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ARTICLE / ARAŞTIRMA

Where to Do Urban Agriculture? Spatial Multicriteria Decision Making in Beylikdüzü, Istanbul

Kentsel Tarımı Nerede Yapacağız? Beylikdüzü, İstanbul'da Mekânsal Çok Kriterli Karar Verme

Ayşe Burcu Kısacık,[1] Turgay Kerem Koramaz[2]

[1]Department of Urban and Regional Planning, Istanbul University Faculty of Architecture, Istanbul, Türkiye

[2]Department of Urban and Regional Planning, Istanbul Technical University Faculty of Architecture, Istanbul, Türkiye

ABSTRACT

Agricultural activities have evolved beyond supplying fundamental food needs to include economic, social, recreational, and environmental aspects. Urban agriculture has gained importance as the primary application of urban food planning. This study aims to examine how ground level urban agricultural areas will be determined to create a more sustainable, safe, and fair food system at the local level. A spatial multi-criteria analysis was conducted to establish the criteria for site selection, resulting in the identification of ten parameters and twenty sub-criteria. The Analytical Hierarchy Process (AHP), a multiple decision-making (MCE) method, was also used to determine the relative weights of these criteria. Spatial analyses were performed for Beylikdüzü, a district in metropolitan Istanbul, using Geographic Information Systems (GIS). Preliminary findings indicate that distance from pollutant sources is the most crucial factor in urban agricultural area selection. Additionally, the built environment was found to exert a greater influence than social and natural factors. The spatial analysis reveals that if the most suitable urban agricultural areas for Beylikdüzü district are allocated for production, 13% of the district's fresh food needs can be met and 350 tons of CO_2 can be saved annually. These areas are predominantly concentrated in three specific regions. Overall, the findings provide a basis for developing and implementing local food policies.

Keywords: AHP; GIS; local food production; MCE; urban agriculture.

ÖZ

Tarımsal faaliyetler, temel gıda üretiminin ötesine geçerek ekonomik, sosyal, rekreasyonel ve çevresel boyutlar kazanmıştır. Kentsel tarım, özellikle kentsel gıda planlamasında öncelikli uygulama olarak öne çıkmaktadır. Bu çalışma, yerel ölçekte daha sürdürülebilir, güvenli ve adil bir gıda sistemi oluşturmak amacıyla, zemin seviyesi/toprak üstü kentsel tarım alanlarının belirlenmesini incelemektedir. Kentsel tarım alan seçme kriterlerini tanımlamak için mekansal çok kriterli analiz yaklaşımı kullanılmış, 10 parametre ve 20 alt kriter belirlenmiştir. Kriter ağırlıklarını hesaplamak için Çok Kriterli Karar Verme (ÇKKV) yöntemi olan Analitik Hiyerarşi Süreci (AHS) yaklaşımı kullanılmıştır. Coğrafi Bilgi Sistemleri (CBS) aracılığıyla İstanbul/Beylikdüzü ilçesi için mekansal analizler gerçekleştirilmiştir. Ön bulguları, kirletici kaynaklardan uzaklığın kentsel tarım alanı seçiminde en önemli faktör olduğunu ve inşa edilmiş çevrenin alan seçiminde sosyal ve doğal çevrelerden daha etkili olduğunu göstermiştir. Mekansal analiz bulguları ise Beylikdüzü ilçesi için en uygun kentsel tarım alanlarının üretime ayrılması durumunda ilçenin taze gıda ihtiyacının %13'ünün karşılanabileceğini ve yıllık 350 ton CO_2 tasarrufu sağlanabileceğini ortaya koymaktadır. İlçenin potansiyel kentsel tarım alanlarının üç bölgede mekansal olarak yoğunlaştığı görülmektedir. Bulgular, yerel gıda politikaları geliştirmemize ve uygulamamıza olanak sağlamaktadır.

Anahtar sözcükler: AHS; CBS; yerel gıda üretimi; ÇKKV; kentsel tarım.

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Correspondence: Ayşe Burcu Kısacık
e-mail: a.burcukisacik@gmail.com

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1. Introduction

World population growth and rising per capita food consumption are driving up overall food demand (FAO, 2009). Forecasts for 2050 predict that food demand could increase by 59–98% and production will need to at least double (Valin et al., 2014; Fukasea & Martin, 2020; European Commission, 2019). However, agricultural land is decreasing due to urban expansion and economic pressures, while incorrect practices are degrading the soil structure, and agriculture is responsible for one-third of global greenhouse gas emissions (FAO, 2020; Foley et al., 2005; IPCC, 2020). It is also argued that climate change poses a significant threat to agricultural productivity (Chatham House, 2021).

While cities account for the majority of food demand, economic access, logistical barriers and energy price volatility are key challenges (Cirera & Masset, 2010). Low-income groups have limited access to healthy food; the length of the food supply chain increases the carbon footprint, leading to price volatility and waste. Urbanization increases pressure on agricultural land, threatening local production and deepening external dependency. Since the 2000s, food security, which also includes the ecological dimension, has been addressed within the framework of climate change, shifting from a rural focus to an urban focus, making cities both consumers and producers (Eriksen et al., 2009; Cruch & Riley, 2018).

The Sustainable Development Goals and the Milan Urban Food Policy Pact, signed in 2015, are important global initiatives to reintroduce food into urban planning. The pact positions local governments as key actors in the fight against food waste and the provision of healthy and accessible food, and advocates that cities address these issues in their planning and legislation. The Paris Agreement (2016) aims to develop sustainable and resilient food systems to reduce the climate impact of the current food system, and signatory countries are expected to reduce food-related carbon emissions. While the Farm to Fork Strategy, developed within the scope of the 2020 European Green Deal, aims to create a climate-friendly supply chain from production to consumption, the Food 2030 Strategy (European Commission, n.d.) envisages a sustainable, circular, and healthy structure for urban food systems. The FAO (2018), in its study Integrating Food into Urban Planning, provides examples of urban planners addressing the food system holistically.

In this context, scientific research on the integration of food in urban planning has shown a significant increase since 2010 (Dobele & Zvirbule, 2020). Urban food planning, which was previously addressed only through land use and transportation, is taking shape within the framework of three main research areas: urban food production, food storage analysis, and food access (Brinkley, 2013; Yang et al., 2020). The primary emphasis of urban food production research is urban agriculture. Although urban agriculture is not a new phenomenon, it is playing an increasingly important role in metropolitan food supply. In this context, several cities and institutions have begun to include urban agriculture in their urban food planning goals.

Urban agriculture is addressed in studies on social empowerment and health (Horst et al., 2017; Veenhuizen & Danso, 2007; Warren et al., 2015), local economic development (Mok et al., 2014; Orsini et al., 2014) and ecological and environmental (Artmann & Sartison, 2018; Clinton et al., 2018; Gondhalekar & Ramsauer, 2017) dimensions. Additionally, where this production takes place within a dense urban fabric it has become an increasingly important research topic. While the literature includes numerous studies on site selection based on various objectives and principles of urban agriculture (Appendix 1), studies that address the subject with a holistic approach are quite limited.

This study aims to contribute to the selection of urban agricultural lands for the establishment of a sustainable, safe, and fair food system at the local scale. Beylikdüzü district of Istanbul was selected as the study area due to its urban-rural character and urban development pressure. In the study, Spatial Multi-Criteria Decision Making (S-MCDM) method is utilized to evaluate the factors affecting the selection of urban agricultural lands. Geographic Information Systems (GIS) and Analytical Hierarchy Process (AHP) from multi-criteria decision-making techniques are also used for geographical evaluation.

2. Urban Agriculture in Planning Literature

The urban food system is shaped by agricultural activities carried out in and around the city. These activities are called "intra and peri-urban agriculture" as well as the more common designation of "urban agriculture" (UA). The FAO defines urban agriculture as "the growing of plants and raising of animals for food and other uses within and around cities and towns..." Although there are different definitions for urban agriculture, since food production in urban areas is central to all definitions; it can be described as agricultural activities conducted in and around the city center. It is distinguished from rural agriculture by its integration into local urban economic and ecological systems (Mougeot, 2000) and varies geographically and terminologically, with distinctions such as peri-urban, metropolitan, and urban fringe agriculture (Opitz et al., 2016). Although spatially distant from urban centers, peri-urban and suburban agriculture are an integral part of urban agriculture by producing large quantities of food and supplying urban markets (Opitz et al., 2016). These forms of agriculture are more market-oriented than intra-urban agriculture (Veenhuizen & Danso, 2007). The scale and market orientation are narrowing as rural and peri-urban agriculture shifts to urban agriculture. While urban and rural agriculture are interrelated, urban agriculture plays a critical role in local food system sustainability, addressing not only food supply but also economic and social resilience.

There are many different types of urban agriculture applications. Urban agriculture encompasses open-space forms (community gardens, allotments, backyard gardens, micro-agriculture), evaluated by ownership, actors, business models, and location, as well as building-related forms (rooftop gardens, vertical farming), which occur within or on buildings. And urban agriculture practices also includes urban farms. Community gardens are collective initiatives supported by public or private entities (Mok et al., 2014), while allotments are rented agricultural plots, particularly in Europe (Opitz et al., 2016). Backyard gardens primarily serve household consumption and can evolve into community-driven initiatives (Orsini et al., 2014; Yang et al., 2020). Urban farms operate on a larger scale, integrating commercial activities such as marketing, education, and retail, typically near city peripheries (Yang et al., 2020). Urban agriculture extends beyond land-based activities, incorporating rooftop and indoor farming, hydroponics, and vertical farming—collectively termed micro-agriculture due to their reliance on advanced technologies (Specht et al., 2014; Artmann & Sartison, 2018). These methods, often classified as zero-acre farming, are prevalent in city centers and offer both commercial and recreational benefits (Yang et al., 2020).

Although the link between agriculture and cities weakened as cities became mass consumers after the Industrial Revolution, these two concepts have been inextricably linked throughout history (Steel, 2013). Cities were often established near productive agricultural lands, and the flow of agricultural knowledge shaped urban development (Dobele & Zvirbule, 2020). The Industrial Revolution separated agriculture from urban planning and dragged it into a different direction within the framework of economic relations. While fertile lands in urban areas were allocated to industry and production, fields with little economic value remained accessible for impoverished farmers' agricultural pursuits (Dobele & Zvirbule, 2020). Before World War I, employers or communities adopted the practice of "allotment gardens" for workers migrating from rural areas to cities (Keshavarz et al., 2016), and food security concerns brought urban agriculture back to the agenda during wartime. During and after World War II, "Victory Gardens" were established to increase agricultural production, and 25% of fresh food in the United States was grown in urban agricultural areas (Mok et al., 2014; Keshavarz et al., 2016; Dobele & Zvirbule, 2020). However, in the post-war period, globalization industrialized agricultural production and excluded it from urban planning, and urban agriculture was treated as a secondary issue in planning processes. Conversely, classical planning approaches such as the City Beautiful, Ebenezer Howard's Garden City, and Frank Lloyd Wright's Broadacre City, which were developed to reduce the negative effects of the Industrial Revolution, see urban agriculture as an integral part of the city.

In the post-World War II era, particularly in America, urban agriculture was linked to African-Americans' pursuit of social justice. The quality of life has increased with the effect of modernization and urban agriculture activities have been encouraged in the areas vacated by those migrating from cities to suburbs. Social justice and community engagement became more prominent in the 70s and 80s; economic crises made urban agriculture an important tool, particularly in Africa, and urban agriculture was discussed on a global scale in terms of providing food security, combating poverty, and protecting the environment. Especially in times of economic stress, urban agriculture has been frequently included in the literature and practices regarding beautifying neighborhoods, increasing land value, and empowering citizen participation (Brinkley, 2013).

Sustainability discussions gained momentum with the Sustainable Development Goals (SDGs) of 2015, and agricultural activities carried out in and around the city were directly and indirectly associated with various SDGs. In particular, SDG #2 (Zero Hunger), SDG #3 (Good Health and Well-being), SDG #8 (Decent Work and Economic Growth), SDG #12 (Responsible Consumption and Production) and SDG #11 (Sustainable Cities and Communities) are directly linked to urban agriculture. Thus, food gained importance in urban planning with sustainability discussions (Brinkley, 2013; Morgan, 2013; Bricas & Conaré, 2019), and the Renaissance period of urban agriculture (Dobele & Zvirbule, 2020) began. Food, which was previously addressed only in terms of adequacy or social justice, is now beginning to be addressed through different dimensions of urban planning.

Urban agriculture contributes to the environmental, social and economic dimensions of sustainability. The environmental benefits of urban agriculture include environmental justice (Jerm´e & Wakefield, 2013), land use implication for urbanization (Olsson et al., 2016; Ayambire et al., 2019), regulating extreme temperatures (Clinton et al., 2018), mitigation of urban heat island effect (QIU et al., 2013), reducing the carbon footprint of food systems (Lwasa et al, 2014), mimicking of the natural water cycle (Rogers & Hiner, 2016) and improving biodiversity (Lin et al., 2015; Yaro et al., 2016). Additionally, urban agriculture increases social interaction, social solidarity and community resilience (Voicu et al., 2008; Okvat et al., 2011; Shimpo et al., 2019), contributes to household food security and food access (Horst et al., 2017; Khumalo et al., 2019) and is closely associated with community wellbeing and nutritional diets (Warren et al, 2015; Egli et al., 2016; Lin et al., 2017). It provides potential economic benefits in areas including reducing input costs such as transportation and fuel (Moustier & Danso, 2006), high-profit margins for the producer with a short supply chain (Starr et al., 2003), reducing urban poverty (Zezza & Tasciotti, 2010) and self-sufficiency (Mok et al., 2014). Although there are plausible arguments for economic benefits, there is little evidence to support them (Eiter et al., 2025). Nevertheless, urban agriculture can increase property values (Voicu & Been, 2008). This situation brings with it discussions about urban agriculture causing gentrification (Meenar et al., 2017; Hawes et al., 2022).

The global urban farming market is expected to grow from USD 160.22 billion in 2024 to USD 290.11 billion by 2032 (Business Research Insights, n.d.). With the increasing interest in urban agriculture in recent years, local governments have taken on a role both as a developer, supporter and regulator of urban agriculture and developed policies. In the USA, several municipalities are developing Urban Agriculture Zones and Land Tenure Regulations to facilitate urban agriculture (Meenar et al., 2017); the 40 most populous cities have more than 400 urban agriculture-related policies (Halvey et al., 2021), and almost one-fifth of city governments are developing food plans and strategies (Clark et al., 2021). There are more than 500 community gardens in New York City, while urban agriculture in the Buffalo-Niagara metropolitan area produces more than 10% of GDP (Raja et al., 2014). In Europe, the 2008 economic crisis led to the establishment of community gardens in countries around the Mediterranean (Fox-Kamper et al., 2023). Developments such as the Milan Urban Food Policy Pact, the European Green Deal 2020 and the Food 2030 Strategy support local governments and entrepreneurs in urban agriculture. While many metropolitan areas such as London include urban agriculture in their strategic plans, agriculture-focused urban development approaches such as the Almere Oosterwold plan are also attracting attention.

3. Method

3.1. Study Area

Approximately one in every five people in Türkiye's population lives in Istanbul. Arable land per person has declined in Türkiye during the past 20 years, from 0.35 ha to 0.23 ha, and in Istanbul, from 0.007 ha to 0.004 ha (IMM, 2021). Istanbul covers only 3.2‰ of the country's agricultural lands[1] and 1.6‰ of the country's agricultural production.[2] Despite being the country's most populous city and the top food consumer, the limited food production has increased its dependence on other cities throughout time. Feeding the aforementioned megacity necessitates intricate and thorough food planning. In the "Istanbul Food Strategy Document" published by Istanbul Metropolitan Municipality (IMM) in 2021, urban agriculture was discussed under the title "Climate Crisis and Nature-Friendly Stable Agriculture" with the aim of "starting urban agriculture in unused areas, balconies and backyards in neighborhoods and increasing urban vegetable gardens". The same document interprets urban agriculture as a recreational and educational opportunity and as a shelter in case of disaster (Fig. 1).

Located in the southern part of the European side of Istanbul, Beylikdüzü district is among the districts that combine rural and urban textures in the city's food strategy. It has a total size of 37.78 km² and a coastal length of 12.4 km to the south. The annual average temperature of the district is 14.3 °C, the coldest months are January and February, and the warmest months are July and August. The district is connected to the megacity's infrastructure via the D-100 highway to the north. While Beylikdüzü used to be a settlement with rural characteristics in the past years, after 1990, with the effect of the D-100 highway, the usage areas quickly turned into industrial facilities and mass housing areas, and the district started to receive high rates of migration. The population of the district, which was 185,633 in 2008, has more than doubled in the last 15 years, reaching 409,347 in 2023 (TÜİK). According to the 1/100000 Scale Istanbul Environmental Plan, the northern side facing D-100 has been determined as the second level sub-center (M2) for Istanbul. Ambarlı Strategic Industrial Zone, which is of regional importance, is located in the east of the study area (Fig. 2).

The district includes land uses such as Organized Industrial Zone, Small Industrial Zone, other industrial areas, energy production area, storage and logistics, and marina, while residential areas constitute 40%; urban density is 93 per/ha. Although the district has a long coastline, the dispersion of the settlement and the fragmented and private use of the coastline increase the importance of the Yaşam Vadisi as a public space, the largest green area of the district extending from north to south. The district has 10 neighborhoods with different characteristics; the northern neighborhoods are densely populated due to their proximity to the D-100, and population and building density decrease toward the south.

The district has experienced a great loss of agricultural land in the last ten years. In 2013, the total agricultural land in the district was 169.1 ha; 20.8 ha of this was fallow, 2.4 ha of vegetables, 145.9 ha of grain and other types of planting. According to 2023 data, these rates have decreased to 0, 0.4 and 30 ha, respectively, and the total agricultural land in the district is 30.4 ha (TÜİK). With this decline, the district will account for 0.03% of the province's agricultural land in 2023, down from 0.23% in 2013. Although the district's agricultural production is not extremely important for the city, increasing industrial-

[1] This rate was calculated according to TÜİK 2023 agricultural area data. Fruit, fallow, vegetable, ornamental plant, grain and other plant production areas are included.

[2] This rate was calculated according to TÜİK 2023 production amount data. Vegetable, fruit, grain and other plant production, greenhouse vegetables and greenhouse fruits are included.

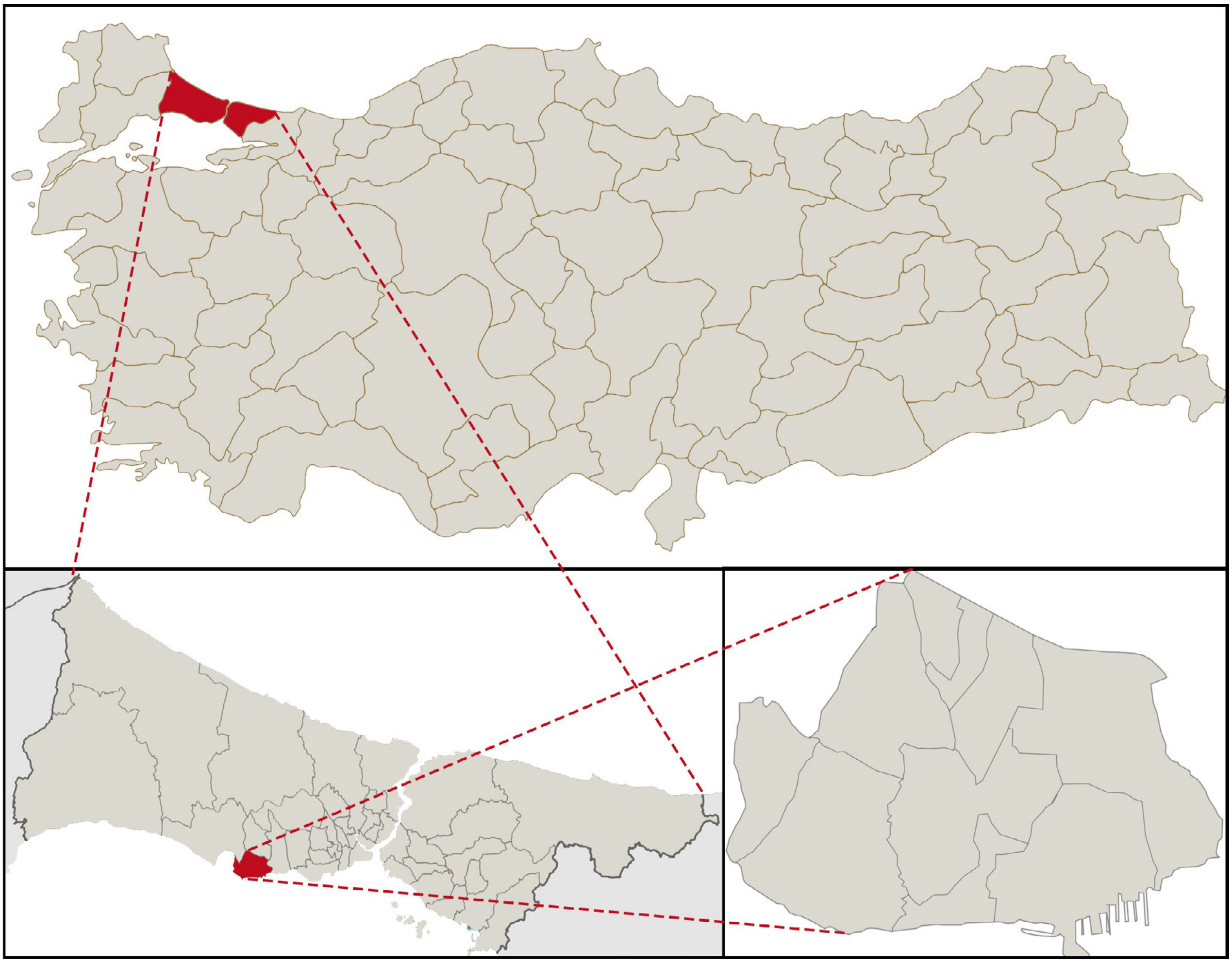

Figure 1. Geographical location of the study area (İstanbul – Beylikdüzü).

ization and urban development, especially in the north of the district, are gradually reducing agricultural production. Furthermore, according to land use statistics from the IMM Urban Planning Directorate, the district has no agricultural land and 1081 hectares of vacant land. The areas that appear as cultivated in aerial photographs are classified as vacant lands. In the Beylikdüzü Municipality GIS Application's zoning plan, the same areas are mainly classified as residential. Figure 3 depicts how industrial and construction activity in the study area evolved over time, beginning with the D-100 road and moving towards the Marmara Sea.

The district is notable for being an industrialized sub-region with rural qualities that is nonetheless easily accessible to the megacity. The district's socio-economic situation and education level are above average compared to the city in general. According to the IMM's Quality of Life Index (2023), the district ranks slightly below the city average, but it performs better in gender equality than other districts in the "outer periphery" group with which it is evaluated.

The local municipality evaluates living gardens and hobby gardens under 'ecological system protection' in its strategic plan (Beylikdüzü Municipality, 2022). The local administration provides impoverished individuals with items produced in Yaşam Vadisi's 2-hectare urban agriculture area through the "Food Bank Service" (Beylikdüzü Municipality, 2021). Concurrently, a second urban agricultural area of 1.97ha is planned by the local municipality, focusing on aromatic plants. The local government established a 0.5ha Küçük Bahçivalar Parkı (Little Gardeners Park) for children to learn and engage in urban agriculture. The district also has ecology-themed private schools at primary and kindergarten levels. One of the ecological/organic markets, which are limited in number throughout Istanbul, is also located in Beylikdüzü. The district is an appropriate case for urban agriculture research due to the above-mentioned characteristics, its partially rural character despite the intense construction pressure, and the local government's food-oriented planning approaches and initiatives.

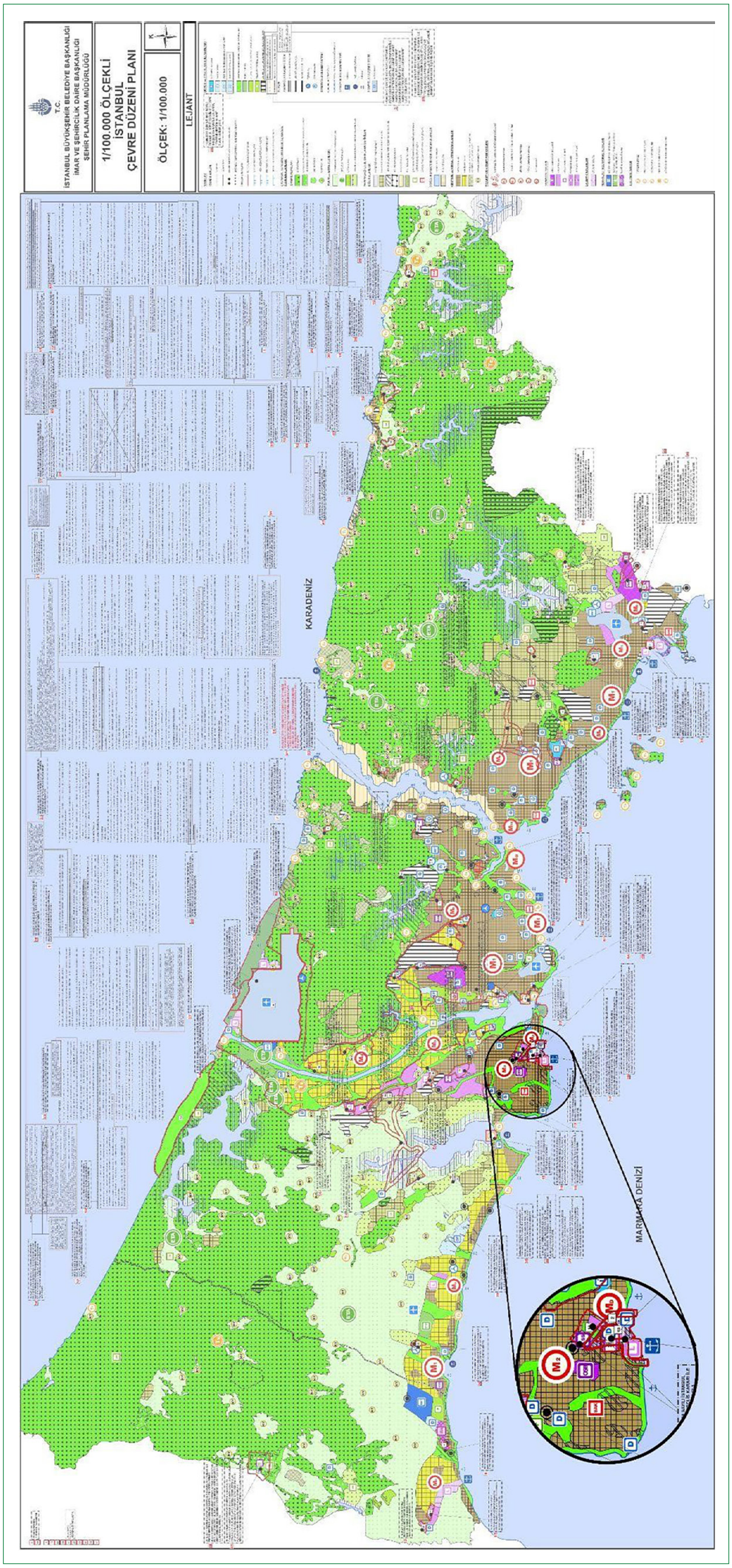

Figure 2. Beylikdüzü in 1/100000 scale Istanbul Environmental Plan.

3.2. Identification of Parameters

A comprehensive literature review was conducted to identify spatial indicators for urban agricultural practices to develop an index that aims to create a "more sustainable, secure, and equitable food system" in urban agricultural land selection at the local scale. Due to the varying requirements of different urban agricultural practices, this study focused only on practices that take place in open areas, excluding urban agriculture on building roofs, balconies, and vertical surfaces. As a result, 10 parameters and 20 sub-criteria were determined by combining the relevant sub-criteria under parameters to facilitate the multiple decision-making method. As seen in Appendix 1, these 10 Parameters: Constraints, Ownership status and land supply, Demographics and Population, Transportation and Accessibility, Security levels, Pollution sources, Distribution, Prevention and Storage, Green system, Topography, and Soil and Geological structure.

Among the sub-criteria, "Empty field" (Q1) and "Field size" (Q2) were chosen as constraints since they are immutable characteristics that will always be deemed fundamental in the selection of urban agricultural land.

3.3. Data Collection and Classification of Sub-criteria

Data collection for this study was mainly carried out through two methods: 1) data collection from TÜİK, IMM Open Data Portal and Beylikdüzü Municipality and 2) point location data via Google Maps (Table 1). Vector and raster data were combined, organized and spatial analyses were performed using the geographic information system (GIS). Previous studies in the literature were taken as a basis for the evaluation of sub-criteria (Appendix 1). Each parameter contains a maximum of three sub-criteria. Since the maximum number of classes formed by the intersection of the sub-criteria under the parameter is eight, a scale was used to compare classes, with 1 representing the lowest and 10 representing the highest preferability. Table 2 presents the weights in the evaluation of the sub-criteria that constitute the parameters.

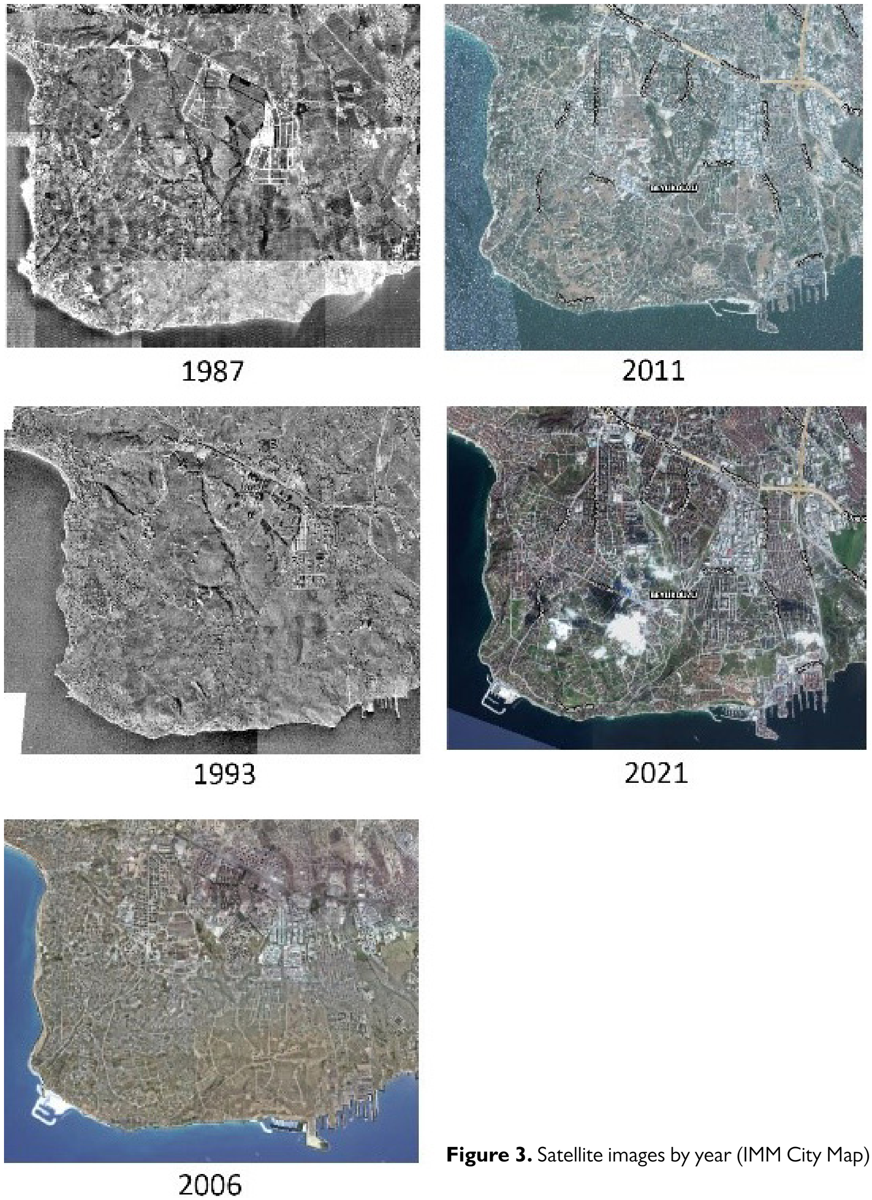

Figure 3. Satellite images by year (IMM City Map)

Firstly, neighborhood-scale population, child (0–14) rate, elderly (65+) rate, child and elderly population and SES scores were obtained via TÜİK and IMM Open Data Portal. Within the scope of demographic structure sensitive to food supply (Q5), the dependency rates of the neighborhoods were calculated and divided into three categories according to the natural distribution; the highest dependent population was classified as 3, and the lowest as 1. Socioeconomic status (SES) scores were reverse coded, with the lowest value receiving the highest score, prioritizing communities with the lowest socioeconomic level and the highest dependent population (Table 3). For High Population Density (Q6), population densities were calculated at the neighborhood scale over residential and mixed-use areas, the natural distribution method was used, and the density values were divided into three groups as 0–300 per/ha, 301–600 per/ha and 601–934 per/ha. Q5 and Q6 maps were integrated to create a Demographic and Population map, and areas with high food sensitivity were prioritized. To ensure fair food access, areas with high Q5 values received higher scores, while those with high levels of both criteria received 10 points.

Secondly, for low land value (Q4), the "Land Square Meter Unit Value Inquiry" values for 2023 were obtained from turkiye.gov.tr based on the main boulevard/street of each neighborhood. These values are based on the land value price values calculated by the Ministry of the Treasury for the taxation system and obtained from official records. In urban agriculture,

Table 1. List of data and sources

Data	Source	Detail	Form
Land use	Local municipality	Pollutant sources, social facilities, storage, and green spaces, empty areas	Digital
Public ownership	Local municipality	Population	Digital
Demographic data	TÜİK	SES scores	Digitized
Land value	IMM open data portal Ministry of Treasury (turkiye.gov.tr)	Land square meter unit value ınquiry - main street/boulevard or street for the year 2023	Digitized
Public transport	Beylikdüzü municipality ınformation processing directorate	Bus, minibus lines routes	Digitized
Bike lanes	Local municipality's transportation master plan (URL-8)	Planned bike route	Digitized
Transportation alternatives	Google maps		Digitized
Location of food sales	Google maps	Bazaar, market, delicatessen, greengrocer, and butcher areas	Digitized
Geology and soil structure	Istanbul geological map from Istanbul metropolitan municipality		Digitized
Erosion	No Data		No Data
Security level	No Data		No Data

SES: Socioeconomic status; IMM: Istanbul metropolitan municipality.

public ownership of land and low land value will reduce costs and facilitate implementation (McClintock & Cooper, 2010; He et al., 2012; Opitz et al., 2016). In the Ownership status and Land Supply parameter, areas with low land value and public ownership obtained the greatest score (10), while areas with private and high land value received the lowest score (1).

Moreover, for proximity to public transport networks (Q7), bus and minibus line arrangements produced by the Beylikdüzü Municipality Information Processing Department Urban Information Systems Bureau in 2019 have digitized public transport arteries. The arteries were divided into three groups according to the density of public transport; a 250 m buffer was applied within a 5-minute walk of the public transport lines. According to the Transportation Master Plan (Çalık, n.d.), cycling paths were digitized, and a 100 m buffer (Smith et al., 2021) was applied for Q8. Main transportation arteries were identified via Google Maps, and a 500 m buffer (He & Genovese, 2012) was applied for Q9. Transportation and accessibility analysis was conducted by integrating Q7, Q8, and Q9 criteria, with public transport identified as the key factor. Transportation arteries were weighted more heavily than cycling infrastructure.

Similarly, for Proximity to distribution centers (Q12), food sales points (bazaars, markets, greengrocers, butchers, delicatessens) in the district were determined via Google Maps, processed into the GIS environment, and an access distance of 500 m (He & Genovese, 2012) was applied. For Q13, municipal service areas, education areas, administrative areas, public areas, cultural facilities, social facilities, sports areas, health areas and religious areas were accepted as social service areas, and a 250m–500m buffer was applied. For Proximity to preservation and storage areas (Q14), storage areas were obtained from land use data and were addressed with 500 and 1000 m buffer areas. The Distribution, Prevention and Storage parameter, which is formed by the combination of Q12, Q13 and Q14 sub-criteria, has been scored by accepting access to food sales as a priority, social facilities have been evaluated as alternative distribution areas, and thus it is aimed to integrate healthy food sales areas more easily into the existing food system.

Further, Organized Industrial Zones, Industrial Areas, industrial service areas, ports, marinas, piers and energy storage areas were accepted as pollutant sources in land use, and a 250m buffer was applied around these areas to create the Q11 sub-criterion and Pollutant Sources parameters. Similarly, under the Green System parameter, green areas in the district were obtained from land use, and a 500m buffer (Orsini et al., 2014) approach was applied for Q15.

Sub-criteria Q16 and Q17 (McClintock et al., 2013) and Q18 (Thapa & Murayama, 2008) were considered under the Topography parameter, and areas with high aspect, slope less than 10% and drainage buffer 300m distance were prioritized. Areas with a slope greater than 30% were eliminated as they were not suitable for agricultural activities.

Table 2. Classification of sub-criteria

1.0. Constraints				
Q1 **Q2**	**Vacant**	**Full**		
<0.2ha	Eliminated	Eliminated		
>0.2ha	Accepted	Eliminated		
1.1. Ownership status and land supply				
Q3 **Q4**	**Public**	**Private**		
Low (659–1350)	10	8		
Middle (1351–2700)	7	6		
High (2701–4334)	5	1		
2.1. Demographics and populations				
Q5 **Q6**	**Low (0–1–2)**	**Middle (3)**	**High (4)**	
Low (0–300)	1	4	7	
Middle (301–600)	3	5	9	
High (600+)	6	8	10	
2.2. Transportation and accessibility				
Q7	**Within 250m**		**Outside 250m**	
Q8 **Q9**	**Within 100m**	**Outside 100m**	**Within 100m**	**Outside 100m**
Within 500m	10	9	7	5
Outside 500m	4	3	2	1
3.1. Pollutant sources				
Q11	**Within 250m**	**Outside 250m**		
	2	10		
3.2. Distribution, prevention and storage				
Q12	**Within 500m**		**Outside 500m**	
Q13 **Q14**	**Within 500m**	**Outside 500m**	**Within 500m**	**Outside 500m**
Within 1000m	10	8	7	4
Outside 1000m	9	6	5	1
3.3. Green system				
Q15	**Within 500m**	**Outside 500m**		
	2	10		
4.1. Topography				
Q16	**Suitable**		**Unsuitable**	
Q18 **Q17**	**Within 300m**	**Outside 300m**	**Within 300m**	**Outside 300m**
<10%	10	8	9	6
10–30%	7	5	4	1
>30%	eliminated			
4.2. Soil and geological structure				
Tdg	10			
Tdç	9			
Tcç + Tçg	8			
Tık	7			
Tçb	6			
Yd	1			

Table 3. Descriptives for socio-economic figures in Beylikdüzü Neighborhoods

Neighbor-hoods	Population 2022 (TÜİK)	SES (Mahallem İstanbul; IMM open data portal)	Child population ratio (0-14) (%) (neighbor-hood report card; IMM)	Elderly population ratio (65+) (%) (neighbor-hood report card; IMM)	Child population (calculated according to neighbor-hood report card)	Elderly population (calculated according to the neighbor-hood report card)	Child and elderly population	Popula-tion class	SES value	Total score for Q5	Land value (TL)
Adnan Kahveci	113.989	B	24	6	27357	6839	34197	3	1	4	2421.98
Cumhuriyet	23.427	B+	20	9	4685	2108	6794	1	1	2	4333.72
Büyükşehir	21.902	B	17	11	3723	2409	6133	1	1	2	3951.05
Barış	58.388	B	20	8	11678	4671	16349	2	1	3	3820.26
Beylikdüzüos	1	0	0	0	0	0	0	0	0	0	658.78
Yakuplu	57.468	C	20	8	11494	4597	16091	2	2	4	1152.86
Marmara	31.889	B	24	6	7653	1913	9567	1	1	2	2699.69
Kavaklı	58.335	C	26	5	15167	2917	18084	2	2	4	1582.36
Sahil	6.724	C	26	6	1748	403	2152	1	2	3	1541.99
Dereağızı	19.427	C	24	6	4662	1166	5828	1	2	3	833.16
Gürpınar	21.286	D	24	6	5109	1277	6386	1	3	4	1840.7

SES: Socioeconomic status; IMM: Istanbul metropolitan municipality.

There is no data on the erosion map of Istanbul (Q19) regarding the district, and according to the soil capacity (Q20) data obtained from the IMM, the district was defined as a built-up area. However, the geological structure data for the district were allocated from the local municipality. Thus, the Soil and geological structure parameter was considered as an independent parameter without sub-criteria for the area, and the relationship between geological formations and agriculture was evaluated according to the “Istanbul Provincial Area Geology” (Özgül, 2011). Neighborhood-scale security data (Q10) for Beylikdüzü is unavailable while existing studies focus on Istanbul as a whole without offering intra-district comparisons.

3.4. Weighting Parameters

In the initial stage of spatial multi-criteria decision-making, the Analytic Hierarchy Process (AHP) was applied to address decision-making challenges. Based on expert-rated comparison matrices, this method provides an analytical framework for integrating actual measurements and preferences (Saaty, 1987). AHP permits the creation of analytical information using a logical planning approach and the production of inclusive decisions rather than subjective ones (Koramaz, 2014). It is a frequently used method in urban planning, especially in land use decisions and participatory procedures.

The AHP is frequently employed in urban agriculture research (Kirnbauer & Baetz, 2012; Motlagh et al., 2021; Peng et al, 2015; Perez et al., 2014; Wang et al., 2021). Research on urban agricultural site selection combines several methods with the GIS environment, extending beyond the AHP methodology (Akbulut, et al., 2018; Akıncı, et al., 2013; Bozdağ, et al., 2016; He & Genovese, 2012; Kazemi & Hosseinpour, 2022; Sarı & Koyuncu Sarı, 2021; Seyedmohammadi et al., 2019; Sonneveld et al., 2021; Thapa & Murayama, 2008; Thapa, et al., 2011; Türker & Akten, 2023; Ustaoğlu et al., 2021; Weerakoon, 2014; Yalew et al., 2016).

To minimize cognitive overload and respondent fatigue, the pairwise comparison matrix was structured based on the main parameters rather than all sub-criteria (n=18). The “Constraints” parameter, deemed essential for urban agriculture, was excluded from the comparison matrix. Instead, a nine-parameter (n=9) matrix with 36 comparisons was developed. A Likert scale ranging from 1 to 7 (only odd numbers) was used for evaluation.

The AHP participants were determined as academia, public institutions, civil society organizations and private urban agriculture enterprises. The survey was distributed to 15 academics[3] yielding six responses. Three local government representatives involved in urban agriculture in Istanbul were contacted, but none responded. One private urban agriculture enterprise participated, while two food-focused NGOs declined due to a lack of expertise. In total, seven participants[4] from diverse disciplines contributed to the AHP process.

[3] 5 urban planners, 4 landscape architects, 1 agricultural engineer, 1 lawyer, and environmental politician, 1 economist, 1 environmental engineer.

[4] 3 Urban Planners, 2 Landscape Architects, 1 Agricultural Engineer, 1 Private Business Representative.

3.5. Spatial Data Analysis

The second part of the study includes the superimposition of the spatial analyses of the weighted parameters obtained as a result of AHP. The Map Algebra method, which allows mathematical operations with raster layers, was used via ArcMap 10.3 software. First, since there was no data for Security Level, the AHP results were recalculated by removing this parameter. Then, the spatial analyses performed for each parameter were converted to raster data. Figure 4 shows the spatial analyses for the remaining eight parameters for Beylikdüzü.

In the Map Algebra analysis, the potential urban agricultural areas of the district were determined and scored between 1 and 5 and ranked as very suitable, suitable, medium, less suitable and not suitable. Finally, the unweighted Constraints parameter was included. For Q1 (Empty Field), identified vacant areas in land use, and for Q2 (Field Size), areas ≥0.2 ha (He & Genovese, 2012; Opitz et al., 2016) were selected, and analysis results were filtered.

4. Results

4.1. AHP Results

As a result of the AHP, λmax=9.851090886 and CI were calculated as 0.1063863608. Random Consistency Index (RI) was accepted as 1.452 (n=9) and the Consistency Ratio was calculated as 0.07326884353. Since this value was <0.10, the comparison matrix was considered consistent.

Pollution Sources parameter is the primary factor in urban agriculture site selection, accounting for 23.1%. This is succeeded by Ownership Status and Land Supply, which constitute 16.8% of the total. Transportation and Accessibility ranks third with 10.4% (Table 4). The high weights of these three parameters indicate that factors based on the built environment are a priority in urban agriculture area selection. The high weights of these three parameters indicate that factors based on the built environment are a priority in urban agriculture area selection. Pollution Sources being at the top of the list highlights the health assurance of urban agriculture, while Ownership Status and Land Supply reveal the importance of applicability. Transportation and Accessibility can contribute to urban agriculture working as a system integrated with daily life. Security Level, Demographics and Populations parameters are at the middle level, while Soil and Geological Structure, Green System, and Topography have the lowest weight. The findings indicate that socioeconomic factors exert a more significant influence than natural environment elements in the selection of urban agriculture areas. Specifically, the negligible impact of topography suggests that the natural environment is comparatively less effective in this regard.

The Security Level parameter was removed from the AHP process and recalculated due to the absence of data regarding the study area. The AHP was conducted with λmax=8.696468427, the consistency index (CI) was calculated as 0.09949548956 and the Random Consistency Index (RI) was accepted as 1.41 (n=8). Because the weights were less than 0.10, the consistency ratio (0.07056417699) was deemed reliable. According to this AHP, the ranking of the first three did not change, but the proportional increase was the highest in Pollutant Sources, which was again in the first place. Conversely, the Demographics and Populations parameter experienced a decline in its ranking, while the Distribution, Prevention and Storage and Green System parameters exhibited an increase (Table 4).

4.2. Urban Agriculture Area Selection in Beylikdüzü

The parameters evaluated between 1–10 for suitability for urban agriculture were subjected to Map Algebra analysis with AHP weights (Table 4); in this analysis, the highest value was determined as 9.6519, the lowest value as 2.1898 (excluding those eliminated) and the average value as 6.4132. The groupings were evaluated according to natural breaks, and the range of 2.19–4.38 was classified as "not suitable", the range of 4.39–5.67 as "less suitable," the range of 5.68–6.63 as "medium", the range of 6.64–7.77 as "suitable" and the range of 7.78–9.65 as "more suitable". The distribution of groups for the entire district before the inclusion of the Constraints parameter is 5.33%, 26.20%, 26.05%, 24.45%, and 17.97%, respectively. It should be emphasized that there is no Q1. Empty Field and Q2. Field Size in these rates.

With Q1 and Q2 restrictions, 18.19% of Beylikdüzü is "more suitable" (266.19 ha) for urban agriculture, while 28.82% is "suitable" (421.63 ha). "Moderate" areas comprise 26.70% (390.73 ha), "less suitable" areas constitute 21.83% (319.48 ha), and "not suitable" areas consist 4.45% (65,16 ha) (Fig. 5).

The final research reveals that the sites "not suitable" for urban agriculture in Beylikdüzü district are concentrated around the port region in the Marmara neighborhood, which is close to pollution sources and does not match the standards of other parameters. Similarly, "less suitable" areas partially meet the requirements of other parameters and are located around pollutant sources. "Suitable" areas are concentrated especially in Dereağzı and Kavaklı neighborhoods in the southwest of the district, where construction activities have not yet been very intense. Three focal points stand out throughout the district for "more suitable" areas: Gülpınar-Dereağzı, Kavaklı, Marmara-Kavaklı.

While the Gülpınar-Dereağzı axis stands out due to its high accessibility, low land value and distance to pollution sources; the fact that the northern part is very close to

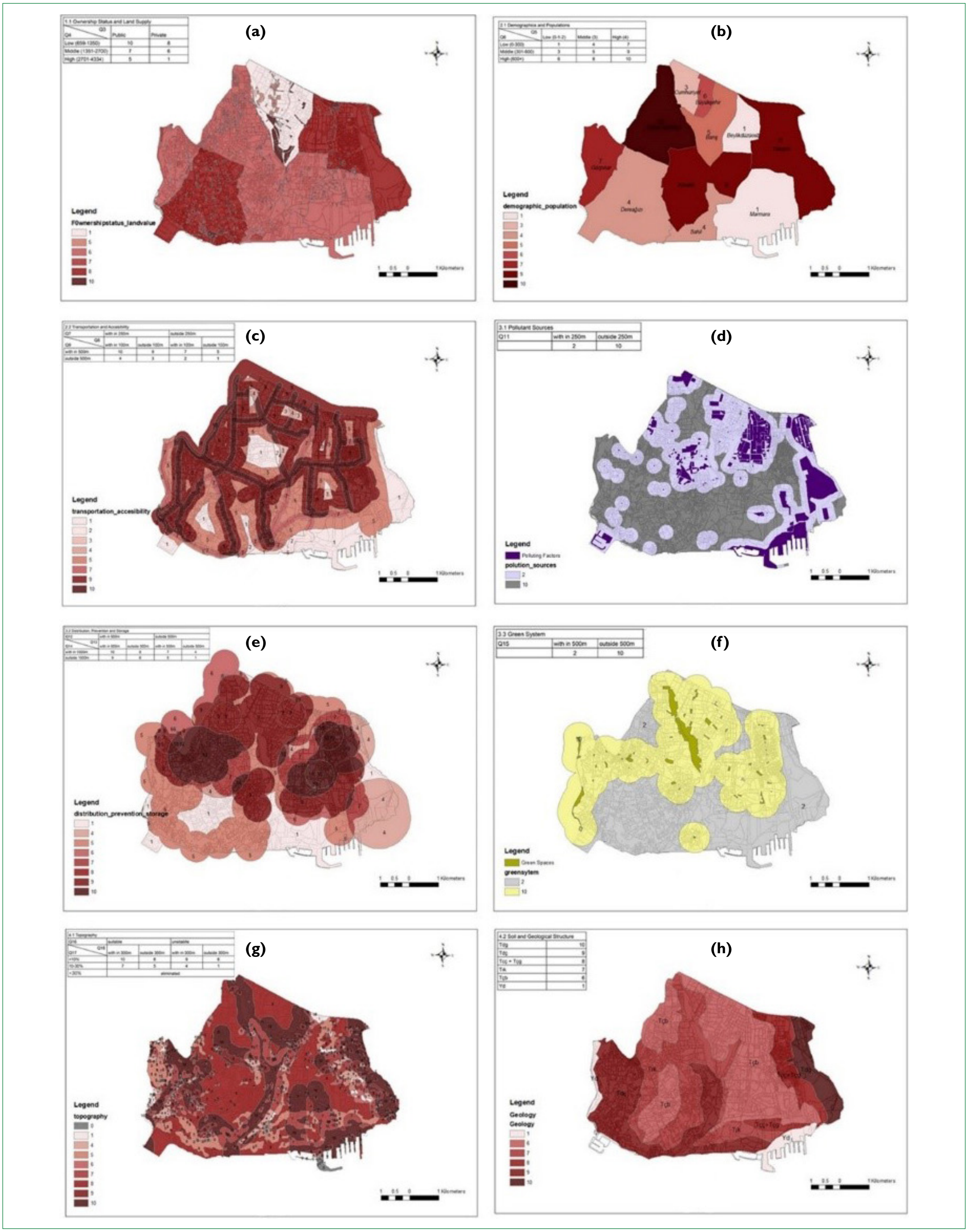

Figure 4. Spatial analysis of parameters **(a)** ownership status and land supply **(b)** demographics and population **(c)** transportation and accessibility **(d)** population sources **(e)** distribution, prevention, and storage **(f)** green system **(g)** topography **(h)** soil and geological structure.

Table 4. Urban agriculture site selection index

Parameters	Definition	Sub criteria	Parameter weights	Rank	Parameter weight without security level	Rank
Constraints	Accepted as a condition for field selection	Q1. Empty field Q2. Field size	–	–	–	–
1.1. Ownership status and land supply	Facilitating factors in the effective budgeting and implementation of urban agriculture	Q3. Public ownership Q4. Low land value	16.8%	2	18.11%	2
2.1. Demographics and population	Widespread access of urban farmland to demographics and populations in need of food access	Q5.Proximity to the demographic structure sensitive to food supply Q6. High population density	8.8%	5	8.91%	7
2.2. Transportation and accessibility	The fact that urban agricultural areas can be fed with different transportation networks, users can reach the area with alternative modes, and the products can be distributed easily	Q7. Proximity to public transportation networks Q8. Access to the area with walking and cycling paths Q9. Proximity to transportation alters	10.4%	3	10.49%	3
2.3. Security level	A high level of security and a controlled environment to ensure the safety of users and products	Q10. High security	9%	4	–	–
3.1. Pollution sources	Distance from polluting factors such as industry, port, etc. in order to preserve the nutritiveness of the food	Q11. Distance from polluting factors in land use	23.1%	1	26.23%	1
3.2. Distribution, prevention and storage	Proximity of distribution and storage areas to the production area in order to preserve the nutritiveness of the food and to reduce the waste rate in the distribution, storage process and to manage it effectively	Q12. Proximity to distribution centers Q13. Proximity to social facilities as alternative distribution stations Q14. Proximity to preservation and storage areas	8.6%	6	10.22%	4
3.3. Green system	Proximity of urban agricultural areas, proximity to green areas for holistic ecological infrastructure	Q15. Integration with the holistic green system within the district	8.2%	8	9.43%	5
4.1. Topography	The suitability of the topographic features of the land, including aspect, slope and drainage, for urban agriculture	Q16. Aspect level Q17. Low slope Q18. Drainage suitability	6.6%	9	7.24%	8
4.2. Soil and geological structure	The suitability of the geological structure and soil structure for urban agriculture	Q19. Low erosion risk Q20. Agricultural suitability of soil structure	8.5%	7	9.38%	6

distribution areas, the population with high food sensitivity lives in it, the green areas remain within the coverage areas and its geological formation distinguish this region from the other two regions. Kavaklı, the geographical core of the district, is particularly noteworthy due to its extremely high topographic parameter drainage adaptability. Subsequently, it draws attention with its proximity to Yaşam Vadisi, which is the backbone of the green infrastructure of the district. Finally, The Marmara-Kavaklı region stands out in terms of demographic and population parameters with its proximity to sensitive groups, distribution, prevention and storage areas and areas with low land value; the Kavaklı region stands out in terms of topography parameters with its very high drainage suitability and proximity to Yaşam Vadisi.

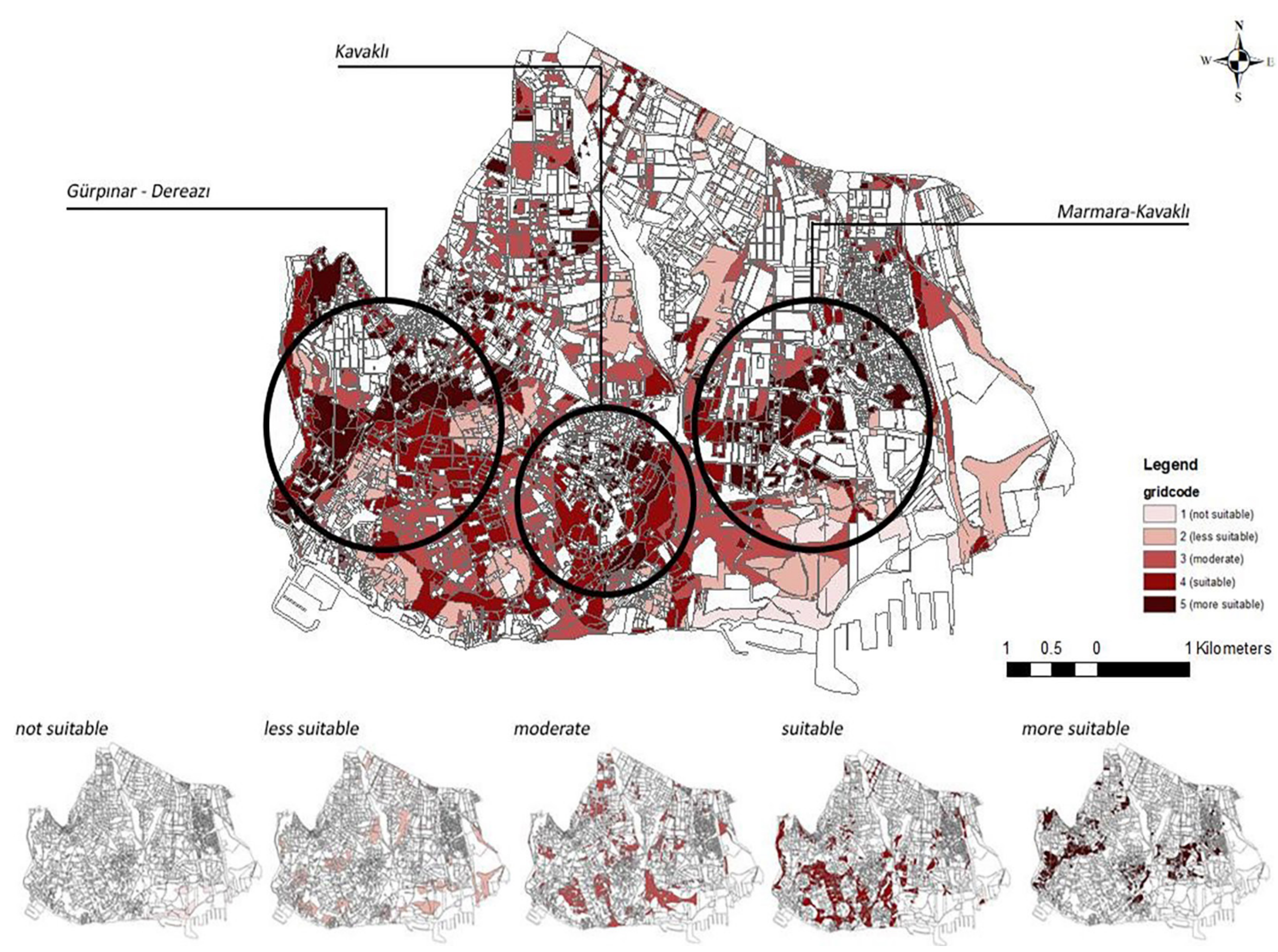

Figure 5. Suitable urban agriculture areas of Beylikdüzü District.

The extent to which the areas suitable for urban agriculture determined in the study will meet the fresh food needs of the district's population may be the subject of a separate study. However, it is possible to estimate by considering the production capacity of the district's 2-hectare garden (Yaşam Vadisi) that is currently producing. According to the official website of the local municipality, at least 30 tons of product is obtained from the garden area in Yaşam Vadisi in summer and winter, and 60 tons of product is obtained annually. Tomatoes, cucumbers, zucchini, eggplant, and pepper varieties are planted in the summer; and lettuce, lettuce, cress, arugula, cauliflower, leek, spinach, radish, broccoli, chard, onion, carrot, beet, chard, and cabbage varieties are planted in the winter. Food diversity is essential for sustainable and healthful diets, even if producing only one type of food results in lower carbon emissions when food is considered. According to the World Health Organization, an individual should consume at least 400 grams of fruit and vegetables per day for a healthy diet (WHO, 2020). This indicates that at least 146 kilograms of fresh food are needed annually for the average person.

According to the 2022 population of Beylikdüzü district, the district needs at least 60273 tons of fresh food per year. If food production is carried out in all areas suitable for urban agriculture determined within the scope of this study (current production in Yaşam Vadisi is taken as a basis), 72% of the fresh food needs could be satisfied. However, since it is not sustainable and realistic to allocate all the land specified for urban agriculture activities, it is important to evaluate the most suitable lands. If the "more suitable" and "suitable" areas with the highest suitability value are implemented for urban agriculture, 34% of the district's fresh food needs could be fulfilled. In a more realistic scenario, only the "more suitable" areas are expected to meet 13% of the fresh food needs. Subsequently, if the district's population is projected to reach 825,000 in 2050, it is anticipated that 36% of the district's annual fresh food demands may be satisfied. However, this estimate ignores the demand for other needs of the increasing population. In a more conceivable scenario, if only "more suitable" areas are allocated for the fresh food needs of the 2050 population, it can be predicted that 6% of the need will be met. It has been calculated that if "suitable" areas are included, the rate could rise to 17%.

In 2018, the transportation of products from different cities of Türkiye to the Bayrampaşa and Ataşehir wholesale markets under the control of the IMM released approximately 100 kilotons of CO_2 (Greenpeace, 2019). The ratio of the Beylikdüzü population to the Istanbul population in the same year is expected to be 2.2 kilotons of CO_2 from the transportation of wholesale products coming from outside to Istanbul, and this rate is expected to be 2.73 kilotons of CO_2 in 2022.[5] Local fresh food production would shorten the supply chain, reducing carbon emissions. Utilizing the "most suitable" areas identified in this study for urban agriculture could meet 13% of the fresh food demand of the 2022 population, contributing to a reduction in associated CO_2 emissions. Accordingly, if it is assumed that there is no need to transport fresh food produced in the "most suitable" areas from outside the city, approximately 350 tons of CO_2 will be saved.[6] In the best-case scenario where all areas identified within the scope of the study are used for urban agriculture, this rate could save 1.96 kilotons of CO_2.[7]

5. Discussion

This study aimed to examine the urban agriculture site selection to achieve a more sustainable, secure, and fair food system at the local scale in Istanbul Beylikdüzü, utilizing a multi-criteria decision-making method. The study contributes to the selection of land use decisions in urban planning and the applications of municipalities at the local scale, thus serving the land use strategy and food planning.

5.1. Choosing the Right Location: The Most Critical Parameters

Research on urban agricultural land selection parameters reveals various approaches and corresponding outcomes. The first group is studies focusing on natural structure parameters (Akıncı et al., 2013; Akbulut et al., 2018, Bozdağ et al., 2016; Kamezi & Hosseinpour, 2022; Seyedmohammadi et al., 2019; Yalew et al., 2016). The scales of these studies cover large urban-rural hinterlands and focus more on peri-urban agriculture. These studies generally evaluate soil structure, soil suitability for agriculture, and topographic parameters. Studies that reveal important factors for land selection other than natural factors in dense urban construction are quite limited. Land value, population, and housing density have been revealed to be the most significant factors outside the natural environment parameters (He & Genoverse, 2012). Consequently, the findings are consistent with previous research on the importance of land supply.

Studies combining two approaches evaluate the parameters required for urban agriculture land selection in complex urban spaces in a more sophisticated ways (Sarı & Koyuncu Sarı, 2021; Thapa & Murayama, 2008; Türker & Akten, 2023; Ustaoğlu et al., 2021; Weerakoon, 2014). These studies, which concentrate on metropolitan areas rather than vast geographic areas, demonstrate that transportation and land use have a significant role in site selection. This study aligns with the third mentioned group, confirming the literature on land use (pollutant sources) and land supply while highlighting the limited consideration of environmental factors like soil structure. However, natural factors compete with artificial factors such as land use in some studies (Sarı & Koyuncu Sarı, 2021; Thapa & Murayama, 2008; Ustaoğlu et al., 2021). It is noteworthy that soil structure holds greater significance than topographic characteristics, regardless of the overall hierarchy of environmental factors, underscoring the robustness of the study's findings.

5.2. Meeting Local Food Needs

Galzki et al. (2017) calculated that urban agriculture based on the foodshed model could provide enough food for the entire population in selected areas of Southern Minnesota, but only one-third in New York State. McClintock et al. (2013) found that urban agriculture on public lands in Oakland could meet 2.9–14.5% of current food consumption and on private lands 2.1–24.5%. According to Orsini et al. (2014), rooftop gardens in Bologna have the potential to produce more than 12,000 tons of vegetables per year, fulfilling 77% of demand. Saha & Eckelman (2017) determined that 7% of the land in Boston is suitable for rooftop and 10% for ground-level agriculture, and that if all suitable areas were used most efficiently, the city could meet 1.5 times its food needs.

The findings obtained in Beylikdüzü demonstrate that the most suitable lands for urban agriculture can meet 13% of the fresh food demand in the most realistic scenario, and 72% if all areas are used for urban agriculture. Beylikdüzü has significant potential for local food production and presents similar characteristics to studies in the literature. However, the fact that the research area is part of a metropolitan city and its external dependency should not be ignored. Moreover, the importance of production capacity and on-building applications such as rooftop gardens in meeting the food needs of cities locally are obvious.

In terms of environmental impacts, it has been calculated that local food production in Beylikdüzü can prevent 350 tons of CO_2 emissions in a realistic scenario (266 ha). The

[5] The calculation is based on the ratio of the Beylikdüzü population (331,525) to Istanbul's population (15,067,724) in 2018. The ratio for 2022 (412835) is based on CO2 per capita.

[6] It was assumed that the food supply of the district from outside emitted 2.73 kilotons of CO_2, and 13% of this was calculated.

[7] The calculation is based on all determined areas meeting 72% of the district's fresh food needs.

Life Cycle Assessment study by Kulak et al. (2013) demonstrates that strategically selected crops and an optimally designed community garden on 26 ha of vacant land in the urban fringe of Sutton, London could reduce emissions by 881 t CO_2e. This assessment considers agricultural activities, distribution, travel to shopping points, and food waste decomposition. Beylikdüzü holds significant potential in this regard; however, the current study relies on basic ratios derived from existing production in Yaşam Vadisi and accounts only for emissions from food transportation between different provinces. Since the analysis is based on the current production capacity of Beylikdüzü, a more efficient crop design could further enhance its impact and contribute to greater emission reductions.

5.3. Comprehensive Food Planning

There are three principal elements of the urban food system: production (supply), distribution (trade), and consumption (demand) (Hsu & Han, 2024). Comprehensive food planning includes food production as well as access to healthy food (Hu et al., 2020), food distribution and logistics (local/short supply chain) (Petruzzelli et al., 2023), food waste management (Parsa et al., 2024), and social innovation (Maye, 2019). This research focuses on the local production aspect of food planning while also attempting to incorporate other components via parameters and sub-criteria. Food access and justice are critical elements that need to be addressed at the household and community level (Opitz et al., 2016), and food availability has been examined in the context of food deserts (Segal, 2010).

Here, Q5 (Proximity to the demographic structure sensitive to food supply) under the Demographics & Population parameter, and Q7 (Proximity to public transportation networks) and Q8 (Access to areas with walking and cycling paths) under Transportation and Accessibility are considered to enhance access to urban agriculture areas. Food storage, although often overlooked, is critical for food security in cities (Hsu & Han, 2024), and food distribution and logistics are associated with the Distribution, Prevention, and Storage parameter. Q12 and Q14 assess the proximity to distribution and storage facilities, while Q13 targets the use of schools and socio-cultural service areas as alternative distribution centers (Appendix 1). The findings reveal that these parameters perform at a moderate level, and socio-economic factors come right after the feasibility of urban agriculture.

Urban agricultural areas are not reduced to a single function but offer social, economic and ecological benefits (Peng et al., 2015). Kavaklı neighborhood will provide recreational opportunities with its proximity to Yaşam Vadisi, while strengthening the green infrastructure of the district. Community-based gardening in Gürpınar-Dereağzı can increase access to nutritious food for disadvantaged groups. Marmara-Kavaklı is a priority intervention area due to its proximity to industrial zones and ecological sensitivity. Although the study focuses on ground-level urban agriculture, rooftop farming, backyard farming, and micro-production can reduce carbon emissions by increasing local food production.

5.4. Implementation and Challenges

Urban food planning encompasses spatial and non-spatial processes; defined food production, processing, distribution and supply policies are shaped by land use plans (Buchan et al., 2018). Although urban agriculture is often considered as a temporary and informal land use, local governments integrate it into planning processes, allowing the use of public lands or the promotion of private property for food production (Meenar et al., 2017). In addition to encouraging short- or long-term rentals on public and private lands, decisions can be made to shape the infrastructure on issues such as the arrangement of structures for urban agriculture, production performance, waste management, etc.

Urban agricultural policies vary for each city; in some, they are firmly integrated into urban planning, but in others, they may remain on a more strategic level. In Italy, Bologna does not select areas when determining implementation indicators, Milan tries to integrate urban agriculture in its newly planned areas, Rome includes it in both plan provisions and zoning, while Turin initially adopted a strategic perspective but integrated it into land use with the revision of the master plan (Forte et al., 2022). In New Zealand, the Christchurch Plan stands out by defining community garden and residential garden allotment (Hanna & Wallance, 2021). In Dawson, Canada, community gardens are permitted in all residential areas and some public spaces, and although urban agriculture is not included in Toronto's zoning, it is seen as the next step in the city's food planning (Huang & Drescher, 2015; Miller & Blay-Palmer, 2018).

To be included in urban food planning, urban agriculture must be supported by regulations and decisions that impact implementation and strategy development. Beylikdüzü district has undeniable driving forces for food production at the local scale. The existence of current food-related practices such as food aid for low-income households and the urban agriculture area in Yaşam Vadisi reveals the district's potential for food planning to develop a sustainable, secure and fair food system. Although there are urban food strategies and initiatives in Istanbul, large-scale decisions such as industrialization, population density and mega projects are restrictive and hindering for urban agriculture.

This study focused on comparing parameters rather than evaluating sub-criteria; various weighting methods may produce different results, but its compliance with the literature reduces this limitation. In addition, the study provides a basis for future research and suggests a spatial approach for local governments and decision-makers. Sustainable food planning should not be limited to local government policies only, zoning and urban planning laws should be developed as process guides. Future research should focus on more comprehensive methodologies that cover all stages of the food chain. Additionally, the absence of comprehensive data on parameters such as soil erosion and security may have affected the precision of the spatial analysis. Addressing these limitations through the inclusion of more extensive datasets, as well as applying the methodology to a wider range of urban settings, will be critical in future studies to enhance the robustness and generalizability of the findings.

6. Conclusion

This study utilizes the spatial multiple decision-making approach to determine the optimal location for urban agriculture in Istanbul's Beylikdüzü district. It develops an index for site selection based on physical, economic, and social parameters derived from the literature and evaluates this index through a case study. The proposed approach provides an analytical foundation for land-based urban agriculture site selection, offering guidance for local governments, policymakers, and practitioners.

The findings revealed that the most essential parameter for urban agriculture site selection is distance from polluting sources. "Ownership status and land supply" and "transportation and accessibility" also carry significant weight, suggesting that physical conditions take precedence over social and ecological factors. This research offers a transferable model that can be applied across urban settings to inform public land-based agriculture planning and policy-making.

Beyond creating a site selection index, this study uses spatial analysis to identify areas in Beylikdüzü suitable for urban agriculture. Results show that the most suitable areas could meet 13% of the district's fresh food needs, based on the capacity of existing public production sites—an important contribution for a highly import-dependent city like Istanbul. These high-potential areas can support diverse urban agriculture initiatives, including community-based projects, ecological enhancement, and recreational functions. These outcomes align with the economic, social, and ecological benefits attributed to urban agriculture.

Overall, the study integrates built environment, socioeconomic, and natural factors into a comprehensive framework for urban agriculture site selection. It offers a spatially grounded method and a foundation for future research in sustainable urban food planning.

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Appendix 1. Parameters and sub-criteria for urban agriculture site selection

Parameters	Definitions	Sub-criteria	Definitions	References
Constraints	Availability of cultivable land.	Q1 Empty field.	The absence of use in the selected area makes the application easier.	area of empty land (He & Genovese, 2012), vacant land parcels (Baker, 2012; Kirnbauer & Baetz, 2012; McClintock et al., 2013), bare groundcover (McClintock et al., 2013), availability of cadaster units (Sonneveld et al., 2021).
		Q2 Field size.	The size of the areas may vary depending on the scope of urban agriculture.	Micro-farming as <500m^2 (0.05ha), family gardens, backyards as <1000m^2 (0.1ha), community farms, and allotments as 1000–3000m^2 (0.1–0.3ha), urban farms as 2000–10000m^2 (0.2–1ha) and suburban farm as >10000m^2 (>1ha) (Yang et al., 2020 community garden as <0.1ha, small market gardens as 0.1-0.4ha, large market gardens, mini-farms as 0.4-2ha, and urban farms as >2ha (McClintock & Cooper, 2010) 0,2 ha- 5,2 ha (Opitz et al., 2016) >0,2ha most suitable, 0,1–0,2ha suitable, <0,1 ha unsuitable (He & Genovese, 2012) Minimum 300 m2 (Kirnbauer & Baetz, 2012).
Ownership status and land supply	Facilitating factors in effective budgeting and implementation .	Q3 Public ownership.	Being in public ownership can make implementation easier and accessible to everyone.	Public lands (McClintock & Cooper, 2010) private and public ownership (McClintock et al., 2013; Opitz et al., 2016; Saha & Eckelman, 2017).
		Q4 Low land value.	Land supply affects the cost. Low land value provides easy supply.	Importance of land value for urban agriculture (Weerakoon, 2014; He et al., 2012).
Demographics and population	To serve the demographic structure and population in need of food access.	Q5 Proximity to demographic structure sensitive to food supply.	Food justice covers ensuring access to more fresh food at the household level.	The percentage of low-income and low-access populations within 1 mile (Smith et al., 2021) percentage of the population at or below the poverty level (Smith et al., 2021). "Healthy Food Priority Areas": average household income, car ownership, availability of healthy food, distance to the nearest supermarket (Baltimore City's Food Environment: 2018 Report, 2018) percentage of the uninsured population (Smith et al., 2021)
		Q6 High population density.	Due to higher population density, more people have access to the food provided by urban agriculture.	Population density and housing density (Weerakoon, 2014) population density within 100m (Smith et al., 2021) distance from urban residential dwellings (Usraoğlu et al., 2021) community garden with min 25 k/ha within 400m, neighborhood farm with min 50 k/ha within 800m, commercial farm, orchards, and farmer's market with min 50 k/ha within 1000m (Kirnbauer & Baetz, 2012).

Appendix 1 (cont.). Parameters and sub-criteria for urban agriculture site selection

Parameters	Definitions	Sub-criteria	Definitions	References
Transportation and accessibility	Fed by different transportation networks, users can reach the area with alternative modes and products can be easily distributed.	Q7 Proximity to public transportation networks.	The proximity to public transportation networks seeks to provide urban agricultural users with convenient access to the site.	Bus or light rail station within a 10-minute walk (Smith et al., 2021) transit bus stop within 400m (McClintock & Cooper, 2010; McClintock et al., 2013).
		Q8 Access to the area with walking and cycling paths.	It improves user access to the area by providing defined pedestrian and bicycle paths.	Bike lane, bikeway, or bike path within 100m (Smith et.al, 2021) Euclidean distance (Sonneveld et al., 2021).
		Q9 Proximity to transportation arteries.	Feeding the area by transport alters provides easy access for users and easy distribution of the food produced.	Road network relationship as high (<1km), medium (1–2km), and low (2–3km) (Thapa and Murayama, 2008) 0.2–3.2km access (Meenar and Hoover, 2012). Fast roads and slow roads (Ustaoğlu et al., 2021). Walking distance from railway and highway if most suitable <500m, suitable 500–1000m, and unsuitable>1000m (He and Genovese, 2012).
Security level	Ensuring the safety of users and products in a controlled environment.	Q10 High security.	The high level of security is influenced by the low number of instances and security issues in and around the region.	Number of thefts reported per district (Sonneveld et al., 2021).
Pollutant sources	To preserve the nutritional value of food, it is important to stay away from pollutants such as industry, ports, etc.	Q11 Distance from polluting sources in land use.	urban soil is damaged by industrial pollution (Saha & Eckelman, 2017).	Five suitability criteria over the soil and groundwater pollution map (Sonneveld et al., 2021). Industrial, port, and airport areas (Ustaoglu et al., 2021). Industrial areas as build-up areas (Thapa & Murayama, 2008; McClintock et al., 2013).
Distribution, prevention, and storage	Proximity between facilities to preserve the nutritional value of food, reduce waste, and manage it effectively during distribution and storage processes.	Q12 Proximity to distribution centers.	Distributed as soon as possible to preserve the nutritional values of the food and to prevent losses.	Accessibility to market areas (Thapa & Murayama, 2008; Baker, 2012; He & Genovese, 2012; Galzki et al., 2017; Smith et al., 2021; Sonneveld et al., 2021; Ustaoglu et al., 2021). Market accessibility over 10–20 and 30 km from the city centers (Thapa & Murayama, 2008). Food supply systems across 2–5 km2 (Galzki et al., 2017). Proximity to market areas is most suitable<500m, suitable 500–1000m, unsuitable>1000m (He & Genovese, 2012). Market areas over 800m (Berger, 2013).

Appendix 1 (cont.). Parameters and sub-criteria for urban agriculture site selection

Parameters	Definitions	Sub-criteria	Definitions	References
				400m radius (Baltimore City's Food Environment: 2018 Report, 2018)100m to commercial areas (Smith et al., 2021).
		Q13 Proximity to social facilities as alternative distribution stations.	Proximity to social facilities such as municipal service areas, schools, and socio-cultural service areas is important for the participation of local people in the process and increasing their access to food.	Schools over 800m (Berger, 2013). 10-minute walking distance to a park, community center, public library, religious institution, or school (Mcclintock & Cooper, 2010). Distance to schools as 400m (McClintock & Cooper, 2010; McClintock et al., 2013).
		Q14 Proximity to preservation and storage areas.	Narrowing production, storage, and distribution distances to shorten the food chain.	Distribution centers and storage areas on large parcels (McClintock & Cooper, 2010; McClintock et al., 2013).
Green system	Proximity of urban agricultural areas to each other, proximity to green areas for holistic ecological infrastructure.	Q15 Integration with the holistic green system within the district.	The presence of green areas will support the ecological system.	>0.3km^2 most suitable, 0.1–0. suitable, and <0.1km2 unsuitable (He and Genovese, 2012). 750–1500m the flying distance of the bees and green infrastructure within 500m (Orsini et al., 2014). 10-minute walking distance (Smith et al., 2021).
Topography	The suitability of the topographic features of the land, including aspect, slope, and drainage.	Q16 Aspect level.	The level of sun benefit during the year, depending on the climatic conditions.	South-facing slopes as a positive criterion for site selection (Baker, 2012; McClintock et al., 2013; Sarı & Koyuncu Sarı, 2021; Ustaoglu et al., 2021). West, southwest, south, southeast, and east as optimal, and northwest, north, and northeast as less desirable (McClintock et al., 2013). At least 6 hours of solar radiation per day (Saha and Echelman, 2017).
		Q17 Low slope.	Slope is one of the indicators frequently used in the selection of urban areas.	Low slope as a positive factor (Baker, 2012; McClintock ve Cooper, 2010; McClintock vd., 2013; Weerakoon, 2014; Saha ve Eckelman, 2017; Smith et al, 2017; Sarı ve Koyuncu Sarı, 2021; Ustaoglu vd., 2021). <10% acceptable, >30% detrimental (Baker, 2012). 10%, 10%–30%, and >30% (McClintock et al., 2013; McClintock ve Cooper, 2010). <5% (Smith et al., 2017). <15% (Saha and Eckelman, 2017). >10% unsuitable (Sarı and Koyuncu Sarı, 2021)

Appendix 1 (cont.). Parameters and sub-criteria for urban agriculture site selection

Parameters	Definitions	Sub-criteria	Definitions	References
		Q18 Drainage suitability.	Water resources are vital for the sustainability of urban agriculture.	Watershed vulnerability (Rogers and Hiner, 2016) close to the water source (Thapa & Murayama, 2008; Baker, 2012; Sonneveld et al., 2021; Ustaoglu et al., 2021). Risk of flooding, surface water availability, groundwater depth (Sonneveld et al., 2021). High (1km), medium (2km), and low (3km) proximity to rivers; high (0.3km), medium (0.6km), and low (0.9km) proximity to ponds/lakes (Thapa and Murayama, 2008). Water source within 3 m (Baker, 2012).
Soil and geological structure	Suitability of geological structure and soil structure.	Q19 Low erosion risk.	The risk of erosion poses a threat to urban agriculture. Geological structure and erosion risk are often the subjects included in upper-scale studies.	Monotonically decreasing linear between 1 and 7 (Usraoglu et al., 2021). Geological suitability on a scale of 1 to 5 (Sonneveld et al., 2021).
		Q20 Agricultural suitability of soil structure	The suitability of soil structure for agriculture is a key component in agricultural sustainability.	Soil suitability in 5 categories (Sonneveld et al., 2021. Soil conductivity, soil depth to restrictive layer, and prime agriculture soil (Rogers & Hiner, 2016). Soil depth, soil limiting factors, and agricultural land capacity on a scale of 1 to 7 (Ustaoğlu et al., 2021). pH, salinity, texture, organic matter (Sarı and Koyuncu Sarı, 2021). Soil types (Parece, 2016).