classification	Categories	Examples
1	Intentionality of introduction	Intentionally introduced	Pets, plants
		Unintentionally	Rats, mosquitos, flies, bugs
2	Motivation of introduction	Aesthetic	Decorative plants, fishes
		Pleasure, amusement	Plants, dogs, cats, hamsters, gerbils, rabbits, guinea pigs
		Company	Dogs, cats, hamsters, gerbils, rabbits, guinea pigs, chinchillas, mice, ferrets
		Food	Edible plants (*e.g.* tomatoes, peppers, basilic)
		Ecological reasons (e.g. indoor air quality, climate, and pest control)	Plants
		Rescue and medical aid	Dogs, cats
		Health (primarily mental)	Plants, dogs, cats, hamsters, gerbils, rabbits, guinea pigs, chinchillas, mice, ferrets
		Security	Dogs
3	Type of interaction	Direct	Pets, decorative plants
		Indirect	Bugs, ants
		Absent or unknown	Small species, nocturnal species
4	Function of the building	Residential	Decorative plants, pets
		Commercial	Plants, fishes, birds
		Offices	Plants
		Research	Species used for experiments
		Production	Plants in greenhouses, animals in farms
5	Dependence of human care	Dependent	Fishes in the aquarium, birds in the cage, indoor plants
		Partially dependent	Cats, dogs
		Independent	Synanthropic species
6	Potential to adapt in outside environment without human care	High	Invasive species, cats, dogs
		Low	Exotic species from other bioregions
7	Expected impact on human health	Positive	Plants
		Positive and negative	Plants, dogs, cats, birds
		Negative	The vector-borne of different illness
8	Expected impact on indoor environmental quality	Positive	Plants, fishes
		Positive and negative	Fish, birds
		Negative	Cats, dogs

Urban citizens spend most of their time indoors[25], and contact with nature is limited[26]. Because of that, there is an increasing interest in assessing the contribution of indoor plants to urban citizen health as a complementary component of outside urban nature. Many variables influence the

impact of indoor plants on the residents` health, some related to the plants themselves (*e.g*., species, number, size, position in the house), and others related to the indoor environment (*e.g*., room size, number and categories of residents, indoor activities, behavior). From the mental health point of view, it has been demonstrated that plats can reduce stress, depression, increase the ability to pay attention, reduce anxiety, increase the mood, the degree of satisfaction and self-esteem, as well as increasing the quality of life, but most of them require direct interaction with the species[27]. Spatial data related to these variables and residents' preferences, motivations, and challenges are still missing[17,19,26,28]. The paper aims to assess specific indicators related to the indoor plants in residential areas in Bucharest city.

STUDY AREA

Bucharest is the most important city in Romanian from both administrative and economic perspective. It is located in the lower Danube plain region, and it has a humid continental climate, mean annual temperatures of 10–11°C, and annual precipitation of 565 mm[29]. The city has a surface of 24,200 hectares and a total population of 1,9 million inhabitants at the latest census[30], but the urban agglomeration is much bigger. Urban green space represents 4506 ha (15% being urban parks) and urban waters 908 ha[31,32,33]. 66.5% of Bucharest's surface is covered by built-up areas[30,34], most of which are residential. There are 888,857 households, with a total living surface of 42 million square meters (around 21 square meters/inhabitant). Collective housing is dominant, with more than 700,000 flats in over 18,000 buildings. Recent dynamic shows that more than 80,000 new households were built in Bucharest between 2010 and 2020 in peripheral areas and the former industrial areas[35]. The city faces societal challenges, such as air pollution[36], climate change (significantly increasing heat waves and heavy rain impact)[29], increasing built-up area density and surface[37], reduction of urban nature surfaces[32,38,39], and orientation to a high consumption society[19].

MATERIALS AND METHODS

A questionnaire was used to collect data about residential areas in Bucharest (Figure 1). The survey was designed to cover six sections describing housing patterns in Bucharest:

1. Housing condition (*i.e*. type of building, surface, number of rooms, utilities)
2. Indoor spaces use (*i.e*. duration of staying inside, cooking, storage, *pets and decorative plants*)
3. Use of appliances (*i.e*. electrical appliances, decorations)
4. Residents profile and behavior (*i*.e. number, age, gender, ecological behaviors)
5. Consumptions and waste data (*i.e*. water, natural gas, electricity, chemicals, waste)
6. Perception on the quality of living (*i.e*. water, heat and energy supply, waste management, environmental quality)

The second section contains details about indoor plants (number, species, location inside the house, specific maintenance activities, such as watering, applying chemicals, benefits perception), all being open questions.

The survey questions were formulated to determine the details about living conditions in Bucharest` residential areas. The survey included both closed and open-ended questions. Survey invitations were addressed face-to-face or via email to each person using snowball sampling. Respondents were given two options for answering the survey: online or by filling a paper copy. The survey was conducted from October 2015–February 2020, and 350 questionnaires were received, only 298 of which could be used in this study. 52 questionnaires were invalidated mainly because they were incomplete.

The analyzed households are located in collective block of flats (87%) and houses (13%). The highest share is represented by those with three (37.9%) and two rooms (36.4%), followed by those with 1 room (8.3%), and more than four rooms (4.5%). The average surface of the analyzed households was 67.8 square meters [10–220; ±29.4], the living area being on average 26.05 square meters per inhabitant [3–96; ±13.3], and the load per room of 1.18 persons [0.33–3.85; ±0.5]. There are 915 inhabitants in the 298 households, 82% being between 18–65 years. The low percentage of older people (5%) is related to the need for more trust in providing personal data. Also, 54% of residents are female, and 51% have university and post-university studies.

The descriptive analysis was performed to analyze the indoor plant features from residential areas of Bucharest city in relationship with residents' features, using Microsoft Excel package.

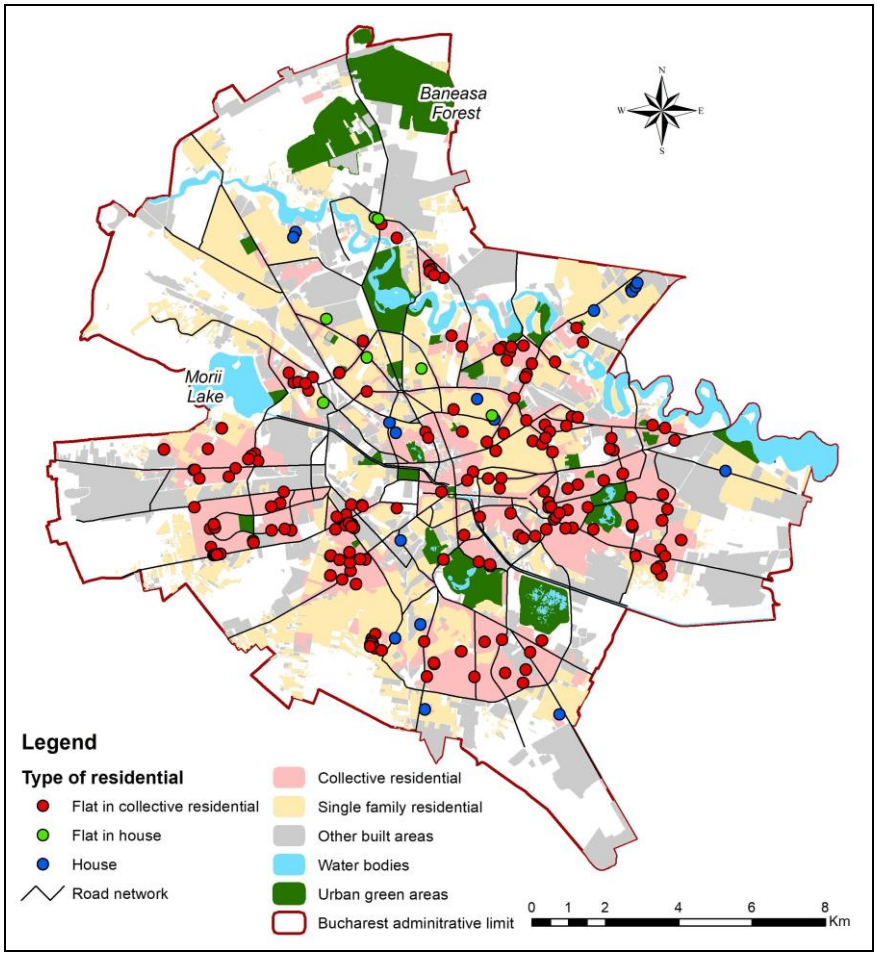

Figure 1. Spatial distribution of analyzed households.

RESULTS

28.9% of the analyzed households do not have plants, and 44.6% have between one and ten plants (Table 2). Most are flowering (50%) and decorative plants (25%), the share of aromatic and edible plants being meager (2–3%). The most common species are from the genus *Ficus*, *Hibiscus*, *Pelargonium*, *Cactus*, *Saintpaulia*, *Orchidae*, *Begonia*, *Dracena*, *Yucca* and *Aloe* (Figure 2).

Table 2

Number of indoor plants in analyzed households

Answer	Number	Percent of households (%)
I don't know	4	1.34
No plants	86	28.86
1–10 plants	133	44.63
11–20 plants	37	12.42
21–30 plants	20	6.71
> 30 plants	18	6.04

Figure 2. Frequency of indoor plant species in analyzed households.

The indoor plants were found in the living room (69%), balcony (65%), bedroom (46%), and kitchen (35%) (Figure 3). In 4% of the analyzed households, the indoor plants can be identified in all rooms. Between the seasons, they are moved from the most exposed location (especially the balcony and external planters), where they stay in the summer, to different rooms (especially the living room), where they are protected during the winter (Table 3).

Table 3

Frequency of indoor plant families/genus in analyzed households

Family/Genus	Number of indoor plants	Percent of households (%)
Ficus	46	11.19
Hibiscus rosa-sinensis	43	10.46
Pelargonium	38	9.25
Cactaceae	32	7.79
Saintpaulia	28	6.81
Orchidaceae	27	6.57
Euphorbia	15	3.65
Lilium	15	3.65
Dracaena	15	3.65
Yucca	13	3.16
Nephrolepis	12	2.92
Aloe	12	2.92
Bambuseae	11	2.68
Arecaceae	10	2.43

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Regarding indoor plant management, all answers show that water consumption and plant availability are relatively straightforward issues. Instead, limited knowledge to manage plant growth and pests (41%), inadequate space (*i.e*. limited surface, insufficient sun light) for keeping the plant in good condition (36%), and limited time to invest in maintenance (31%) are the main arguments of residents to have no or fewer indoor plants. Only 13% of answers mention using pesticides for indoor plant pest control in a responsible way. 60% of respondents report a minimum one indoor plant dead in the last year.

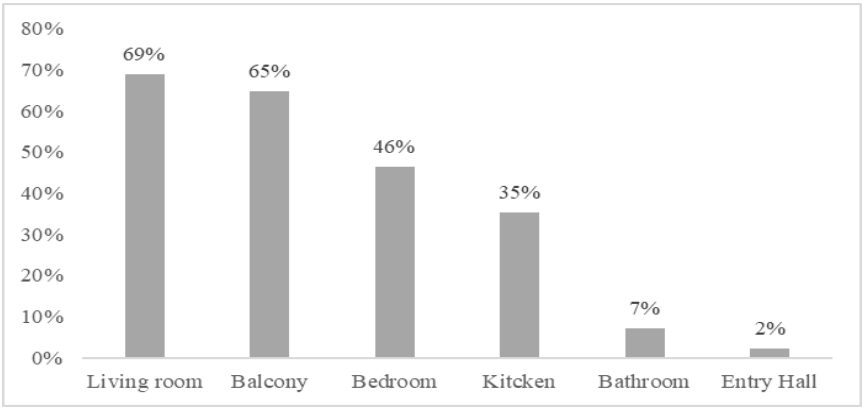

Figure 3. Location inside the housing unit of indoor plants.

In terms of perceived benefits, all respondents recognize the importance of indoor plants for physical and mental health, aesthetics, and air quality improvements. The impact on microclimate is mentioned only in the case of households with more than 30 indoor plants. Few answers mention the responsibility of caring for life, producing food, and managing a gift from a close friend. Considering the negative impacts of indoor plants (15% of answers), the increasing humidity, mold development, taking up too much space, and development of unexpected organisms are mentioned.

DISCUSSIONS

Analysis carried out for the 298 households in Bucharest indicate a moderate presence of indoor plants, with 29% reporting no indoor plants and 45% reporting between 1 and 10 indoor plants. The results are close to[39], which report 26,7% households with no indoor plants, considering a global study with 4,205 answers from Europe, South America, North America, and Australia. Our results are completely different from those in Netherlands, where less than 9% of households have no indoor plants. Many factors explain this situation, including gardening education, plant buying and maintenance costs, living conditions (household size, sun light intensity, time spent inside), and lifestyles (including the interest for gardening). Such as[40], ease of growth, aesthetics, and affordability are the most important aspects when keeping houseplants. The findings have high relevance for planners, showing that indoor nature is not a realistic alternative to compensate for the deficit of outdoor green areas.

The second significant findings show that the most frequently mentioned species in Bucharest indoor households are from genus *Ficus, Hibiscus, Pelargonium, Cactus, Saintpaulia, Orchidae, Begonia, Dracena, Yucca,* and *Aloe*. High differences arise when compared with the global situation, where only *Dracena* and *Saintpaulia* appear[15]. These could be explained through the species availability on the market, former experience in gardening, and specific indoor conditions (primarily the existence of winter seasons). Besides, the position of the indoor plants in the house is influenced by the seasonality, the household's size and structure, and the collective living. Thus, to reduce the impact on the neighbors, many residents prefer to reduce the number of plants and/or put them inside (especially in the living room). Also, an emerging trend is the collective building is to have plants on the hall (so outside of household, but not outside of the building). These findings are relevant for understanding the potential interactions between residents and indoor plants.

The perceived benefits of interactions between residents and indoor plants show the positive impact on physical and mental health, as well as the aesthetic and reducing indoor air pollution (Table 4). This finding is similar with the results of other researches[18,22,23]. However, other benefits, as producing food, reducing the impact of noise, enhancing the task performance, satisfaction, and happiness are peripheral. For example, in Germany[41], mention the importance of indoor plants to support the orientation to edible cities. The perceived challenge of interactions between residents and indoor plants is similar to the literature[23]. The profile of the residents strongly influences the results, with more than 50% being university and post-university graduates. It is worth mentioning that the perception of health is greatly influenced by socio-economic factors, social involvement or pre-existing diseases[42]. In the same time, we have not recorded a high number of negative interactions, which in other studies[43] have been found: biological air pollution with pollen or biogenic volatile organic compounds.

Table 4

Air pollutants removed by indoor plants

Plants	Benzene	Formaldehyde	Trichloroethene	Xylene and Toluene	Ammonia
Dypsis lutescens (Areca)		✓		✓	
Nephrolepis exaltata (sword fern)		✓		✓	
Hedera helix (ivy)	✓	✓	✓	✓	
Chlorophytum comosum (spider plant)		✓		✓	
Epipremnum aureum (devil's ivy)	✓	✓		✓	
Spathiphyllum (peace lily)	✓	✓	✓	✓	✓
Chamaedorea seifrizii (bamboo)		✓		✓	
Sansevieria trifasciata	✓	✓	✓	✓	
Chrysanthemum (Chrysanthemum)	✓	✓	✓	✓	✓
Aloe vera (Aloe)	✓	✓			

Source:[44]

The study has some assumed limitations. First, it is the low number of respondents compared to the number of Bucharest households. This was influenced by the sampling procedure (snowball sampling) and the people's reluctance to give details about private aspects of the housing pattern. The study assumes these limitations and tries to be oriented to a low sample size where the built trust could be managed. In addition, answers are strongly related to personal experiences or observations of the interviewer/interviewed persons, as well as the beliefs they have about plants and their interactions, and there are limited alternatives to validate the information people provide about indoor plants. In this case, for 21% of the sampling size, the authors realized indoor air quality measurements and partially validated the information provided by the residents.

CONCLUSION

The paper details the characteristics related to indoor plants in Bucharest households, including numbers, species, and location in the households' rooms, management practices, perceived benefits, and challenges. The interest in having indoor plants is moderate, with 27% of analyzed households having more than ten plants. This is related to limited free time, limited knowledge of

gardening, and inadequate housing conditions (e.g., limited sunlight, the small windowsills). There is specificity in terms of indoor plant species, influenced by the species availability on the market and the experiences in managing them. Additional research must be developed to realize the connection between the indoor plants and the resident's profile. The results are essential for urban planners and health experts, who must better understand the connection between urban nature and residents and develop new projects to increase its multifunctionality of urban green infrastructure.

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