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Geospatial characteristics of allotment garden provision in Tokyo

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Research Paper

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Abstract

Allotment gardens (AGs), one of the most popular forms of urban agriculture (UA), have attracted social attention because of the ecosystem services they provide to citizens. However, the services and availability of AGs may be unevenly distributed, owing to their geographic location. The patterns underlying the provision of AG plots and facilities to users in Tokyo are unclear. Thus, this study quantitatively examines the characteristics of different types of AG provision and their determinants in the metropolitan region of Tokyo. We classified a sample of 313 AGs gathered from governmental open data via a non-hierarchical cluster analysis of AG provision patterns based on their properties, including number of plots, plot size, contract price and duration, and facilities such as agricultural equipment and access to instructors. Moreover, we examined the influence of urban development and residential characteristics on these classes using the Kruskal–Wallis test. The analysis identifies six AG provision patterns based on their properties. It also revealed that AG provision in Tokyo was differentiated by the percentage of agricultural land and the socio-demographic characteristics of residents, including population, percentage of young population, and income levels from the city center to the suburban areas, corresponding to urban sprawl. These findings could provide valuable insights to help local governments, farmers, and non-profit organizations address the challenges and opportunities arising from each AG provision pattern and to make AG plots and facilities more adaptable to upcoming urban shrinkage, business opportunities, and possible excessive subdivision and price hikes.

Introduction

In cities worldwide, urban agriculture (UA) has attracted social, municipal, and scholarly attention (International Resource Panel, 2021), owing to its cross-cutting ecological, economic, and social significance (Peng et al., 2015) for citizen participation, recreation, and the maintenance of agricultural landscapes, among others (Lovell and Johnston, 2009; Lovell, 2010). Allotment gardens (AGs) are a popular form of UA, among other forms such as community gardens (essentially the same as AGs), vertical farms, rooftop gardens, school gardens, residential gardens, and institutional gardens (Taylor and Lovell, 2012; Pulighe and Lupia, 2016; Hsiao, 2021). AGs are not only used for producing vegetables, but also provide ecosystem services, such as access to fresh and healthy food, biodiversity conservation, nutrient cycling, and water runoff mitigation, in addition to providing recreation and learning opportunities (Guitart, Pickering and Byrne, 2012; Ruggeri, Mazzocchi and Corsi, 2016; Mitarai and Matsushima, 2017; Cabral et al., 2017). AGs also facilitate air quality control and rainwater infiltration in the surrounding areas (Speak, Mizgajski and Borysiak, 2015; Cabral et al., 2017). By maintaining AGs, users can experience a sense of fulfillment (Partalidou and Anthopoulou, 2017). Families with children can learn much from engaging in the processes, hardships, and joys of growing vegetables (Pothukuchi, 2004). Participants also become acquainted with others as they exchange information, collaborate, and help each other, leading to social cohesion (Teig et al., 2009; Veen et al., 2016). Therefore, scholars describe AGs as a ‘third space’ after home and work (DeSilvey, 2003). The evidence of the benefits of AGs indicates the need to expand their distribution across urban areas.

Despite the value provided by AGs, the land dedicated for these purposes has constantly declined in most cities because of urbanization (Acton, 2011; Spilková and Vágner, 2016; Dobson, Edmondson and Warren, 2020; Fletcher and Collins, 2020). Conservation policies for agricultural land-use and AGs have generally been promoted in the context of urban planning (Ponizy and Stachura, 2017) and local greening policies (Partalidou and Anthopoulou, 2017; Moriya and Funakubo, 2020). For instance, Japan enacted the Basic Act on the Promotion of Urban Agriculture in 2015 to conserve and promote UA, including AGs (Ministry of Agriculture, Forestry and Fisheries (MAFF) and Ministry of Land,

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Infrastructure, Transport and Tourism (MLIT), 2016; Tokyo Metropolitan Government, 2017). In some instances, specific policies have been introduced to enhance the quality and efficiency of AGs' management (Fletcher and Collins, 2020). However, such policies have generally been enacted without clarifying where and how the benefits by AGs will be prepared, managed, and delivered.

Existing studies imply that the context of urbanization and characteristics of residents influence the distribution of AGs. The benefits provided by AGs are often not universally accessible. First, the increase in urbanization affects the supply of AG plots. For instance, in European cities such as London (UK), the relationship between the number of AGs and people on waiting lists for plots differs significantly between the inner and outer parts of the city; for example, people in inner areas must wait several years for a plot (Fletcher and Collins, 2020). AGs in Chicago (US) are primarily concentrated in areas with low levels of developmental pressure (Taylor and Lovell, 2012). The distribution of AGs is negatively associated with the distance from the central area in Philadelphia (US) (Park and Ciorici, 2013) and positively associated with the urban greenery in Poznań (Poland) (Dymek et al., 2021). Second, the characteristics of the residents, especially income level and age, affect the demand for AG plots. In Philadelphia (US), AGs are prevalent in low-income communities (Kremer and DeLiberty, 2011; Park and Ciorici, 2013). In Chicago (US), AGs are more evenly distributed, but mainly in low-income communities that are supported by non-profit activities (Taylor and Lovell, 2012). In contrast, AGs are also found in middle-income communities of Madison (US) (Smith, Greene and Silbernagel, 2013), high-income communities of Philadelphia (US) (Park and Ciorici, 2013), and communities with a high socio-economic status in St. Louis (US) (Braswell, 2018). The distribution of AGs is negatively associated with high rates of aging populations (Park and Ciorici, 2013). Some studies have noted AG distribution in Asian cities; in Osaka (Japan), AGs mainly appear in areas with a moderate population density and a high rate of aging populations (Ye and Yoshida, 2018). In Taipei (Taiwan), AGs are 2–4 km from the railway stations (Hsiao, 2022). More recently, researchers reported that the distribution of AGs in Tokyo (Japan) is associated with population density, land price, and other factors (Zheng et al., 2022). Respectively, based on the supply- and demand-side constraints of urbanization and residents' characteristics, these studies reveal that AGs are widely dispersed in cities and their provision patterns are quite diverse. This is unique compared to other forms of UA, such as school gardens and residential gardens (Taylor and Lovell, 2012), because AGs are public spaces accessible to everyone. However, the management of AGs in different urban contexts remains unclear.

Generally, well-managed AGs provide users with appropriate plots and facilities, such as shelters, bicycle stands, parking lots, and washrooms, at various costs (Wiltshire and Burn, 2015). Such provisions may differ based on the location of the AGs and the demands of potential users (Wiltshire and Burn, 2015). Differences in plots and facilities frequently influence user preferences (Suda, Kusunoki and Tokunaga, 1995; Yuzawa, 2012). Therefore, AG provision is defined as the allocation of plots and facilities available in an AG to the users. Few studies have elucidated the context underlying AG provision. A review by Guitart, Pickering and Byrne (2012) demonstrated that many publications on AGs have investigated low-income areas in the United States, whereas research on AGs in Asia has been limited (Hsiao, 2021). Studies in Japan reveal that the economic and environmental performances of AGs are mostly defined based on land-use zoning rules: urbanization promotion areas (UPAs) and urbanization control areas under Japan's City Planning Act (Hashimoto, Sato and Morimoto, 2019). However, the spatial distribution of AGs in metropolitan regions and the process of allocating AG plots and facilities amid severe competition for urban land use are aspects that remain unclear.

Unlike in other countries, urban growth in East Asia has created a pattern of mixed agricultural and residential land use in suburban areas (Yokohari et al., 2000; Yagi and Garrod, 2018). Urban areas in Japanese megacities are generally developed around railroad stations to enable workers from the surrounding suburban areas to commute to the city center by train. This pattern has resulted in an urban sprawl from the city centers to suburbs. Therefore, considering the regional urbanization context, this study examines the extent to which urban development and the residents' diverse demands, as key factors, affect the provision of AG plots and facilities in Tokyo, the largest metropolis. Examining AG provision patterns may provide valuable information for local governments, farmers, and non-profit organizations (NPOs) aiming to improve the management of AGs in different urban contexts.

Accordingly, this study has two primary aims:

- To examine the differences among existing AGs in terms of characteristics such as number of plots, plot sizes, and the main facilities.
- To clarify the relationship between AGs' provision of plots and facilities and the influence of urban sprawl from the city center to the suburbs of Tokyo's metropolitan area.

By doing so, we expect to clarify some unique aspects of AG provision in Japanese megacities, distinguishing them from other types of UA or other countries, which may also help municipalities experiencing similar conditions improve their UA policies.

Methodology and data

Development of urban sprawl and the urban–rural mixture in Tokyo

Administratively, Tokyo Metropolis is home to approximately 14 million people and covers a territory of 2,194 km^2. Except for the mountains and islands, the UPA classifies most of the area as a densely inhabited district, with a density of more than 4000 people per km^2. The Tokyo Metropolis, which is governed by the Tokyo Metropolitan Government, consists of a central business district (CBD), sub-centers along or encircled by the Yamanote Line, suburban areas in 23 special wards, cities in the Tama area 20 km west of the Yamanote Line, and islands. However, these islands were excluded in this study.

After over 50 years of development and significant improvements in the city's urban infrastructure, Tokyo experienced its first wave of urbanization in the early 20th century (Okata and Murayama, 2011; Yoshida, 2014; Liu et al., 2022). During this period, the Yamanote Line was established, which encircled the CBD and sub-centers. Its main stations were radially connected to the suburban areas through private railways. The central regions lying inside and outside the Yamanote Line were mainly urbanized during this period (Hong, 1993; Liu et al., 2022), when vegetables for consumption were mostly produced in the suburban areas. The second wave of urbanization or suburbanization occurred amid the rapid economic growth of the 1960s and the 1970s, when vast tracts of agricultural land were converted into built-up areas (Okata and Murayama, 2011). Residential areas were mainly constructed near railway stations and sprawled outward from central Tokyo, which resulted in the conversion of more than 50% of the land to built-up areas within a distance band of 5–25 km from the Yamanote Line (Yamamoto et al., 1977). In addition, Tokyo experienced suburbanization in the 1980s and the 1990s as land prices in the city center soared owing to the bubble economy (Kanda, Isoda and Nakaya, 2020). However, during the 2000s, Japan faced low economic growth, and Tokyo entered a new phase of urbanization (Kanda, Isoda and Nakaya, 2020), or the so-called re-urbanization (Ushijima, 2012), when people returned to the city center for convenience. Consequently, only a limited space was reserved for agricultural land use, mostly on the fringes of the metropolitan area, away from the railway stations. These developments have created a pattern of mixed urban–rural land use in suburban areas distant from the Yamanote Line (Yokohari et al., 2000; Yagi and Garrod, 2018).

Figure 1 illustrates the urban sprawl from the CBD to extra-urban areas, where built-up land within each 10 km distance band from the Yamanote Line is approximately 87.4, 75.3, 64.7, 49.0, and 5.7%, respectively. Areas located 15 km outside the Yamanote Line retained an agricultural land use pattern and were the so-called urban–rural mixtures.

AGs' supply and demand in Tokyo

AGs in Japan expanded in the 1960s when farmers converted their idle agricultural lands to AGs to diversify their businesses (Oba and Obase, 2001; Kudo, 2009). Simultaneously, many people began to use AGs for recreational purposes (Kudo, 2009). Present-day AG activities are supported by two pieces of legislation related to agricultural land lease and the promotion of AG in 1989 and 1990, respectively, and the demand for AG and their ecosystem services (Kudo, 2009).

In Japan, the provision of AGs involves the participation of local governments, farmers, Japan Agricultural Cooperatives, and NPOs. A tenant family can use an individual plot only under a limited-period contract. Many AGs provide facilities for agricultural equipment storage and rest, as well as instructors to facilitate learning activities. The harvest belongs to the tenants, who are not allowed to stay at the AG overnight, except for stay-type AGs (known as kleingartens) (Takano and Akita, 2016; Zheng et al., 2022). In addition, some AG managers employ local farmers or other managers as part-time instructors to teach users how to grow vegetables. Most AGs provide agricultural equipment to gardeners if they have storage facilities. AGs benefit people who do not have much experience in farming and do not have their own equipment. AG users in Japan are motivated by several reasons: opportunities to grow their own vegetables, source fresh vegetables, improve one's health, exercise outside the home, and relax (Amemiya et al., 2017). Moreover, many private companies have started supporting these gardens because of the emerging demand for AGs (Morofuji, 2013; Amemiya et al., 2017; Kamo and Yamada, 2020).

As of the end of March 2018, 432 AGs were registered in Tokyo, excluding those in the islands (Tokyo Metropolitan Government, 2019). According to the Tokyo Metropolitan Government (2019), local governments own most AGs (84.8%), followed by farmers (10.7%), Japan Agricultural Cooperatives (2.8%), and NPOs (1.6%). Most AGs in Tokyo (73.6%) were founded after 2000 (Tokyo Metropolitan Government, 2019). In most AGs, the number of applicants in demand for plots exceeds the number of supplied plots available. In terms of competitiveness, applicants have a 1-in-1.88 chance of accessing a plot in the eastern part, a 1-in-1.43 chance in the central part, and a 1-in-1.02 chance in the western part of Tokyo (Tokyo Metropolitan Government, 2019).

The Japanese government's MAFF regularly publishes a list of AGs across the country as part of its open government data initiatives (https://www.maff.go.jp/j/nousin/kouryu/tosi_nougyo/index.html); it published a list of 317 (73.1%) AGs in the Tokyo Metropolis. Some AG managers have not agreed to disclose their information on the list; however, the MAFF list is the most accessible dataset. This list includes attribute data on number of plots, plot size, annual rent, contract duration, instructors, agricultural equipment storage facilities, and address as of March 2020. Four properties (i.e., specific plot areas, contract period in months, instructor, and agricultural equipment) include those of kleingarten. We created point data using the Geographic Information System (GIS; Esri ArcGIS Pro 2.7.4) by geocoding the addresses in the list, using data gathered from our prior fieldwork, interviews with managers, the National Land Numerical Information by the MLIT, websites, city bulletins, and aerial photos of Google Maps, as needed. Three AG locations could not be identified, and one was excluded because it was located on an island. Hence, we analyzed a final sample of 313 AGs (one garden has both regular plots and kleingarten). Prior to the research, interviews and fieldwork indicated that the pattern of provisioning plots and facilities for AGs varied.

Analytical framework

This study hypothesizes that AGs' provision of plots and facilities reflects the differences in urban development and the characteristics of residents in the Japanese urbanization context. As mentioned previously, AG provision is defined as the allocation of plots and facilities to users. AG provision involves a balancing of supply and demand, as described in the approach by Park and Ciorici (2013), wherein the supply-side context is presented as the land use corresponding to the stage of urban development, and the demand-side context is presented as the residents' socio-demographic characteristics.

This study surveyed the provision of plots and facilities, grouped similar gardens, and treated each group as having a single type of AG provision. We hypothesized that properties including specific plot areas, number of plots, contract period in months, price per unit area, instructor, and agricultural equipment are potential determinants of AG provision. Specific plot areas and the number of plots are related to how many citizens can use gardens or whether the parcel of land allocated to each gardener within the limited garden area is spacious or narrow. AG managers may supply more plots in areas with many potential users and few gardens in the surrounding areas. The price per unit area is assumed to be determined by the number of potential users and the supply of surrounding gardens. Longer contract periods may provide users with opportunities to grow as many vegetables as desired. Research in Japan indicates that access to instructors and agricultural equipment (storage facilities) is more important (Aizaki, Endo and Yagi, 2004; Yuzawa, 2012) than other facilities. Therefore, we excluded

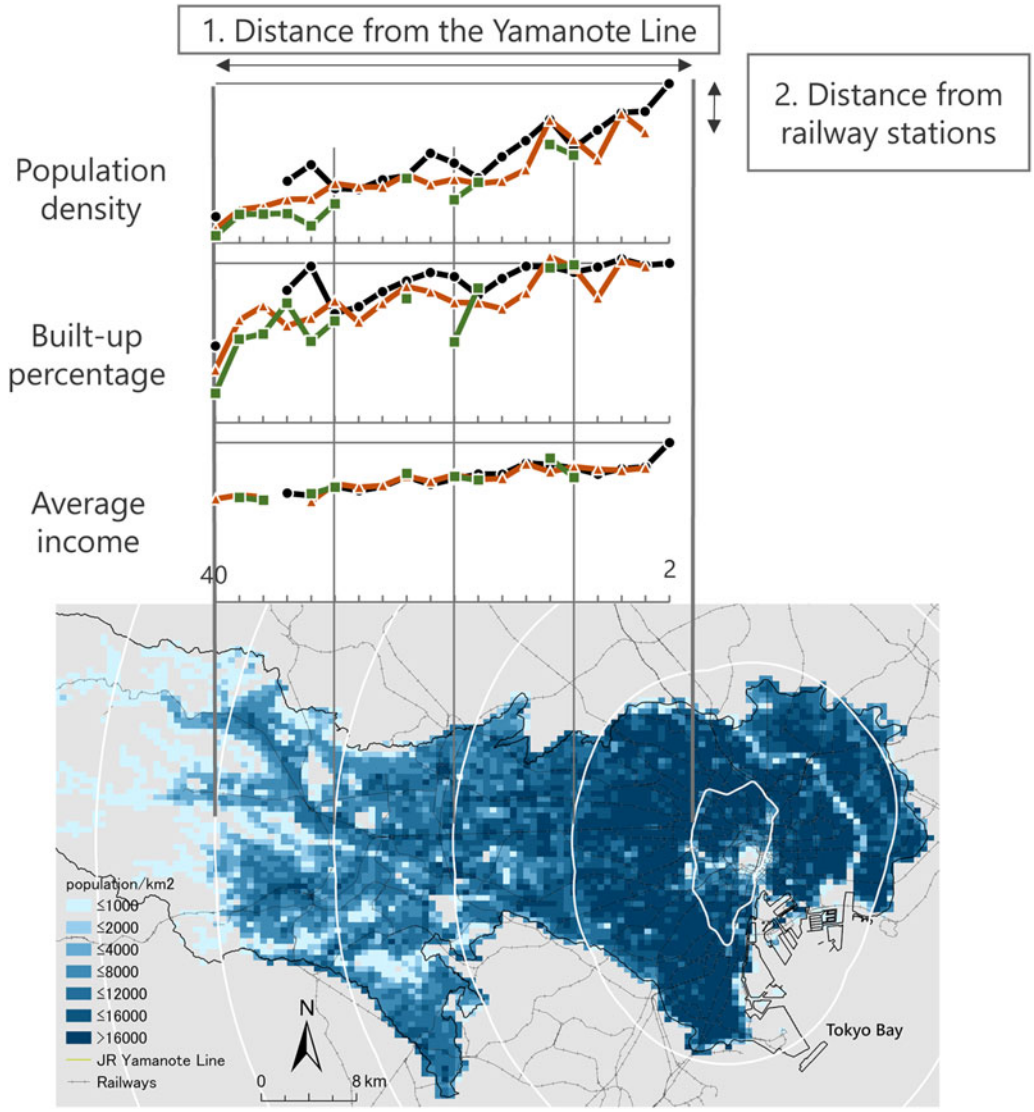

Figure 1. The graphs present the three main variables (population density, built-up land-use percentage, and average income), and the map illustrates the population density indicating the urban sprawl in Tokyo. The graphs show the average values of each variable in points (more than five points) where each 2 km buffer line from the Yamanote Line crosses each 500 m buffer line from the stations. Data source: National Census in 2015 (500 m resolution grid). Estimated worker income in 2018 by Nippon Statistics Center Co (500 m resolution grid). High-Resolution Land Use and Land Cover Map of Japan, Version 21.11 (10 m resolution grid) provided by the Japan Aerospace Exploration Agency (https://www.eorc.jaxa.jp/ALOS/jp/dataset/lulc/lulc_v2111_j.htm).

other facilities such as water supply and drainage, compost, rest facilities, washrooms, parking lots, bicycle parking lots, and gardens for the welfare of persons with disabilities because of their low relative importance (Aizaki, Endo and Yagi, 2004; Yuzawa, 2012), limited data samples, and the expected difficulty in observing significant patterns.

On the supply side, this study assumes that variables including built-up land-use percentage covered by buildings, agricultural land-use percentage, distance from train stations, and distance from the Yamanote Line are key to understanding urban development. These variables influence the percentage of agricultural land. As urbanization pressure is correlated with the cost of land acquisition and management, the percentage of agricultural land is expected to be lower in areas with a high built-up land-use percentage. The urbanization pressure is related to the distance from train stations and the Yamanote Line, as explained in the context of Tokyo's urban sprawl.

On the demand side, this study considers socio-demographic variables including population, percentages of younger and older populations, number of households, daytime population, and income. Households with children may increase their willingness to participate in AGs because of the expected educational value of the gardens (Pothukuchi, 2004; Mitarai and Matsushima, 2017). Older people may be hesitant to participate because of the physical load of working in the gardens (Park and Ciorici, 2013); however, participating in AGs can help them build an active and healthy lifestyle (Van den Berg et al., 2010). The nighttime population refers to the people living near the AG plots, whereas the daytime population refers to the number of people working or studying in the area. The amount of income may differentiate AG distribution in areas with low (Kremer and DeLiberty, 2011; Taylor and Lovell, 2012; Park and Ciorici, 2013; Castro, Samuels and Harman, 2013) and high income (Park and Ciorici, 2013; Braswell, 2018).

Data

We used the following variables to describe the urban sprawl around each AG in Tokyo (Table 1):

Among the urban development variables, we included the built-up land-use percentage, agricultural land-use percentage, distance from the nearest station, and distance from the Yamanote Line. The built-up land-use and agricultural land-use percentages were recalculated from the High-Resolution Land Use and Land Cover Map of Japan, Version 21.11 (10 m resolution grid) provided by the Japan Aerospace Exploration Agency (https://www.eorc.jaxa.jp/ALOS/jp/dataset/lulc/lulc_v2111_j.htm). The dataset was processed using images obtained via Sentinel-2, Landsat-8, and ALOS-2 from 2018 to 2020; the classification accuracy was 88.9% (https://www.eorc.jaxa.jp/ALOS/jp/dataset/lulc/lulc_v2111_j.htm). The Euclidean distance from the AGs to the nearest station or central area was calculated directly using GIS. The distance from the central area denotes the distance from the AGs to the Yamanote Line.

The socio-demographic variables included population, percentages of younger and older populations, number of households, daytime population, and worker income. The 2015 Population Census (2018) was used to gather demographic data on the population (total, male, and female populations); percentage of the young population (individuals aged up to 14 years), percentage of the older population (individuals aged 65 years and over); and number of households on a 500 m resolution grid. We utilized the Nippon Statistics Centre's data on daytime population, including the working population and students, estimated in 2015, and worker income, estimated in 2018, using a 500 m resolution grid.

Data processing

Data processing consisted of three steps. First, we prepared a simple tabulation of the properties for AG provision, including specific plot area, number of plots, contract period in months, price per unit area, instructor, agricultural equipment, and additional features, including cultivated area, total area, water supply and drainage, compost, rest facilities, washrooms, parking lots, bicycle parking lots, and gardens for the welfare of persons with disabilities. We visualized the median value for each 10 km distance band away from the Yamanote Line using GIS.

Second, we surveyed the AGs' provision of plots and facilities. Six properties were extracted from the AG list, after which each property was standardized, and a cluster analysis was conducted to provide an overview of the AG provision patterns. The properties did not follow a normal distribution; thus, we calculated the robust z-scores, which are considered robust to the outliers, using formulas (1) and (2). Instructors and agricultural equipment were dummy variables, but were also transformed into robust z-scores for cluster analysis.

$$z_i = \frac{x_i - median(x)}{NIQR} \tag{1}$$

$$NIQR = \frac{Q_3 - Q_1}{N_3 - N_1} \tag{2}$$

where the robust z-score z is obtained from property x in AG i, the median value of property x, and the interquartile ranges Q_3–Q_1 and N_3–N_1 in the normal distribution. Cluster analysis was applied in a non-hierarchical (k-means) manner using the 'scikit-learn' library in the python3 environment (Pedregosa et al., 2011). The clusters were categorized into various AG provision patterns, based on the significant characteristics of each property.

Third, we examined the relationship between the location of AGs, urban development, and the characteristics of residents using GIS. We calculated the built-up land-use percentage, agricultural land-use percentage, population density, percentages of younger and older populations, number of households, daytime population density, and average worker income, using 500 m resolution grids (target grid) and neighborhood grids (target grid + surrounding eight grids). Many datasets in Japan provide data in a 500 m grid. Citizens prefer AGs that are located closer to them (Aizaki, Endo and Yagi, 2004), within an average distance of 837 m in suburban cities (Kurita, Yamamoto and Shigeoka, 2010). Thus, the use of the target and neighborhood grids was considered potentially valuable. Of the five clusters obtained in the cluster analysis, only three clusters had sufficient samples of AGs; hence, only these were statistically analyzed using IBM SPSS Statistics 27. Non-parametric variables were verified using the Kruskal–Wallis test to determine whether significant differences existed in the aggregate values for each cluster (parametric variables are typically checked using an analysis of variance). If significant differences were evident, multiple comparisons were conducted using the Dunn–Bonferroni method to determine which combinations of clusters differed significantly (P: adjusted P-value using Bonferroni's method, $P < 0.05$).

Results

Characteristics of AGs in Tokyo

During the study period, 19,563 plots, spanning a total area of 430,266 m^2 were provisioned across 313 AGs in Tokyo; however, the number of plots and plot size in each AG varied greatly. Table 2 depicts the AG plots and facilities provisioned in Tokyo and in each 10 km distance band. Approximately 83% of the total garden area contained plots, whereas the rest of the area was used for other purposes such as pathways and facilities. The median plot area was 15 m^2 and the median number of plots was 52. The median annual contract price was 467 Japanese yen (JPY) per m^2 (1 dollar [USD] ≈ 110 JPY). The contract period was typically two years; in certain cases, however, it was only 10 months or was as long as four years. In addition, 82 AGs provided instructors and others provided welfare facilities (five AGs provided plots to persons with disabilities, and seven reserved parking lots and toilets for persons with disabilities).

Clusters of AGs

Using a non-hierarchical cluster analysis, we identified six clusters of AGs and regarded them as having distinct provision patterns: simple, hands-on, intermediate, high-class, middle-class, and large-area provision patterns. Figure 2 illustrates the difference between the range of the robust z-scores of each cluster, Table 3 provides the descriptive statistics, and Supplementary Fig. A1 shows examples of each type of AG provision.

Simple provision (69 gardens): This pattern is characterized by a long duration of contracts and cheap annual contract price per square meter. The median contract period was 34 months, and

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Table 1. Properties of allotment gardens (AGs) derived from the national list of AGs and variables of urban development derived using ArcGIS

Category	Variable	Unit	Source
Allotment garden	Plot area	m^2	National list of allotment gardens in 2020 by the Ministry of Agriculture, Forestry and Fisheries
	Number of plots	Number of plots	
	Contract period	Months	
	Price per m^2	JPY/m^2	
	Instructor	Categorical (yes/no)	
	Agricultural equipment	Categorical (yes/no)	
Urban development	Built-up percentage (%)	%	High-Resolution Land Use and Land Cover Map of Japan, Version 21.11 (10 m resolution grid) provided by the Japan Aerospace Exploration Agency (https://www.eorc.jaxa.jp/ALOS/jp/dataset/lulc/lulc_v2111_j.htm)
	Agricultural land-use percentage (%)	%	
	Distance from the nearest station (m)	m	Calculated by the authors
	Distance from the Yamanote Line (m)	m	
Characteristics of residents	Population	Number of persons	National Census of 2015
	Male	Number of persons	
	Female	Number of persons	
	Population: age 0–4 years	Number of persons	
	Population: age 65 + years	Number of persons	
	Households	Number of households	
	Daytime population	Number of persons	Daytime population estimates from 2015 by Nippon Statistics Center Co.
	Average income	JPY	Estimated worker income from 2018 by Nippon Statistics Center Co.

the median annual contract price per square meter was 375 JPY. In addition, less than one-quarter of the AG managers provided an instructor and less than one-third provided agricultural equipment. The median plot size was 15 m^2 and the median number of regular plots was 52. The managers of these types of AGs sublet the plot to the users for nearly three years and provide only a few facilities, which is the simplest approach for managing an AG.

Hands-on provision (40 gardens): This type of provision is characterized by a large plot size, short contract period, and relatively large number of facilities. The median plot size was 30 m^2, which was larger than that in all gardens, except for those of the large-area provision category. The median contract period was 11 months or less than a year. Many gardens provide instructors and agricultural equipment. In addition, the median annual contract price per square meter was 1,467 JPY, which is much higher than that under the simple and intermediate provision types. The median number of regular plots was 72, which is more than that under the simple and intermediate provision types. The AG manager prepares the facilities and recruits users every year, which indicates a hands-on approach of AG provisioning.

Intermediate provision (195 gardens): This pattern was named based on its positioning between the simple and hands-on provision types. The median contract period was 23 months, the median annual contract price per square meter was 467 JPY, and the percentage of gardens providing agricultural equipment was 59.5%, which is between the percentages of agricultural equipment provided under simple and hands-on provision. However, the median size of the plots was 15 m^2, and the median number of plots was 51, which fell below the median size and number of plots in hands-on type AGs, respectively. Finally, only a few gardens had instructors.

High-/middle-class provision (four and three gardens, respectively): AGs following these provision patterns have high annual contract prices. The median annual contract prices per square meter of the plots allocated under the high- and middle-class provision patterns were 20,387 JPY and 11,100 JPY, respectively. In addition, farm instructors and agricultural equipment were available in all gardens. However, the median plot areas (the median number of plots) for the high- and middle-class provision type were 7 and 8 m^2 (93 and 166), respectively. These characteristics indicate that the gardens were divided into smaller plots to attract more users. Regarding the contract duration, six gardens were

Table 2. Basic statistics of allotment gardens (AGs) in Tokyo ($N = 313$)

(A)	Min	Max	MD Total	0–10 km distance band ($N = 84$)	10–20 km distance band ($N = 123$)	20–30 km distance band ($N = 57$)	30–40 km distance band ($N = 45$)
Total garden area in m^2	85	28,554	1,177	1,178	1,173	1,417	1,041
Total plots area in m^2	48	15,000	981	900	940	1,210	1,006
One plot area in m^2	6	270	15	15	15	16	15
Number of plots	10	400	52	48	54	60	47
Annual contract price in JPY	0	264,000	7,000	10,800	6,600	6,600	3,300
Annual contract price per m^2 in JPY	0	26,400	467	688	467	600	220
Contract period in months	10	47	23	23	23	23	33

(B)	Installed Total	0–10 km distance band ($N = 84$)	10–20 km distance band ($N = 123$)	20–30 km distance band ($N = 57$)	30–40 km distance band ($N = 45$)
Instructor	82	7	44	19	11
Water supply and drainage	215	72	96	32	14
Agricultural equipment storage facility	172	72	78	17	3
Compost	25	4	13	7	0
Rest facility	111	29	54	27	1
Washroom	94	32	34	18	8
Parking lot	10	1	0	1	6
Bicycle parking lot	79	1	50	20	7
Gardens for the welfare of persons with disabilities	5	3	2	0	0

The table shows the median in each 10 km distance band from the Yamanote Line. Two gardens were omitted due to data uncertainties. (A) Basic information about AGs and the plots. (B) Facilities and services provided. Min, minimum; Max, maximum; MD, median.

used for one year and one was used for two years. Cluster analysis categorized several gardens into these two clusters, and we regarded them as two different AG provision patterns. However, these patterns essentially possess the same characteristics, except for the annual contract prices.

Large-area provision (two gardens): The two AGs in this category have, by far, the largest plot sizes (218 and 270 m^2); however, these gardens had only 13 and 18 plots, respectively, which indicates that a large parcel of land was devoted to one plot. One garden also had 13 plots for kleingarten. For gardens one and two, the contract periods were 36 and 12 months; the prices per square meter were 112.4 JPY and 37.0 JPY, respectively. One had an instructor; one did not have an instructor. However, both gardens were equipped with agricultural equipment.

Characteristics of the potential determinants

Figure 3 shows the geospatial characteristics of the six patterns of AG provision. Inside the area surrounded by the Yamanote Line or within a 5 km-radius outside the line, there were no AGs or instances of agricultural land use. Within a 10 km distance band from the Yamanote Line, nearly all the gardens were clustered into the intermediate provision category. Within the 10–25 km distance band from the Yamanote Line, multiple patterns were found. AGs under the simple and hands-on provision types were clustered in the north and south, respectively. Beyond a 25 km radius from the Yamanote Line, the number of AGs decreased sharply; however, there were many cases of agricultural land use, and a clear distinction was observed between areas with and without AGs. AGs located 50 km outside the Yamanote Line showed a simple provision pattern. AGs showing high- and middle-class provision patterns were dispersed in the 10–20 km distance band from the Yamanote Line.

We used the variables in Table 4 and Supplementary Table A1 to clarify the distribution of each AG provision pattern. The three provision patterns (simple, hands-on, and intermediate) exhibited sufficient sample sizes and did not follow a normal distribution. The Kruskal–Wallis test and multiple comparisons were conducted to determine whether the patterns differed significantly for each variable. In the following paragraphs, the values in parentheses are the medians.

On the supply side, we observed the following differences in the variables of each AG provision pattern. The built-up land-use percentage in the target grid showed that compared with AGs under the hands-on (84%) and simple (83%) categories, a significantly higher percentage of intermediate provision AGs (89%) were located in areas with more built-up land. AGs under the high- and middle-class provision categories also tended to be located in highly urbanized areas (90% and 78%,

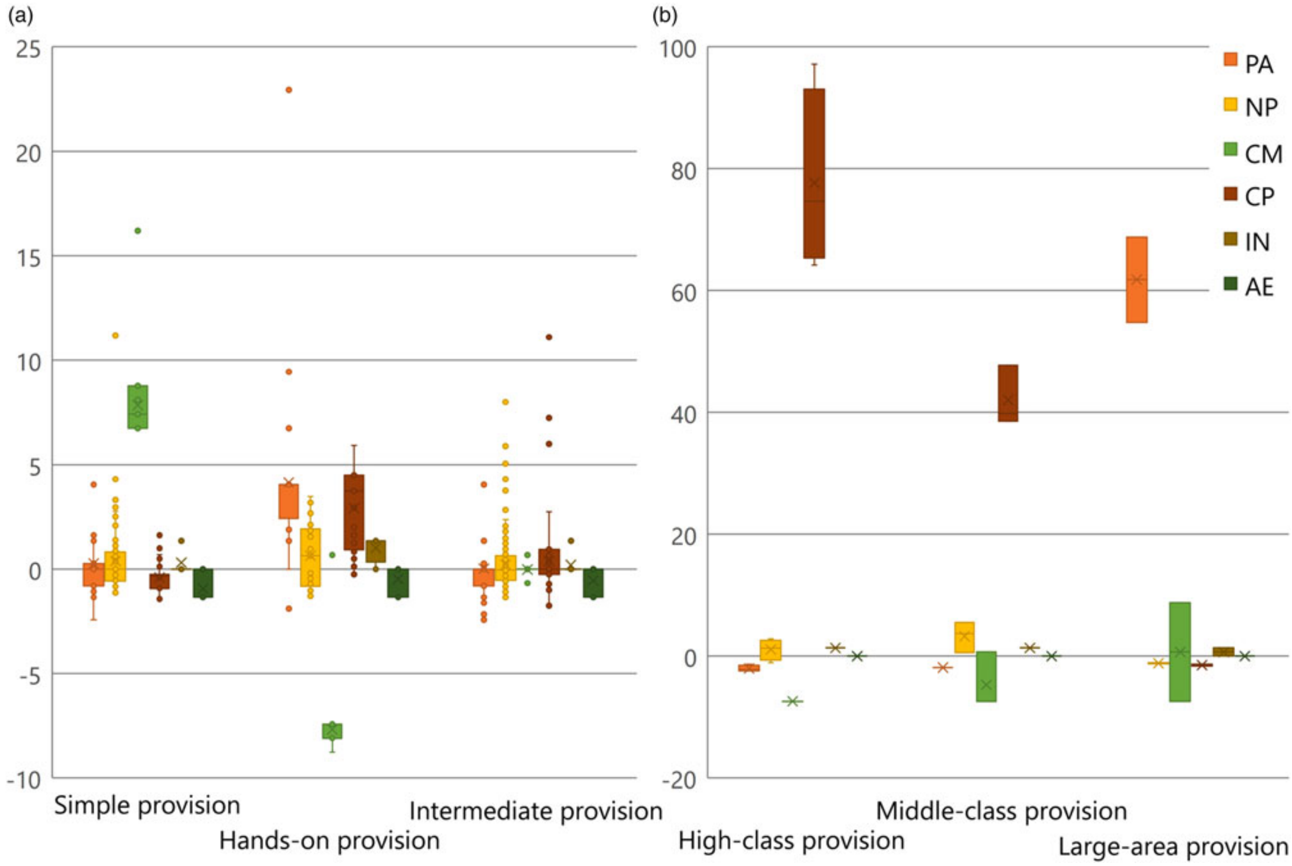

Figure 2. A box plot of the *z*-scores of properties of the provision pattern of each allotment garden (AG). Patterns are divided into (A) and (B) based on the values for visual clarity. PA, plot area; NP, number of plots; CM, contract period in months; CP, annual contract price per area (square meter); IN, instructor; AE, agricultural equipment.

Table 3. Statistics for each variable in allotment gardens (AGs)

	Simple provision (*N* = 69)	Hands-on provision (*N* = 40)	Intermediate provision (*N* = 195)	High-class provision (*N* = 4)	Middle-class provision (*N* = 3)	Large-area provision (*N* = 2)
Median of plot area in m^2 (IQR)	15 (12–16)	30 (28–30)	15 (12–15)	7 (6–8.5)	8 (8–8)	244 (231–257)
Median of number of plots (IQR)	52 (35–76)	72 (29–110)	51 (36–72)	93 (60–119)	166 (118–196)	16 (14–17)
Median of contract period in months (IQR)	34 (33–36)	11 (11–12)	23 (23–23)	12 (12–12)	12 (12–18)	24 (18–30)
Median of annual contract price per area in JPY/m^2 (IQR)	375 (220–400)	1467 (771–1,667)	467 (400–720)	20,387 (18,500–23,081)	11,100 (10,926—12,150)	75 (56–93)
Percentage of instructors provided	23	75	14	100	100	50
Percentage of agricultural equipment provided	30	65	60	100	100	100

IQR, interquartile range.

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respectively), whereas those under the large-area category were located in less urbanized areas (11%). In the neighborhood grid, the median built-up land-use percentages of most patterns were lower than those in the target grid. The agricultural land-use percentage in the target grid showed that compared with AGs under the simple (9%) and hands-on (10%) categories, a significantly lower percentage of intermediate provision AGs were located in areas with less agricultural land (5%). AGs of the high- and middle-class provision and large-area provision categories also tended to be located in areas with less agricultural land (5, 6, and 12%, respectively). A similar trend was observed in the neighborhood grids. The Kruskal–Wallis test indicated no significant difference in distance to the nearest station among AGs showing the simple (836 m), hands-on (867 m), and intermediate (790 m) provision patterns; however, those showing a high- and middle-class provision and large-area provision patterns tended to be located farther away from the stations (1,343, 1,143, and 1,833 m, respectively). An analysis of the AGs' distance to the Yamanote Line indicated that AGs of the hands-on and intermediate-provision types were closer to the Yamanote Line (14,916 and 11,082 m, respectively) than simple provision AGs (24,743 m). AGs of the high-class provision type were closer to the Yamanote Line (9,729 m) than those of the middle-class provision type (17,576 m); large-area AGs tended to be in the suburbs (47,617 m).

On the demand side, this study considered the role of various socio-demographic variables. The population of areas showing the intermediate provision pattern in the target grid was significantly higher (3,051) than those showing the simple provision (1,890) pattern. Populations of areas showing hands-on, high-, and middle-class provision patterns were 2,554, 3,105, and 3,227, respectively; areas under the large-area provision category had the lowest population (200). Further analysis of the neighborhood grid revealed significant differences between AGs of the hands-on and simple provision categories. The percentage of the young population in the target grid areas showing hands-on provision was higher (14%) than those showing simple provision (12%). The corresponding percentages for the intermediate, high-, and middle-class provision patterns were 13, 13, and 14%, respectively; that for areas showing large-area provision was the lowest (7%). For the subsequent variables (population of older adults, number of households, and daytime population), a similar trend was observed between the target and the neighborhood grids. Hence, for these variables, we describe only the trends for the target grid. The older-population percentages in areas showing the simple, hands-on, intermediate, high-class, middle-class, and large-area provision patterns were 22, 23, 22, 20, 22, and 59%, respectively. The number of households under the intermediate provision category was higher (1,374) than those under the simple (831) and hands-on (1,093) categories. Areas showing high- and middle-class provision patterns had 1,540 and 1,384 households, respectively; areas under the large-area provision category had 37 households. According to the daytime population data, AGs of the intermediate provision category were located in significantly more populated areas (1,844) than those of the simple (1,369) and hands-on (1,462) categories. Large-area provision was observed in less-populated areas with a median of 222 people within the target grid. The daytime population of areas showing the middle-class provision pattern was higher (2,134) than of those showing the high-class pattern (1,855); however, the opposite trend was observed in the neighborhood grid (daytime population under middle-class provision: 18,189; under high-class provision: 19,678). The average income of residents in the target grid areas with a simple provision pattern was significantly lower (4,034 thousand JPY) than that in areas with the hands-on (4,505 thousand JPY) and intermediate (4,431 JPY) patterns. The average median income under the high- and middle-class provision categories was higher than that in the simple and intermediate categories, at 4,436 thousand JPY and 4,848 thousand JPY, respectively. In contrast, the average income of residents under the large-area provision category was approximately 3,356 thousand JPY, lower than the estimates under other patterns. A similar trend was observed within the neighborhood grids.

Discussion

Diversity in AG provision patterns

The results illustrate the diverse provision patterns of plots and facilities in AGs and their distributions, along with the variables of the state of urban development and the residents' characteristics. The underlying implications of the six provision patterns are discussed below.

First, the results show the relationship between each type of AG provision and the state of urban development. The results showed that intermediate provision occurred in areas with a high built-up land-use percentage and a low agricultural land-use percentage. This trend can perhaps be explained by the characteristics of this pattern, in which AGs provide smaller and fewer plots in one garden, as well as few instructors; therefore, AGs in this category are too small to facilitate learning activities. Hands-on and simple provision occurred mainly in areas at a median distance of 15 and 25 km from the Yamanote Line, respectively. Compared with other patterns, these patterns were observed in areas with more agricultural land. This trend reflects the fact that the AG managers following these provision patterns tend to allocate more or larger plots. Large-area provision was observed in areas at a median distance of 48 km from the Yamanote Line and provided large plots. These results suggest that the percentage of agricultural land use may be a key determinant of AG provision. This finding is partially explained by the fact that most AGs in Japan were converted from idle agricultural land (Oba and Obase, 2001; Kudo, 2009), unlike in other countries where the gardens were converted from other types of land, including vacant spaces (Park and Ciorici, 2013; Drake and Lawson, 2014).

Second, the demand-side results showed complicated relationships between AG provision and resident characteristics. Three population-related variables—total population, number of households, and daytime population—distinguish intermediate provisions from other patterns. A larger population implies a higher demand for AGs, resulting in a smaller plot size for intermediate provision, as shown by Fletcher and Collins (2020). Most AGs have a higher number of applications compared to the number of plots (Tokyo Metropolitan Government, 2019). The percentage of young people distinguished hands-on provision from simple provision. AGs under the hands-on provision category had large plots and more instructors. This result may be explained by the fact that households with children expect an educational value from AGs (Pothukuchi, 2004; Mitarai and Matsushima,

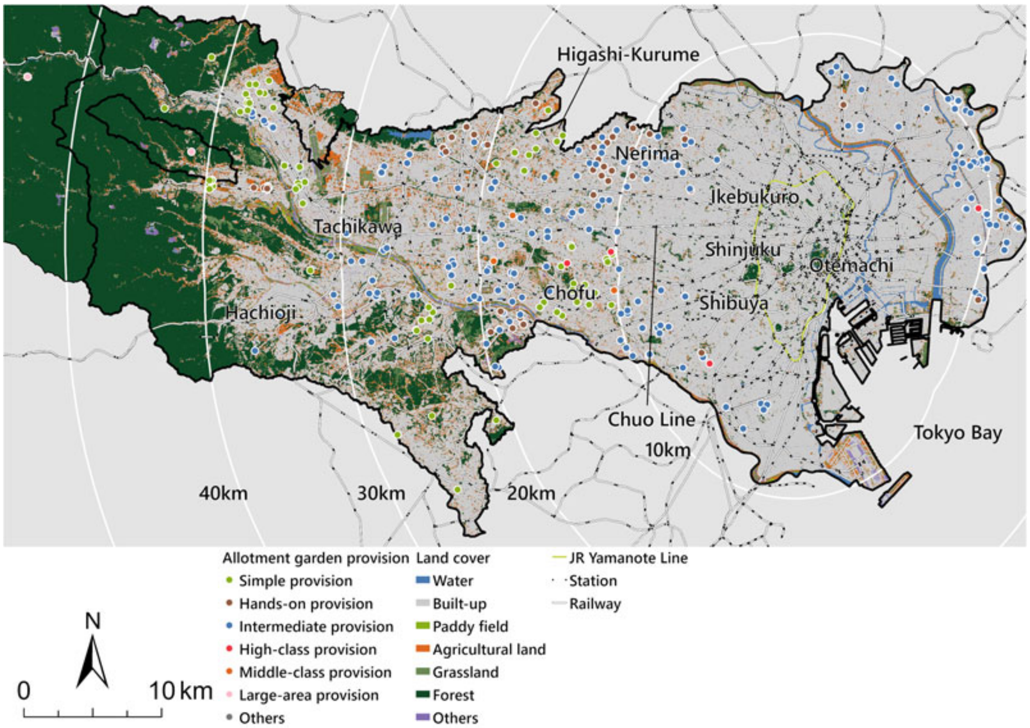

Figure 3. Distribution of allotment gardens (AGs) in Tokyo. The background map shows the land cover from the High-Resolution Land Use and Land Cover Map of Japan, Version 21.11 (10 m resolution grid) provided by the Japan Aerospace Exploration Agency (https://www.eorc.jaxa.jp/ALOS/jp/dataset/lulc/lulc_v2111_j.htm).

2017). The results showed a weak association between the percentage of the older population and AG provision patterns, although some studies have reported that older people account for many AG users in Japan (Higuchi, 1999; Yuzawa, 2012), possibly because of AGs' health benefits (Van den Berg et al., 2010). The residents' income level distinguishes simple provision from other patterns. This finding is probably related to the fact that under simple provision, plots are provided at cheaper rates. Notably, AGs in the high- and middle-class provision categories were located closer to the city center. Although their annual contract prices are too high for many people, they provide high-income households with an opportunity to easily engage in agricultural activities.

In summary, the supply-side variables, including the percentage of agricultural land use, and the demand-side variables, including the population, young population percentage, and income, significantly determine the provision of AG plots and facilities in Tokyo.

Geospatial contexts underlying AG provision

Some variables of the state of urbanization and the residents' characteristics changed depending on the distance from the city center to the suburbs (Table 2). For instance, no AGs were located inside the CBD, and each distance band (i.e., 5–10, 10–25, and 25–50 km) exhibited a different AG provision pattern. This gradation was possibly enabled by the uniqueness of the wide range of built-up areas, a mixed urban–rural land use pattern, and the city's development history. As discussed in section 'Development of urban sprawl and the urban–rural mixture in Tokyo', Tokyo has a wide range of built-up areas, similar to those in Chicago and Los Angeles and different from those in European cities (Angel et al., 2016; Liu et al., 2022). This diversity in built-up areas has enabled agricultural land to survive in areas with a mixed urban–rural land-use pattern (Yokohari et al., 2000) during Tokyo's rapid urbanization (Bagan and Yamagata, 2012) and re-urbanization (Ushijima, 2012; Kanda, Isoda and Nakaya, 2020). These developments have resulted in the gradual spread of urbanization outward from the city center (i.e., urban sprawl in Tokyo).

The Kruskal–Wallis test did not reveal any significant difference within neighborhood-scale urbanization, that is, from the stations to the hinterlands. Seemingly, AGs are widely dispersed in areas outside the Yamanote Line, regardless of the distance from the line. AG managers may not consider accessibility to the stations as important, because many people visit gardens by walking, riding a bicycle, or riding a car during holidays (Amemiya et al., 2017). A recent study in Japan focused on access to agricultural lands on foot (Iida et al., 2023). However, the decrease in population or built-up land-use percentage (Fig. 1) of areas containing AGs was possibly related to the spread of simple provisions in the hinterlands at a 14–18 km distance from the Yamanote Line. This aspect was not observed in the overall study area but is a local characteristic for profiling certain AGs.

In addition, the distribution map (Fig. 3) shows collective trends observed in the three most popular AG provision patterns: simple, hands-on, and intermediate provisions. The AGs along the Chuo Line mostly showed intermediate provision, whereas those away from the Chuo Line were divided into the simple and hands-on provision types. By scrutinizing the administrative divisions, we noted that these patterns were partially defined by city boundaries. In the hinterlands at a distance of 14–18 km from the Yamanote Line, the simple provision type was mainly observed, especially in the Chofu and Higashi-Kurume cities.

Table 4. Descriptive statistics of each variable of allotment garden (AG) provision: median (IQR); Kruskal–Wallis test: TS and *P*-value; multiple comparisons in target grid

	Descriptive statistics						Kruskal–Wallis test		Multiple comparison		
	(1) Simple provision (*N* = 69)	(2) Hands-on provision (*N* = 40)	(3) Intermediate provision (*N* = 195)	(4) High-class provision (*N* = 4)	(5) Middle-class provision (*N* = 3)	(6) Large-area provision (*N* = 2)	TS	p-value	(1)–(2)	(1)–(3)	(2)–(3)
Population	1,890 (1,157–2,765)	2,554 (1,545–3,394)	3,051 (2,269–3,982)	3,105 (2,884–3,425)	3,227 (2,881–3,304)	200 (151–248)	40	<0.001*	0.063	<0.001*	0.053
Male	961 (589–1,386)	1,297 (777–1,664)	1,537 (1,171–1,952)	1,564 (1,444–1,675)	1,448 (1,377–1,542)	90 (70–110)	40	<0.001*	0.067	<0.001*	0.049*
Female	961 (573–1,380)	1,281 (769–1,701)	1,555 (1,097–2,023)	1,542 (1,427–1,763)	1,592 (1,410–1,763)	110 (81–138)	39	<0.001*	0.060	<0.001*	0.065
Young-population percentage (ages 0 – 14 years)	12 (10–15)	14 (12–16)	13 (11–15)	13 (11–13)	14 (11–15)	7 (4–10)	7	0.031*	0.027*	0.269	0.319
Older-population percentage (ages 65 years and above)	22 (19–28)	23 (20–25)	22 (19–25)	20 (20–22)	22 (21–22)	59 (48–70)	1	0.572			
Households	831 (461–1,252)	1,093 (660–1,395)	1,374 (1,023–1,775)	1,540 (1,199–1,891)	1,384 (1,327–1,636)	37 (35–39)	35	<0.001*	0.297	<0.001*	0.020*
Daytime population	1,369 (724–1,912)	1,462 (963–1,987)	1,844 (1,355–2,454)	1,855 (1,402–2,443)	2,134 (1,761–2,771)	222 (144–299)	28	<0.001*	1.000	<0.001*	0.005*
Average income (10^3 yen)	4,034 (3,601–4,473)	4,505 (4,023–4,674)	4,431 (3,954–4,735)	4,436 (4,031–5,774)	4,848 (4,696–4,919)	3,356 (3,347–3,364)	18	<0.001*	0.007*	<0.001*	1.000
Built-up percentage (%)	83 (60–87)	84 (69–89)	89 (80–94)	90 (84–95)	78 (77–83)	11 (9–12)	31	<0.001*	0.729	<0.001*	0.011*
Agricultural land-use percentage (%)	9 (7–17)	10 (7–19)	5 (3–10)	5 (3–7)	6 (5–8)	12 (11–14)	46	<0.001*	1.000	<0.001*	<0.001*
Distance from the nearest station (m)	836 (608–1,375)	867 (513–1,110)	790 (510–1,120)	1,343 (802–1,979)	1,143 (648–1,262)	1,833 (1,539–2,127)	2	0.300			
Distance from the Yamanote Line (m)	24,743 (15,537–37,710)	14,916 (11,030–21,647)	11,082 (8,775–19,741)	9,729 (8,055–11,212)	17,576 (13,937–18,257)	47,617 (44,454–50,780)	60	<0.001*	<0.001*	<0.001*	0.226

IQR, interquartile range; TS, test statistics. Asterisks indicate significant differences (*$P < 0.05$). The results for the neighborhood grid are presented in Supplementary Table A1.

However, the hands-on and intermediate provision patterns were observed in Nerima City, based on the degree of urbanization. This finding reflects the fact that 84% of AGs are owned by municipalities. The zoning system under the City Planning Act was determined by the municipalities (Zheng et al., 2022). Therefore, municipal boundaries are potential determinants of AG provision; however, a municipality-level analysis is beyond the scope of this study, which focuses on residents' access to AGs.

Challenges and opportunities for AG provision

Our study aimed to identify the patterns and the demand- and supply-side characteristics of AG provision to support local governments, farmers, and NPOs in addressing the challenges arising out of specific provision patterns. In areas with intermediate provision, urgent political action is required to sustain urban agricultural land use and meet the emerging demand for AGs. However, for Japanese cities entering the re-urbanization phase, more agricultural land may be available in less populated areas owing to urban shrinkage in the near future. For example, in a related context, Leipzig in Germany has been hosting AGs to cope with vacant areas in urban shrinkage (Cabral et al., 2017). This upcoming trend could not only provide municipalities that manage most of the AGs with a chance to find new AGs and to provide larger and more plots in one garden of intermediate provision, but also provide private companies and NPOs with valuable investment opportunities. In areas with a high average income, private companies and NPOs can grow their business by managing the AGs under the high- and middle-class provision categories. In fact, Kamo and Yamada (2020) found that such businesses are continuing to expand in Tokyo. Such forms of interim usage in shrinkage cities could improve the social and environmental value of urban settings (Rall and Haase, 2011). The potential transformation of AGs from hands-on provision to intermediate and high- or middle-class provisions can probably be observed in response to changes in the supply- and demand-side characteristics within the 10–25 km distance band from the Yamanote Line. If the population and corresponding demand increase in areas with a hands-on provision, municipalities may subdivide plots into smaller plots, as observed in the intermediate provision pattern, so that public services can maintain their equity. However, this may reduce the chances of benefiting from advantages such as easy access for households with children to AGs of the hands-on provision type. In summary, the relationship between AG provision and the influence of urban sprawl in Tokyo's metropolitan area draws our attention to the necessity to increase the number of plots available while responding to urban shrinkage, to take advantage of business opportunities in areas with a high average income, and to control possible excessive subdivision and price hikes under urbanization through policy.

Additional research is required to further observe the differences in the objectives and behaviors of actual and potential users. Structured interviews and questionnaires would be more practical for investigation and will be the subject of future research. In particular, identifying changes in the supply of and demand for AGs during the COVID-19 pandemic and considering the possible responses to the changes in urban planning could be meaningful. An increase in people's motivation to grow one's own vegetables has attracted attention during the pandemic, leading to discussions of the lifestyle supported by AGs as part of the new normal (Music et al., 2021). Iida et al. (2023) found that farming in AGs improved gardeners' health and subjective well-being in Tokyo. Regardless of the end of the pandemic, urban planning must become more sensitive to societal changes to adapt to an uncertain future.

Conclusion

This study classified AGs in Tokyo based on the provision patterns of plots and facilities and examined the relationship between the geographical distribution of each AG provision pattern and urban sprawl. Our analysis yielded six AG provision patterns: simple, hands-on, intermediate, high-class, middle-class, and large-area provisions, based on the number and size of the plots, annual contract price and duration, and provision of instructors and facilities. Furthermore, we described the following determinants of AG provision: (1) the percentage of agricultural land; and (2) the characteristics of residents, including the population, percentage of the young population, and income. The Japanese context of urban sprawl alongside the scale, the mixed urban–rural land use, and rapid urbanization and re-urbanization influenced these determinants, resulting in a unique distribution of AGs and showing a basic gradation from the city center to the suburbs. Awareness of the characteristics of different AG provision types and their underlying contexts can encourage AG landowners, managers, and local government policymakers to design garden plots and facilities while responding to upcoming urban shrinkage, business opportunities, and possible excessive subdivision and price hikes.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S1742170523000376.

Data availability statement. The data are available from MAFF (https://www.maff.go.jp/j/nousin/kouryu/tosi_nougyo/index.html), the Japan Aerospace Exploration Agency (https://www.eorc.jaxa.jp/ALOS/jp/dataset/lulc/lulc_v2111_j.htm), the National Census (https://www.e-stat.go.jp/gis/statmap-search?type=1), and Nippon Statistics Center Co. (https://www.nihon-toukei.co.jp/simulation_mesh/).

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Competing interest. None.

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