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An investigation to the potential integration of productive landscapes in high-rise buildings in cold-climate regions:A case study of Tabriz, Iran

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Abstract

Increasing migration to the cities has caused environmental, psychological and social problems. The construction of high-rise buildings to address the problem of land shortage was proposed and implemented as the most important strategy, which in turn led to the intensification of many environmental, cultural and social problems. The approaches such as urban green spaces, urban ecology, green architecture, and etc. were proposed by experts in order to reduce the adverse environmental, social and psychological effects of urban life. On the other hand, concerns about the economy and food security reduced agricultural land and increased energy and food prices have made widespread debate and research by some researchers in developed countries about urban agriculture (farming and / or gardening) and green space in urban and residential areas. In recent years, the use of agriculture in high-rise buildings has been the subject of research by many researchers and organizations in developed countries. In this paper, according to a literature review of urban agriculture and the measures taken in the world in relation to agriculture in buildings, including various agricultural concepts integrated in buildings, spaces used for agriculture in buildings and agricultural examples implemented in buildings in the world, we study the consistency of the study results with the potential of high-rise Iranian buildings and case studies of Tabriz buildings, and finally present a model for implementing green spaces in the form of suggestions on how to create these spaces in unused spaces of high-rise buildings in Tabriz, according to features of this city.

Keywords: Productive environments, Urban agriculture, productive green space, residential green spaces, green residential complex
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1 Introduction

By 2050, more than 66% of the world's population will live in cities according to estimates by United Nations. The rapid growth of the urban population will lead to problems and challenges such as air pollution, traffic, human

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health and waste management. Scattered urban growth, rapid and unplanned physical development of cities, and the consequent excessive use of motor vehicles have posed many environmental challenges for cities. This massive machine-centred urbanization process, while physically developing cities, has increased environmental pollution, destruction of agricultural land and cost of urban infrastructure. The lack of urban land due to population growth on the one hand, and deforestation that destroys the environment and natural resources, on the other hand, made the issue of food security and production even more difficult. One of the solutions that have been emphasized by researchers in recent years is the use of vertical or horizontal surfaces related to buildings and public spaces for food production [27, 2, 6, 28]. On the other hand, due to the growth of the urban population, destruction of agricultural lands and topics related to food shortage and security, a new approach to designing green spaces has been created around the world under topics such as productive green spaces, environments, urban agriculture, and urban landscape. In this regard, topics such as zero farming, indoor agriculture, rooftop agriculture, rooftop greenhouse agriculture and vertical agriculture have been proposed. Since, according to statistics released by the World Food Organization, Iran is facing a food security crisis due to long periods of drought, it is necessary to address food production in the city.

In this regard, due to the lack of open and green urban spaces in high-rise buildings due to technological limitations and various ecological, social and economic advantages of green space coexistence [29], many studies on high-rise buildings have proposed a variety of patterns of green skyscrapers/vertical green farms to meet the needs of green and productive urban spaces [3, 18]. Considering public spaces in high-rise residential complexes to produce agricultural products can lead to the creation of a productive green space that will finally increase public participation in the process of preparation, social integrity, health and well-being of citizens, and increase employment opportunities, as a result, production and utilization of agricultural products as well as access to seasonal fresh agricultural products [15].

The purpose of this paper is to develop and integrate urban agriculture using high-rise residential buildings in large cities and specifically the city of Tabriz in northwest Iran. We examined the conditions for the realization of the concept of food production in relation to horizontal and vertical surfaces in high-rise buildings in Tabriz and provided solutions to implement this idea. This paper is organized into two main sections. In the first section, after explaining the idea of urban agriculture, different concepts and approaches to food production in urban buildings are presented. In the second section, the physical features and available evidence of the residents' participation in planting fruitful plants in high-rise buildings of Tabriz were examined and finally, suggestions for the development of this idea were presented.

2 Literature review

2.1 Urban agriculture

Urban agriculture is defined as the production and distribution of food and other products by planting plants and livestock in cities to feed the local population [9]. The changes in climate reduced food grain production by increasing temperature and changes in precipitation patterns, and according to the definition provided by the International Development Research Center (2003), urban agriculture is a practice that is located within the city that uses human and material resources to cultivate, process and distribute a variety of food or non-food products within or around the city. A noteworthy point in the definition of urban agriculture is that urban agriculture usually occurs in a place where agricultural activity is not expected to occur. Urban agriculture does not mean general agriculture and cultivation. The production of basic agricultural products such as wheat, rice and cereals requires professional and developed agricultural conditions to meet national needs on a macro scale. Agriculture in the city means planting and producing small food products using easy methods and with minimal facilities. Urban agriculture usually occurs for two main purposes earning income and food, and recreation in lands around houses such as backyards, balconies and roofs, or in common lands between citizens. According to the report of United Nations Development (2014), approximately 800 million people worldwide are engaged in agricultural work [9]. Since urban agriculture is one of the strategies to strengthen urban sustainability, researchers have different economic values (such as social integrity and development) [13, 16, 8], economic advantages (production and supply of food products and employment) [17, 4] and environmental advantages (such as reducing the effects of climate change and ecosystem advantages) [14, 10]. For example, [5] considered urban agriculture advantages as strengthening people's participation in collective activities, bringing people closer to nature, preserving old traditions, training children about food, producing high-quality food, and creating beauty and vitality in cities in addition to job creation and income generation [5].

FAO estimated that urban agriculture, which produces food for a quarter of the world's population, reduces food transportation, packaging, etc., and improves food health [19]. Urban agriculture provides a tangible and accessible opportunity for citizens to engage in food production and reconnect with a food system that many people feel is out of their reach and far from them [1]. This approach is well coordinated with urban planning and seeks to integrate cities using a continuous and productive ecosystem for producing food, water, soil, air and natural media. Urban agriculture not only produces and provides food in cities, but also solves problems such as poverty, malnutrition and environmental degradation, and provides food security while providing many business opportunities to small and medium-sized entrepreneurs. Different types of urban agriculture have been proposed based on scale and other objectives (economy and environment). Urban agriculture can be formed on buildings or on land.

2.2 Productive urban landscapes

The productive urban landscape (PUL) perspective in the sense of integration of food production and urban landscapes into sustainable urban development has been proposed by experts over the past few decades. The key concept in this approach is to create a network of food-producing urban spaces that support the built environment. The PUL is an integrated policy for linking fertile plants to cities acting based on the creation of a new urban infrastructure and support of redefinition of the meaning of urban open spaces. The main function of this network is the presence of fruitful plants in the city with the aim of producing organic fruits and vegetables, as well as increasing the productivity of each square meter of urban land. Intra-city and suburban lands are re-designed in this policy with the aim of producing food and new species of sustainable urban landscapes are formed, which are composed of transportation infrastructure, energy and natural lands. According to previous studies, by providing three factors of organic farming, local use and local trade of crops in the PUL network, we can hope for energy balance and reduction in environmental problems such as CO2 emission. Due to the lack of land in large cities, various spaces such as private and participatory gardens, roofs and terraces and/or small spaces in the courtyards can be used to realize the idea of urban agriculture. One of the most accessible and suitable places for the development of PUL are the buildings in the cities, for which many researchers have emphasized the possibility of integrating urban agriculture with them [11, 28, 25, 7].

2.3 Agriculture in buildings

In parallel with the emphasis of researchers and government officials on creating green spaces in skyscrapers, in recent years the topic of agriculture in urban buildings has received much attention and is increasingly studied [25**?**]. Several models have been proposed to integrate urban agriculture with buildings, which are referred to as "Building Integrated Agriculture" (BIA) in literature review [30]. This model can lead to the design of sustainable vertical cities through better analysis and use of water, land and energy, and is compatible with the principles of bioclimatic design used by architects and environmental designers [20, 28]. The advanced hydroponic systems (zero farming), artificial energy-saving lighting, and an automatic control system for the production of plants and fruits are a variety of agricultural models in buildings [15]. Among the wide range of models available, Rooftop Greenhouse Farming is the most acceptable because it uses the space left on the roof instead of the limited urban land, and because of being light does not impose excessive load on the building. Rooftop Greenhouse Farming not only helps produce food but also has many social and environmental advantages for the surrounding areas (10). These advantages include energy use reduction, water management, heat islands reduction, boosting the local market, using empty and unused spaces, creating new job opportunities, saving on the transfer of goods and materials, increasing biodiversity and strengthening the presence of nature in the built environment [12, 28, 23, 22].

In areas facing water shortage and/or adverse effects of drought by high water use for agriculture, the use of hydroponic systems or zero farming instead of soil bed will reduce water use four times less than conventional agriculture [28]. Perhaps the main advantage of hydroponic agricultural systems in buildings, in addition to occupying minimal space, is their stable performance for optimizing water use and returning it to the cycle of plant production and cultivation. One of the main advantages of this system is that it does not require pesticides, which are very harmful to air pollution and human health. In addition, crops and plants grown in hydroponic media are not limited to a specific season and can grow throughout the year, which has many economic advantages [15]. Zero farming can be done on rooftops, rooftop greenhouses, and green walls, as well as innovative forms such as indoor farms and/or vertical greenhouses [24, 28]. Along with green roofs, which are now considered the main source of agricultural integration in buildings, green walls play an important role in food production. A green wall is created by climbing plants inside or outside the building walls [27, 21].

Table 1: Social-Economic-Environmental benefits related to different types of integrating productive landscapes with urban buildings

Categories	subcategories	Individual or collective benefits
	Productive facade	Using PF in BIA contribute to positive changes in the urban environment strengthening biophilia, increasing the awareness of the need for GHG emissions reduction, and positively influencing the well-being of residents while enabling them to grow food in dense urban environments by themselve
Building integrated agriculture	Rooftop Greenhouse	Using RG in BIA require less energy, occupy less land, and generate less GHG emissions than some cultivation methods on natural landscapes
	Indoor farming	BIA reduce stress snd enhance psychological well-being BIA can be easily collected when needed The vegetables are grown in an environment that protects them from wind, pests and floods
	Open rooftop farming	The benefits using RF in BIA is carbon fixation, recycling of organic vaste, increasing horticultural yields, enhancing closed cycles, and improving the habitability of buildings
	Productive facade	Increase aesthetic factor on the urban context, requires less space for food, purify and reduce the temperature of air near the vegetation cover, sound insulation
	Rooftop Greenhouse	RTGs (both isolated and integrated) can provide environmental, economic and social benefits and can therefore improve the sustainability of urban areas (reducing transportation, lessening pressure on fertile agricultural areas, increasing the availability of urban fresh produce
Zfarming	Indoor farming	ZFarms on residential, commercial or mixeduse buildings serve as recreational spaces where residents or employees can grow their own food and enjoy a green space Zfarming, Create transparency in production and access to fresh food through involvement of residents/consumers Offer green recreational spaces Connect and close energy and water loops between building and farming reduce food miles Reuse urban waste products locally Can increse the self-sufficiency of the involve people
	Open rooftop farming	Most previous studies of ZFarming focus on one specific type named Open-air rooftop gardens. Existing studiesabout Z_FARMING refers to holistic frameworks, such as multifunctionality or sustainability, and acknowledge the integration of agriculture into urban areas as a strategy that has economic, environmental, and social effects

3 Methodology

3.1 Study area

Tabriz is one of the largest cities in Iran and is the capital of East Azarbaijan Province that is located at 38- and 4 degrees latitude and 46- and 18-degree longitude with a mean altitude of 1366 m above sea level. The climate of Tabriz is cold and dry. The mean annual temperature of Tabriz is approximately 12°C, while. the absolute maximum temperature is approximately 41°C and the minimum absolute temperature is -25°C. The mean annual precipitation in this city is about 308 mm and the mean number of frosty days during the year is about 102 days. The destruction of natural gardens and green spaces in Tabriz, like many other large cities such as Tehran, in order to build residential spaces, in addition to reducing the city's green space, increases the area under residential neighborhoods and the lack of land to create horizontal open spaces for urban agriculture.

Also, Tabriz, like many other cities in Iran, undertook the process of vertical construction in order to solve the problems related to the increasing urban population and land shortage. The physical development of Tabriz was based on the proposal of the Tabriz development plan, development from within the city by regenerating old texture due to limited suburban development, especially in the north, south and west, which is mainly in the form of destruction of old traditional buildings and constructing high-rise apartments. According to the Tabriz development plan, the per capita of green space in Tabriz is 3.63, which is much less than the minimum per capita of green space approved by the plan of the Supreme Council of Urban Planning and Architecture of 8% for cities with a population of more than one million people. This highlights the need to develop green spaces and integrate them with buildings as the only space resource in the city and promote ideas such as urban agriculture.

In the present study, two high-rise buildings in Tabriz in Districts 1 and 5 have been selected which accommodate most of the high-rise buildings (Fig. 1). Tabriz Rushdieh Tower was built in District 5 of Tabriz Municipality located in Rushdieh town. Rushdieh town is a residential town located in the northeastern part of Tabriz, which is famous for its modern and beautiful architecture. This tower is designed as 2 Blocks A and B, 18 and 14 stories, with 9 units in each story in Block A, and 5 units in each story in Block B. Block A of this tower is designed with a curved façade to the south, and 6 of the 9 corresponding units can benefit from the south light. Block B units are only able to illuminate the east, west, and north fronts because they are located behind Block A. Aftab Complex in District 1 of Tabriz Municipality, located in Valiasr Town, with 6 Blocks of 10 and 14 stories, which has been fenced off, including the area with green space, has been selected as the second case study. There are 4 units in each story.

Cochran's formula of limited society:

$$n = \frac{Nz^2pq}{Nd^2 + z^2pq}$$

$$n = \frac{1400 \times (1.96)^2 \times 0.5 \times 0.5}{(1.96)^2 \times 0.5 \times 0.5 \times (1401 - 1) \times (0.05)^2} = 300.$$

In this regard:
N = population size
n = sample size
Z = the normal variable value of the standard unit, which is equal to 1.96 at the 95
d = allowed error value, (d = 0.05)
p is the value of the trait ratio in the community. If it is not available, it can be considered 0.5. In this case, the value of variance reaches its maximum value.
q = the percentage of people who lack that attribute in the society.

Based on the above formula, the minimum statistical sample size of 300 people is selected by simple random sampling method.

Figure 1: Map of the city of Tabriz and indication of the towers studied

3.2 Analysis

To reach the target of the investigation, two towers of Tabriz city including Roshdieh and Aftab as well-known high-rise buildings in the city were analyzed by field study method. Authores refered to buldings for detailed analysis along with some conversations with residents about potential benefits of applying productive landscapes in their houses and outsoor environments. This was the most suitable method to obtain findings about possibilitis to qualify components related to:

- Balconies;
- Roofs;
- Shared spaces (corridors, halls, staircase, etc);
- Façade; and
- Courtyard.

In this case, the field observation was carried out in February 2019 seperately in order to recognizing potential spaces in both outdoor and indoor of twoers.

In this connection, the T-Test test was used for independent groups and at a significant level of $\alpha = 0.05$, and the results of the analysis are shown in the following tables and explanations.

$$T = \frac{\overline{X} - \mu}{\frac{S}{\sqrt{N}}}.$$

4 Results and discussion

4.1 High-rise building integrated productive landscapes (HRBPL) in Tabriz

According to the above, study of the possibility of combining productive green space in high-rise buildings in the metropolis of Tabriz requires attention to the multiple climatic, economic, social, energy, physical, cultural and technological dimensions. For feasibility study of the type of intervention and provision of possible options for combining the idea of urban agriculture using high-rise buildings, since a complete field analysis of all the texture of Tabriz required long and costly studies, references and study reports approved related to Tabriz including papers of the Ministry of Jihad Agriculture, the Land Affairs Organization and the Environment Organization. The summary of the study results is presented in Table 2.

Table 2: Summary of potential factors for high-rise building integrated productive landscapes (HRBPL) in Tabriz, Iran

Factors	Evidence
Food security and production	- Pollution of farms with wastewater - Limit water resources and reduction in aquifers and precipitation - Increasing the price of food products - Extensive use of chemical fertilizers and water and soil pollution - Reducing the share of the province's agricultural sector in national income - High food waste due to cold climate
Agricultural lands	- Turn agricultural lands into other uses in recent years - Establishment of 70% of the country's cities on agricultural lands - Reduction in legal installations for turning rural areas into cities - Per capita reduction in agricultural lands in the last three decades from more than 0.5 to 0.3 hectares
Environmental status	- Reducing the level of open and green spaces due to increasing density and number of stories of apartment complexes - Pollution of farms with wastewater
Socio-cultural status	- Reducing the level of social integrity in high-rise buildings due to the lack of common and collective spaces - Lack of cultural, educational and recreational spaces in apartment living - Ignoring the lifestyle, culture and attitude of residents in high-rise buildings
Economic status	- Turn agricultural lands to other uses -Good foreign products market

Regarding mandatory components of creating a productive green space in Tabriz, which is presented in Table 2, and experiences of other countries in creating productive spaces in the city, to achieve a successful urban agriculture in Tabriz buildings, Table 3 is presented with the aim of measuring generalizability of mandatory components collected in Table 2 to create productive green spaces in the buildings of Tabriz by two concepts of BIA and Z-FARMING. According to the results of Table 3, these two concepts are able to respond to most of mandatory components, so standards and criteria of the above concepts can be used to create green spaces in buildings in Tabriz.

Table 3: The pixels adjacency correlation of red, green and blue spectrums of plain and cipher images

HRBPL concpets	Food security and production					Agricultural lands		Cultural and social status			Environmental status			Economic status	
	Reduce pollution of fields with wastewater	solve water shortage	Reduce the widespread use of chemical fertilizers	Reduce food product price	Reduce high food waste due to cold climate	Reducing turn agricultural land to other uses	Per capita increase of green space in Tabriz	Increased social integrity due to job shortage	Increasing recreational spaces in apartment living	Pay attention to the style, culture and attitude of residents in apartments	Increase open green space in buildings	Adaptation of agricultural products to climatic conditions	Reduce pollution of fields with wastewater	Reducing turn agricultural land to other uses	Reduce foreign exchange market boom
(BTA)			✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		
Z Farming	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓

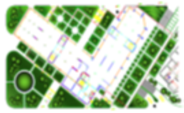
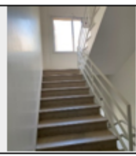
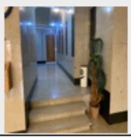
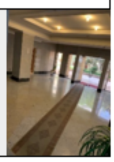
5 Case study analysis

Table 4 shows the location of usable spaces for the implementation of productive green space in 2 case studies. As shown in Table 4, the presence of balconies in all residential units is one of the main potentials for creating this type of space in these units. Since separation of life of the Iranians from houses with yards full of flowers, plants and trees occurred during a short period of time and almost in the last 3 decades, so the existence of a balcony in addition to the above applications is considered as an element to fill the gap of yard removal from Iranian houses so that there are at least a few pots in many of these balconies. Therefore, the design of part of these spaces to create productive green spaces regarding other applications can be welcomed by residents. It should be noted that attention to the cold climate of Tabriz and the orientation of balconies in terms of lighting and wind should be considered when choosing the type of plant.

Additionally, the area of both cases has green space and tree planting, so it has a suitable platform for the implementation of productive green spaces. Combining the facade of both towers with productive green space, in addition to its beauty, will also change the integrated facade of the tower. According to the cold climate Tabriz, it is possible to use the interior spaces of the apartment that have the potential and suitable space for the implementation of productive green spaces. In the study cases, stairs are among the common spaces that can be used for this purpose that design of which also in most apartments in Tabriz has been less considered, so the use of shade-loving houseplants in such spaces will lead to a lively atmosphere and compensate for the lack of attention to aesthetic design in these spaces.

Furthermore, the roof in most high-rise buildings in Tabriz does not have any green space and is often used as a place to install satellite equipment. Regarding the suitable potential of roofs such as large and invisible space, this part of the building, along with the appropriate design, can be considered as one of the main spaces for creating a productive green space.

Table 4: Potential productive landscapes provided by building's components in Roshdieh and Aftab towers

Component	Dominant use in the current situation	Recommended use for a productive landscape	Examples of existing buildings
Balcony	Space for sitting - keeping accessories	Indoor farming Productive facade	  
Courtyard	Playground for children Sitting area with green space	productive landscapes	 
Façade	Facade as a protector, the interface between indoor and outdoor space and as an indicator	Productive facade	 
Roof	Installation of accessories	Open rooftop farming	
Shared spaces	Dead spaces as well as common spaces such as stairs	Indoor farming	  

6 Conclusion

We advanced a general application of High-rise building integrated productive landscapes (HRBPL), and tested its usefulness for food security in case study of Tabriz, Iran. Our results suggest that we can apply this notion in a cold-climate city of Tabriz due to its economic, environmental and socio-cultural conditions.

We argue that there is some strong evidence in Tabriz city for applying new model of HRBPL in high-rise buildings in order to partially compensate food security issues. The lack of agricultural lands, lack of cultural, educational and recreational spaces as well as social cohesion in apartment living in recent years are some of the most important facts regarding this notion. Architectural strategies intended to integrate productive landscapes with high-rise buildings should focus on different components of the buildings including but not limited to balconies, roofs, facades, shared spaces and courtyards. A promising strategy could consist of a policy mix combining heating coverage and rearranging interior and outdoor spaces, accompanied by residetns' awareness on the links between productive landscapes and human food security.

From our study, we contend that the framework of HRBPL can contribute to the successful integration of the productive landscapes in high-rise buildings because it provides a comprehensive picture of the ecological, social and economic underlying factors. It can be expected that potential spaces in twoers will gain even more importance in cold-climate cities due to a shift in health and energy problems. Therefore, architects and agriculture engineerings should be aware about the value of outdoor and indoor spaces in the high-rise buildings, which is confirmed by this study. It is surprising that with this potential, high-rise buildings are less destructive of urban green structures in comparison to others and more adaptable to development decisions.

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