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Original Research Article

Developing the Evaluation Indicators of Urban Agriculture in Residential Environments Using the Delphi Method*

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Abstract | Urban agriculture has historically served the residents of cities by producing and supplying food. Today, due to instabilities in social, economic, and environmental dimensions in the field of urban construction—particularly in residential areas caused by the dominance of modern lifestyle patterns, population growth in cities, and the increase of indiscriminate constructions with high density—there is a growing interest in urban agriculture as a suitable response to achieve sustainability. This trend has gained significant popularity among various communities. The purpose of this research is to identify the influential indicators of urban agriculture in residential environments. In this research, first, influential indicators of urban agriculture in residential environments were extracted using documentary and content analysis methods. Subsequently, to validate these indicators, the Delphi method was employed in three rounds with the participation of 20 experts and academic specialists in architecture and landscape architecture. Ultimately, 80 indicators were identified, and their importance in residential environments was determined based on the Likert ranking scale and statistical analyses. According to the research findings, the influential indicators of urban agriculture were classified into four dimensions: economic, social, environmental, and spatial-physical desirability. The results indicated that, from the specialists' perspective, the beneficial effects and influential indicators included "increased per capita urban green space," "increased carbon dioxide absorption," "reduced temperature," " increased freshness and pleasant aromas," "increased resident participation in greening their living environment," and "increased biodiversity through planting various plants and raising different animals" in environmental dimensions; "increased leisure time," "stress reduction," and "development of social relationships and interactions" in social dimensions; "investment in underutilized resources such as rooftops, terraces, balconies, etc.," "increased savings," and "increased property values" in economic dimensions; and finally, "increased the vitality of residential spaces," "improved quality and spatial capabilities for growth," and "Beautification of landscapes" in physical-spatial desirability dimensions were prioritized respectively.

Keywords | *Urban Agriculture, Residential Environments, Impacts Of Urban Agriculture, Delphi Method.*

Introduction| Today, the search for sustainable development methods has led to the emergence of various forms of urban agriculture (Yang et al., 2010). Urban agriculture provides approximately 15% of the world's food and can take various forms, including compact and small urban farms, home food production, land sharing, green roofs, beekeeping, educational greenhouse centers, restaurant gardens, food production in public spaces, guerrilla gardens, community gardens, balcony vegetable production, and any other

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production methods (Burgin, 2018). The most significant feature of this type of agriculture is its integration into the urban economic, social, and environmental systems. This integration utilizes urban resources such as land, water, labor, and urban organic waste while also impacting food security, environmental sustainability, economy, social cohesion, culture, physical and mental health, and reducing unemployment and poverty (Dieleman, 2017).

Smit et al. (2001) recognized areas around residential buildings, including backyards, gardens outside residential structures, rooftops, balconies, and walls, as the best places for growing food in cities, where a wide range of agricultural activities such as vegetable gardening, flower cultivation, fruit tree cultivation, poultry raising, and growing medicinal plants can be carried out. Therefore, addressing urban agriculture and its influencing factors can be crucial in determining the role of agriculture in sustainable development within residential environments. In this context, given the high importance of urban agriculture, particularly in residential areas, this research aims to clarify the evaluation indicators of urban agriculture in residential environments and seeks to answer the following questions: What are the dimensions and influential indicators of urban agriculture in residential environments? How are these indicators evaluated and prioritized? How can they be utilized to create desirable residential environments? Although scattered studies have been conducted on understanding the role of urban agriculture at urban scales, a comprehensive study on the impacts of this type of agriculture in residential environments has not been undertaken.

Research Background

Throughout human history, urban agriculture has existed with various functions, including food production and leisure activities. In contemporary times, significant actions and research have been undertaken to promote urban agriculture.

Today, urban agriculture is recognized as a new approach, first introduced in 1996 in the book "Urban Agriculture: Food, Jobs, and Sustainable Cities" by Jack Smith, often referred to as the father of urban agriculture. In this work, he discusses issues such as the past and future of urban agriculture, urban farmers, the benefits and impacts of urban agriculture, challenges and limitations, and advancements in urban agriculture (Smit et al., 1996). The publication of this book in 1996 marked a turning point in defining the international role of urban agriculture (Bohn & Viljoen, 2012). This book is based on the research and study trips, as well as surveys conducted by this researcher in approximately 20 countries worldwide, supported by the United Nations Development Programme[1] between 1991 and 1992 (Smit et al., 2001).

In 1996, around 40 international organizations involved in urban agriculture formed the International Support Group for Urban Agriculture[2] to create a common agenda and coordinate their activities. Urban agriculture and urban food security received increasing attention from international organizations such as the Food and Agriculture Organization of the United Nations[3], the United Nations Development Programme, the United Nations Human Settlements Programme4, and international summits. In 2000, international research organizations affiliated with the Consultative Group for International Agricultural Research[5] also included urban agriculture in their research agenda and launched a comprehensive research program titled "Urban Harvest," operating in many countries (FAO, 1996; Smit et al., 2001). All these actions represent a small portion of the initial efforts following the introduction of urban agriculture by Jack Smith.

Theoretical Foundations:

• Concept of urban agriculture

According to the Food and Agriculture Organization of the United Nations (FAO), urban agriculture refers to the production and supply of food security and income generation based on agricultural activities, pursuing goals such as sustainable development and environmental protection. Its scope includes the margins and interiors of cities, with production occurring in spaces such as home yards, rooftops, community vegetable and fruit gardens, and unused public spaces. Its distinction from rural agriculture lies in its ability to integrate the urban economy with urban ecological systems (FAO, 1996). Furthermore, in 2022, this organization briefly defined urban and peri-urban agriculture as the production of food, other products, and related processes carried out in various lands and spaces within cities and their surrounding areas (Urban and peri-urban ..., 2022).

In another definition, Vagneron (2007) describes urban agriculture as a collection of agricultural activities, including horticulture, crop production, livestock raising, aquaculture, and forestry, conducted within and around cities. This type of agriculture relies on a range of available resources such as land, water, labor, waste, and energy, and can meet some of the basic needs of households through the production of food and non-food items or supply them to the market.

Urban agriculture also refers to the production of any agricultural product within cities or suburbs, including the cultivation of food, medicinal plants, and ornamental plants. It is considered one of the sources of urban nutrition systems and one of several food security options for households. It encompasses various methods and approaches, from backyard and rooftop gardening to

extensive urban gardening, hydroponic greenhouses, and aquaculture (Dimitri et al., 2016).

In 2013, the World Bank defined urban agriculture as an industry within a city or metropolitan area, or in the periphery of a city, that utilizes available human, land, and water resources within and around that urban area to grow, cultivate, process, and distribute a variety of food and non-food products. It identified the locations for this type of agriculture as gardens, rooftops, vacant public lands, warehouses, or agricultural lands. The orientation and scale of these activities vary, ranging from subsistence farming to recreational types, and can be managed at small scales by residents, local gardeners, and livestock keepers, or at medium to large scales by commercial enterprises (Urban Agriculture: Findings ..., 2013).

In fact, urban agriculture is a multifunctional agricultural system that connects traditional agricultural activities with leisure and recreational activities, economic vitality, individual health, community well-being, landscape aesthetics, and environmental protection issues (Miccoli et al., 2016).

- **Dimensions of the impact of urban agriculture**

Urban agriculture has gained more attention today due to its economic, social, environmental, and spatial dimensions (Mukherji & Morales, 2010). It has positive impacts on sustainability in economic, social, and environmental dimensions (Pradhan et al., 2023; Azunre et al., 2019; Gray et al., 2020; de Oliveira Alves & de Oliveira, 2022; Pradhan et al., 2024; Specht et al., 2014). The most distinguishing feature of urban agriculture is not its size or location, but the fact that it is an integral part of the urban economic, social, and ecological system (Mougeot, 2000).

A sustainable approach to urban agriculture focuses on maximizing its potential social, environmental, and economic contributions. Urban gardening, if managed properly, can play a significant role in alleviating social, economic, and environmental issues in cities (Veenhuizen, 2006).

Indraprahasta & Agustina (2016) presented the advantages of urban agriculture in the three dimensions of social, economic, and environmental aspects. Mougeot (2000) regarded urban agriculture as an inseparable part of the urban economic, social, and ecological system, impacting urban systems such as urban food security, poverty, and health.

Grădinaru et al. (2018) categorized the benefits of urban agriculture into tangible and intangible advantages. Tangible benefits include food and raw material production, while intangible benefits encompass its cultural values. The expansion of this type of agriculture enhances neighborhood beautification, community empowerment, self-esteem, and individuals' ability to maintain cultural identity and traditions (Colasanti et al., 2012). It also increases the use of communal spaces, enhances environmental security, reduces depression, and facilitates access to healthy food from a health perspective (Mohammadi & Ebrahimi Nia, 2019). Urban agriculture enables city residents to access safe and healthy food, participate in social activities, expand social inclusion by strengthening rural-urban ties, raise awareness about food systems and resources, and recreate connections with nature and community (FAO, 2017). In other words, urban agriculture leverages urban resources such as water, labor, urban organic waste, and vacant green spaces to create value-added functions, impacting the economy, food security, social cohesion, culture, physical and mental health, and poverty reduction (Hagey et al., 2012).

Urban agriculture contributes to urban resilience and synergy between agriculture, urban water resources, and food waste recycling, and is seen as a strategy to combat future climate change (Pulighe & Lupia, 2016). Additionally, this type of agriculture helps create greener cities, adapt cities to changing climates, reduce carbon footprints by shortening supply chains, increase urban and peri-urban biodiversity, mitigate the urban heat island effect, protect urban ecosystems, and improve landscapes (FAO, 2017).

In its 2013 report, the World Bank highlighted environmental benefits such as the integration of urban farms with urban green spaces, creating opportunities for community participation in greening programs, enhancing city resilience to climate change, and reusing urban waste. It also noted economic benefits such as the development of local economies, non-commercial access to food for poor and low-income individuals, and the creation of job and income opportunities through the provision of products to urban markets (Urban Agriculture: Findings ..., 2013).

According to studies and reviews of credible sources in this field, the effects of urban agriculture encompass a wide range of impacts. Some studies have been very in-depth due to the researchers' personal perspectives, often only addressing broader impacts such as social, economic, and environmental dimensions. Many studies, however, have neglected spatial-physical impacts, and the scale of these studies has mostly been at the metropolitan level, with less focus on determining the impacts of urban agriculture at the residential building scale. Based on a review of 75 relevant domestic and foreign sources, raw impact indicators were extracted. Content analysis was employed to categorize these raw data, as explained in the research methodology section. The categorization was done across four areas: economic, social, environmental, and consideration of impactful indicators in architectural dimensions in terms of physical-spatial desirability. Although some of these indicators have roots in other dimensions, indicating their high importance, this overlap cannot be overlooked. This

research attempts to present these indicators in dimensions that have the most significant impacts in their respective areas.

Research Methodology

This research aims to elucidate the benefits and impactful indicators of urban agriculture, characterized by a descriptive-analytical nature based on content analysis and the Delphi method. In the first step, raw data were obtained from the review of 75 relevant domestic and foreign sources in the field of urban agriculture, and content analysis was used to categorize these raw data. Content analysis is a technique related to documentary methods (Barden, 1996, 35), which previously emphasized determining the frequency of studied variables but is now used to gain insights into complex social issues and psychological variables (Delavar, 2014, 277).

In the second step, the frameworks and indicators extracted were evaluated and validated by a group of specialists and experts in architecture and landscape architecture using the Delphi technique, which involved developing a questionnaire in three stages based on a Likert scale for ranking. The main goal of the Delphi method is to achieve the most reliable group consensus from expert opinions through a series of focused questionnaires with controlled feedback (Dalkey & Helmer, 1963, 458).

Subsequently, the data obtained from the Delphi process were analyzed using SPSS-26, and reliability was assessed using Cronbach's alpha, while sample adequacy was evaluated using the KMO[6] test. For content validity, after designing the Delphi questionnaire, it was distributed to a group of academic specialists, and their feedback was incorporated into the questionnaire.

• Formation and composition of Delphi panel members

The Delphi method involves the participation of individuals with knowledge and expertise in the research topic, and selecting these individuals is one of the most crucial steps in the Delphi technique, as the credibility of the research results depends on their knowledge and qualifications (Powell, 2003). Delphi participants should be well-trained and possess sufficient relevant knowledge and competence regarding the issue under investigation (Hsu & Sandford, 2007, 4). Typically, the number of participants in the Delphi method ranges from 10 to 20 individuals (Powell, 2003). Therefore, the statistical population in this study comprised 20 specialists in architecture and landscape architecture. The sampling method for the initial participants was theoretical and purposeful, followed by a snowball network approach. The adequacy of the sample size for the Delphi survey was assessed using the KMO test in the reliability measurement section.

Research Findings

In the first step, based on library studies and the review of 75 credible domestic and foreign sources, and using content analysis, 76 impactful indicators of urban agriculture were extracted, categorized, and compiled across four dimensions: economic, social, environmental, and physical-spatial desirability, as shown in Table 1.

In the next step, to complete and validate these impactful indicators, approval from specialists and experts in architecture and landscape architecture was required, which was achieved using the Delphi method through a questionnaire in three stages.

• The first stage of Delphi

In the first stages of the Delphi method, a semi-structured questionnaire was sent to selected professors and researchers in the fields of architecture, landscape architecture, and urban agriculture after reviewing the background of Specialists. Prior to sending the questionnaire to the experts, it was revised and completed by five university professors. The questionnaire designed in this initial phase aimed to validate the structure and impact indicators with two objectives:

1. To verify the extracted indicators, categorize them, remove or transfer them to other impactful dimensions, or even propose new impactful indicators.
2. To assess the importance of each indicator and achieve a ranking of these indicators.

In the open-ended questions section, 21 new indicators were provided by the experts and categorized into three main dimensions (physical-spatial desirability, social, and environmental) as shown in Table 2. In the section for indicators extracted from content analysis, the indicators were categorized and ranked by the experts using a 10-point Likert scale. Ten indicators with an average score below the threshold of 7 were removed, as detailed in Table 3.

In the first stage of the Delphi method, based on the evaluation and statistical analysis of the data using SPSS-26, the reliability of the questionnaire in the closed questions section was found to be 0.991, which is acceptable as it is higher than 0.7.

• The second stage of Delphi

In the second round of the Delphi method, the indicators that were scored and approved in the first round, along with the indicators proposed by the experts, were sent again in a new questionnaire for scoring based on the 10-point Likert scale. Additionally, the average scores from the first round were presented alongside the indicators to inform decision-making.

In this phase, by evaluating each indicator, seven indicators were removed by the experts, including "improvement of self-confidence and self-esteem," "Health education and environmental care," "social welfare," and "support for innovation and creativity" from the social dimension, as

Table 1. Beneficial effects and impactful indicators of urban agriculture from environmental, social, economic, and physical-spatial desirability perspectives. Source: Authors.

Perspective	Beneficial Effects and Influential Indicators		
Environmental	Improving weather, climate conditions and microclimates	- Increasing per capita urban green space - Increasing humidity - Reducing temperature - Increasing freshness and pleasant aromas - Absorbing air pollution and dust - Controlling wind and storms - Reducing the transmission of solar radiation - Creating shade and protected areas - Absorbing noise pollution	
	Water resources management	- Direct use of surface water - Reusing grey water and wastewater after treatment	
		Increasing the volume of soil permeability	- Surface water management, runoff, and groundwater recharge - Reducing storm runoff volume and flood and landslide risk - Reducing the need for sewers and drains
		- Reducing infrastructure costs	
	Soil protection	- Composting of agricultural residues, kitchen waste, old newspapers, leaves from city trees, etc. - Reducing the use of chemical fertilizers - Productive reuse of contaminated land - Aeration of abandoned urban soils	
	Waste recycling and waste reduction	- Reducing waste by reducing food packaging and local production - Reusing urban waste and household waste - Recycling materials: Using recycled materials in growing food with compost and preparing fertilizer	
	Global warming and air pollution	- Reducing the volume of polluting gases due to the proximity of production, supply, and sales locations and reducing transportation - increasing carbon dioxide absorption in the air by increasing urban greenery per capita - Reducing energy consumption and time consumption	
	Environmental awareness	- Improving people's knowledge in the field of agriculture and the environment - Increasing people's sensitivity to nutrition, health, and the environment through direct experience - Resident participation in greening programs - Recreational-environmental training	
	Biodiversity	- planting various plants and raising various animals	

Rest of Table 1

Perspective	Beneficial Effects and Influential Indicators	
Social	Physical and mental health	- Food security - Developing physical activity and health - Improving nutrition and access to healthy food - Improving self-confidence and self-esteem - Reducing depression - Health education and environmental care
	Social-cultural life	- Preserving cultural identity and traditions - Social inclusion - Social capital - Social dynamics - Social cohesion and solidarity - Development of social relationships and interactions - Sense of belonging and social sense - Community Capacity Building and Empowerment - Trust Building - Social Welfare - Leisure time - Social Security - Creating Educational Opportunities and Transferring Experiences
	Community participation	- Participation in the food system - Women's social participation - Low-income groups participation - Participation in collective investment in common interests
Economic		- Poverty reduction - Local and indigenous economic development - Income generation - Increase in savings - Increasing property value - Entrepreneurship and increasing job opportunities - Investing in underutilized resources (rooftops, terraces, balconies, and vacant spaces and lands)
Physical-spatial Desirability		- Providing green space - Creating ecological open space - Wider and more productive use of lawns and green space - Increasing dynamism - Growing recreational spaces - Developing tourism - Reduction and revitalization of abandoned, derelict, and unused spaces, lands, and buildings - Utilization of minimal spaces - Improving the quality and spatial capabilities for growth - Improving flexibility - Improving the quality and visual appeal - Increasing landscape homogeneity - Beautifying the landscapes - Bringing life to the general spirit of housing - Creating and increasing the use of communal spaces to establish social contacts and form constructive relationships (creating environments for family, friendly gatherings, and important business appointments) - Integrating residential spaces with nature (strengthening the connection of urban people with nature and the sense of presence in nature)

Table 2. Indicators proposed by experts in the first phase of the Delphi method. Source: Authors.

Indicators suggested by experts	Physical-spatial desirability	Social	Environmental
Increasing the vitality of residential spaces	✓		
Creating an intimate relationship between humans and the surrounding environment	✓		
Increasing the use of open and outdoor spaces	✓		
Sense of belonging to the place	✓		
Dual use of residential spaces (multifunctionality of spaces)	✓		
Community participation in the design, space-building, and maintenance of residential environments	✓		
Residents' sense of responsibility towards the common spaces of residential buildings	✓		
Improving local infrastructure	✓		
Stress reduction		✓	
Promoting healthy and sustainable lifestyles		✓	
Reducing isolation and connecting people with shared experiences		✓	
Promoting intergenerational cooperation and participation		✓	
Social bonding of neighbors		✓	
Supporting innovation and creativity		✓	
Enhancing volunteer activities		✓	
Strengthening local identity		✓	
Improving and treating diseases using the medicinal properties of some plants		✓	
Improving children's knowledge and creativity related to agriculture in residential spaces			✓
Protecting natural habitats			✓
Protecting wildlife			✓
Continuous maintenance and care of plants			✓

Table 3. Excluded indicators with a threshold of less than 7 in the first two Delphi stages. Source: Authors.

Dimensions	Indicators	Mean
Social	Trust Building	6.9
	Social Security	6.65
Economic	Poverty Reduction	6.20
Physical-spatial desirability	Tourism Development	6.75
Environmental	Wind and storm control	6.85
	Productive reuse of contaminated land	6.85
	Aeration of abandoned urban soils	6.85
	Reducing the need for sewers and drains	6.55
	Reducing infrastructure costs	5.95
	Reducing energy consumption and time consumption	6.70

Table 4. Indicators removed with a threshold below 7 in the second Delphi round. Source: Authors.

Dimensions	Indicators	Mean
Social	Improving self-confidence and self-esteem	6.46
	Health education and environmental care	6.6
	Social welfare	6.2
	Supporting innovation and creativity	6.13
Economic	Local and indigenous economic development	6.06
	Income generation	6.26
	Entrepreneurship and increasing job opportunities	6.26

well as "development of local and indigenous economies," "income generation," and "entrepreneurship" from the economic dimension, as shown in Table 4. Eighty indicators received an average score above 7.

According to the evaluation and statistical analysis of the data using SPSS-26, the reliability of the questionnaire in this phase was found to be 0.988, which is acceptable as it is above 0.7. Furthermore, using the KMO test and Bartlett's test of sphericity in Table 5, the sample adequacy test was conducted, with results showing a KMO value of 0.714, which is acceptable as it is above 0.6.

• The third stage of Delphi

In the third round of the Delphi method, the 80 indicators approved in the second round with an average score above 7 were sent again in a new questionnaire for scoring based on the 10-point Likert scale. The average scores from the second round were presented alongside the indicators to guide decision-making. In this phase, no indicator had an average score below the threshold of 7, and the scoring and ranking of the indicators were aligned with the four main dimensions presented.

According to the evaluation and statistical analysis of the data using SPSS-26, the reliability of the questionnaire in this phase was found to be 0.983, which is acceptable as it is above 0.7. Additionally, using the KMO test and Bartlett's test of sphericity in Table 6, the sample adequacy test was conducted, yielding a KMO value of 0.721, which is acceptable as it is above 0.6.

The results from the three rounds of the Delphi method indicate that consensus among the participants has been achieved for the following reasons, allowing for the conclusion of the rounds:

- In the third round of Delphi, no indicators were removed; all indicators had scores above the threshold of 7.
- The KMO test results were 0.714 in the second round and 0.721 in the third round, indicating sample adequacy and consensus among experts across the two consecutive rounds.

Based on the results and scores from the experts in this study, a total of 80 indicators were identified, and the importance of each indicator in enhancing social, economic, and environmental systems, and physical-spatial desirability in residential environments was determined, as shown in Tables 7 & 8.

The findings revealed that the top rank was jointly held by the indicator of increasing the vitality of residential spaces from the perspective of physical-spatial desirability and the indicator of providing leisure time from the social perspective, both with a score of 8.75. The second rank was attributed to the indicator of helping to reduce stress from the social perspective with a score of 8.66, followed by the increase in per capita urban green space from the environmental perspective, which scored 8.58, placing it third. In fourth place, importance was given to indicators related to enhancing quality and spatial capabilities for growth from the physical-spatial desirability perspective and developing social relationships and interactions from the social perspective, both scoring 8.5. Following these, indicators from the physical-spatial desirability perspective, such as beautifying landscapes and creating a close relationship between humans and their environment, along with the social perspective indicators of Developing physical activity and health, averaged a score of 8.41, ranking fifth. In sixth place, six indicators with equal importance averaged 8.32, which included five indicators from the spatial quality perspective: creating and increasing the use of communal spaces, Improving the quality and visual appeal, increasing the use of open and outdoor spaces, bringing life to the general spirit of housing and integrating residential spaces with nature, along with one social indicator, which was the reduction of depression.

The seventh priority was jointly assigned to five indicators:

Table 5. KMO and Bartlett's sphericity test for sample size adequacy in the second stage of the Delphi method. Source: Authors.

KMO and Bartlett's Test		Amount
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.714
Bartlett's Test of Sphericity	Approx. Chi-Square	397.663
	df	105
	Sig.	0.0

Table 6. KMO and Bartlett's test for sample adequacy in the third phase of the Delphi method. Source: Authors.

KMO and Bartlett's Test		Amount
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.721
Bartlett's Test of Sphericity	Approx. Chi-Square	184.033
	df	66
	Sig.	0.000

reducing temperature, increasing carbon dioxide absorption in the air by increasing urban greenery per capita, increasing freshness and pleasant aromas, and resident participation in greening programs, from the environmental perspective, as well as providing green space from the physical-spatial desirability perspective, with an average score of 8.25. The indicators of a sense of belonging and social connection, improving nutrition and access to healthy food, Promoting a healthy and sustainable lifestyle and increasing dynamism from the social perspective, the growth of recreational spaces, and creating ecological open spaces from the physical-spatial desirability perspective, as well as indicators for increasing biodiversity through planting various plants and raising different animals from the environmental perspective, achieved an average score of 8.16, ranking eighth.

The ninth priority was jointly held by seven indicators: continuous maintenance and care for plants, increasing people's sensitivity to nutrition, health, and the environment through direct experience, composting agricultural residues, kitchen waste, old newspapers, city tree leaves, etc., absorbing air pollution and dust, increasing humidity, continuous maintenance and care for plants, Reducing the volume of polluting gases due to the proximity of production, supply and sales locations and reducing transportation from the environmental perspective, with an average score of 8.08.

In the tenth position, indicators related to Reducing isolation and connecting people with shared experiences from the social perspective, Creating shade and protected places, Improving people's knowledge in the field of agriculture and the environment and providing recreational-environmental training from the environmental perspective, as well as indicators for utilizing minimal spaces, improving flexibility, and aiding in the reduction and revitalization of abandoned, derelict, and unused spaces, lands, and buildings from the physical-spatial desirability perspective, achieved an average score of 8.

However, these results can also be interpreted in another order. In Table 9, three impactful indicators of urban agriculture are presented separately across all four dimensions: environmental, social, economic, and Physical-spatial desirability. In the environmental dimension, the highest importance was given to increasing per capita urban green space with a score of 8.58, followed by reducing temperature, increasing freshness and pleasant aromas, resident participation in greening programs, and increasing carbon dioxide absorption in the air by increasing urban greenery per capita, scoring 8.25, and Increasing biodiversity by planting various plants and raising various animals with a score of 8.16. In the social dimension, leisure time scored 8.75, stress reduction scored 8.66, and the development of social relationships and

Table 8. Ranking of influential indicators of urban agriculture based on the average obtained from Delphi stage 3 (rank 11-21 including 39 indicators). Source: Authors.

Priority	Mean	Indicators	Dimensions
11	7.91	Improving children's knowledge and creativity related to agriculture in residential spaces	Environmental
	7.91	Creating educational opportunities and transferring experiences	Social
	7.91	Increasing the volume of soil permeability (Surface water management, runoff, and groundwater recharge)	Environmental
	7.91	Sense of belonging to place	Physical-spatial
12	7.83	Community participation (participation in collective investment in common interests)	Social
	7.83	Social cohesion and solidarity	Social
	7.83	Social dynamism	Social
	7.83	Reducing the transmission of solar radiation	Environmental
	7.83	Community participation (participation in the food system)	Social
	7.83	Protecting natural habitats	Environmental
	7.83	Dual use of residential spaces (multifunctionality of spaces)	Physical-spatial
	7.83	Community participation in the design, space-building, and maintenance of residential environments	Physical-spatial
13	7.75	Recycling materials: Using recycled materials in growing food with compost and preparing fertilizer	Environmental
	7.75	Direct use of surface water	Environmental
	7.75	Residents' sense of responsibility towards the common spaces of residential buildings	Physical-spatial
	7.75	Increasing landscape homogeneity	Physical-spatial
	7.75	Promoting intergenerational cooperation and participation	Social
	7.75	Community participation (social participation of women)	Social

Table 7. Ranking of impactful indicators of urban agriculture based on the average obtained from the third phase of Delphi (Ranks 1-10, including 41 indicators). Source: Authors.

Priority	Mean	Indicators	Dimensions
1	8.75	Increasing the vitality of residential spaces	Physical-spatial
	8.75	Leisure time	Social
2	8.46	Stress reduction	Social
3	8.58	Increasing per capita urban green space	Environmental
4	8.5	Improving the quality and capabilities of space for growth	Physical-spatial
	8.5	Developing social relationships and interactions	Social
5	8.41	Beautifying landscapes	Physical-spatial
	8.41	Developing physical activity and health	Social
	8.41	Creating an intimate relationship between humans and the surrounding environment	Physical-spatial
6	8.33	Creating and increasing the use of communal spaces to establish social contacts and form constructive relationships	Physical-spatial
	8.33	Improving the quality and visual appeal	Physical-spatial
	8/33	Increasing the use of open and outdoor spaces	Physical-spatial
	8.33	Bringing life to the general spirit of housing	Physical-spatial
	8.33	Integrating residential spaces with nature (strengthening the connection between urban people and nature and the sense of presence in nature)	Physical-spatial
	8.33	Reducing depression	Social
7	8/25	Reducing temperature	Environmental
	8/25	Increasing carbon dioxide absorption in the air by increasing urban greenery per capita	Environmental
	8/25	Increasing freshness and pleasant aromas	Environmental
	8/25	Resident participation in greening programs	Environmental
	8/25	Providing green space	Physical-spatial

Rest of Table 7.

Priority	Mean	Indicators	Dimensions
8	8.16	Sense of belonging and social sense	Social
	8.16	Improving nutrition and access to healthy food	Social
	8.16	Promoting a healthy and sustainable lifestyle	Social
	8.16	Increasing biodiversity by planting various plants and raising various animals	Environmental
	8.16	Creating ecological open space	Physical-spatial
	8.16	Increasing dynamism	Social
	8.16	Growing recreational spaces	Physical-spatial
9	8.08	Continuous maintenance and care of plants	Environmental
	8.08	Increasing people's sensitivity to nutrition, health, and the environment through direct experience	Environmental
	8.08	Composting agricultural residues, kitchen waste, old newspapers, leaves from city trees, etc.	Environmental
	8.08	Absorbing air pollution and dust	Environmental
	8.08	Increasing humidity	Environmental
	8.08	Continuous maintenance and care of plants	Environmental
	8.08	Reducing the volume of polluting gases due to the proximity of production, supply, and sales locations and reducing transportation	Environmental
10	8	Reducing isolation and connecting people with shared experiences	Social
	8	Creating shade and protected places	Environmental
	8	Improving people's knowledge in the field of agriculture and the environment	Environmental
	8	Recreational-environmental training	Environmental
	8	Reduction and revitalization of abandoned, derelict, and unused spaces, lands, and buildings	Physical-spatial
	8	Using minimal spaces	Physical-spatial
	8	Improving flexibility	Physical-spatial

Rest of Table 8.

Priority	Mean	Indicators	Dimensions
14	7.64	Community participation (participation of social strata) Low-income)	Social
	7.66	Social bonding of neighbors	Social
	7.66	Enhancing volunteer activities	Social
	7.66	Increasing the volume of soil permeability (Reducing storm runoff volume and flood and landslide risk)	Environmental
	7.66	Investing in underutilized resources (rooftops, terraces, balconies, vacant spaces, and land)	Economic
15	7.58	Protecting wildlife	Environmental
	7.58	Social capital	Social
16	7.5	Absorbing noise pollution	Environmental
	7.5	Community Capacity Building and Empowerment	Social
	7.5	Reducing the use of chemical fertilizers	Environmental
17	7.41	Reducing waste: by reducing food packaging and local production	Environmental
	7.41	Increase in savings	Economic
	7.41	Social inclusion (community building)	Social
18	7.23	Improving local infrastructure	Physical-spatial
	7.23	Reusing urban waste and household waste	Environmental
	7.23	Strengthening local identity	Social
19	7.25	Reusing grey water and wastewater after treatment	Environmental
	7.25	Food security	Social
20	7.16	Preserving cultural identity and traditions	Social
	7.16	Increasing property value	Economic
21	7	Improving and treating diseases using the medicinal properties of some plants	Social

interactions scored 8.5, indicating the highest importance. In the economic dimension, investing in underutilized resources scored 7.66, an increase in savings scored 7.41, and increasing property values scored 7.16, representing the highest importance. In the Physical-spatial desirability dimension, increasing the vitality of residential spaces scored 8.75, Improving the quality and spatial capabilities for growth 8.5, and beautifying the landscapes scored 8.41, indicating the highest importance.

Table 10 presents the results of the evaluation of 20 indicators proposed by the experts. Among the proposed indicators, the indicator for increasing the vitality of residential spaces in terms of Physical-spatial desirability was rated as the top priority by the experts and holds significant importance, reflecting the special role of urban agriculture in enhancing the quality of residential environments. Among the indicators, only the indicator for "supporting innovation and creativity" had an average below the threshold of 7, leading to its removal in the second stage of Delphi.

In conclusion, a review of the indicators reveals that they are distributed across all four dimensions, with 28 impactful indicators identified in the environmental dimension, 26 in the social dimension, 23 in Physical-spatial desirability, and 3 in the economic dimension, as shown in Fig. 1.

Conclusion

This research aimed to identify impactful indicators of urban agriculture in residential environments. Through library studies and content analysis, 76 indicators were categorized into four dimensions: social, economic, environmental, and Physical-spatial desirability. Subsequently, using the Delphi technique and developing three questionnaires over three phases, 80 final indicators were validated. These indicators were prioritized and ranked through a Likert scale scoring system, and analyzed using statistical software. While some of these indicators may overlap or influence each other, this study has attempted to categorize them into dimensions with the most significant impacts.

The findings indicate that urban agriculture holds value in all four dimensions: environmental, social, economic, and Physical-spatial desirability. According to the experts, the environmental dimension has the highest number of impactful indicators, and today, urban agriculture can play a crucial role in improving environmental conditions and challenges. Following closely is the social dimension, which, despite being more theoretical and time-consuming to quantify, can enhance physical and mental health and improve the quality of social life in residential areas through tangible aspects of urban agriculture. The Physical-spatial desirability dimension ranks next, emphasizing that the growth of urban agriculture in residential environments can enhance the architecture of spaces and create desirable,

Table 9. The top three priorities of impactful indicators of urban agriculture in the four dimensions: environmental, social, economic, and physical-spatial desirability. Source: Authors.

Dimensions / Rank	Environmental	Social	Economic	Physical-spatial desirability
1	Increasing per capita urban green space (8.58)	Leisure time (8.75)	Investing in underutilized resources (rooftops, terraces, etc.) (7.66)	Increasing the vitality of residential spaces (8.75)
2	Reducing temperature (8.25)	Stress reduction (8.66)	Increase in savings (7.41)	Improving the quality and spatial capabilities for growth (8.5)
	Increasing freshness and pleasant aromas (8.25)			
	Resident participation in greening programs (8.25)			
	Increasing carbon dioxide absorption in the air by increasing urban greenery per capita (8.25)			
3	Increasing biodiversity by planting various plants and raising various animals (8.16)	Development of social relationships and interactions (8.5)	Increasing property values (7.16)	Beautifying the landscapes (8.41)

Table 10. Average values and ranks of each of the new indicators proposed by experts. Source: Authors.

Indicators suggested by experts	Physical-spatial desirability	Social	Environmental
Increasing the vitality of residential spaces	8.75		
Creating an intimate relationship between humans and the surrounding environment	8.41		
Increasing the use of open and outdoor spaces	8.33		
Sense of belonging to the place	7.91		
Dual use of residential spaces (multifunctionality of spaces)	7.83		
Community participation in the design, space-building, and maintenance of residential environments	7.83		
Residents' sense of responsibility towards the common spaces of residential buildings	7.75		
Improving local infrastructure	7.33		
Stress reduction		8.66	
Promoting healthy and sustainable lifestyles		8.16	
Reducing isolation and connecting people with shared experiences		8	
Promoting intergenerational cooperation and participation		7.75	
Social bonding of neighbors		7.66	
Enhancing volunteer activities		7.66	
Strengthening local identity		7.33	
Improving and treating diseases using the medicinal properties of some plants		7	
Continuous maintenance and care of plants			8.08
Improving children's knowledge and creativity related to agriculture in residential spaces			7.91
Protecting natural habitats			7.83
Protecting wildlife			7.58

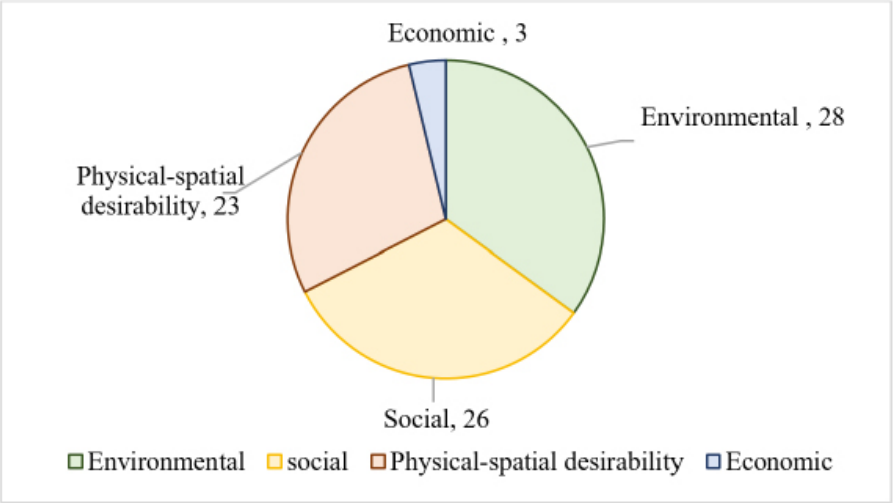

Fig. 1. Frequency of impactful indicators of urban agriculture across the four dimensions: environmental, social, Physical-spatial desirability, and economic. Source: Authors.

high-quality living environments, a topic that has received less direct attention in architecture to date. If we consider the ranking of the indicators, the top priority is related to increasing the vitality of residential spaces from the Physical-spatial desirability perspective, underscoring the need to focus on this issue. The economic dimension has the fewest impactful indicators and ranks last, with three identified indicators averaging below 8. This suggests that the economic aspects of urban agriculture in residential environments are less pronounced than other dimensions, although they may have the most significant impacts at the neighborhood scale, particularly in community or social gardens. Nonetheless, the economic impacts of urban agriculture in residential environments cannot be entirely overlooked, even if they are minimal. Ultimately, the structure established here allows for a more detailed and precise examination of each of the four dimensions in future research. The conducted studies indicate that considering all these dimensions, urban agriculture can serve as a comprehensive strategy for sustainable architectural development and improving the quality of life in residential environments. Citizen participation in green programs, the development of agricultural spaces in residential areas, and leveraging the latent capacities of urban environments can lead to the creation of more sustainable, vibrant, healthier, more beautiful, and ultimately human-centered cities.

Finally, the results of this study can assist policymakers, urban planners, and city managers in developing more effective strategies for urban agriculture in residential environments by taking into account the identified indicators. Given that many cities around the world face challenges such as unchecked population growth, reduced per capita green space, and increased environmental pollution, focusing on urban agriculture as an innovative and effective solution, along with developing supportive regulations, expanding integrated design models with productive green spaces, and raising public awareness about the benefits of this approach, can significantly improve urban living conditions.

Declaration of No Conflict of Interest

The authors declare that they have no conflict of interest in conducting this research.

Endnotes

* This article is derived from the Doctoral thesis of Rana Soleymanpour Asl Navasar, entitled "Conceptual and Operational Models and Evaluation Indicators of Urban Agriculture in Low-Rise Housing Based on Regenerative Development (case Study: Open Spaces of Residential Buildings in Urmia City)" which is being conducted under the supervision of Dr. Mohammad-Ali Khanmohammadi and Dr. Seyyed-Bagher Hosseini at the Faculty of Architecture and Urban Planning, Iran University of Science and Technology.

1. United Nations Development Program (UNDP)
2. Support (SGUA) Group on Urban Agriculture
3. Food and Agriculture Organization (FAO)
4. United Nations Human Settlements Programme (UN-Habitat)
5. Consultative Group for International Agricultural Research (CGIAR)
6. Kaiser-Meyer-Olkin (KMO)

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