Exploring the spatial planning dimensions of urban informal food systems in Nanjing, China

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Abstract

Modern food systems have achieved great success in efficiency and productivity. Long food chains with many food miles and nodes emphasize food processing, packaging, and marketing. These activities have threatened the sustainability of food systems. Many countries have carried out various urban agriculture activities to respond to challenges such as food security issues and climate change. However, small-scale farming and local food vending that support the lower socioeconomic population groups in China are ignored by legislation and urban planning. This study aims to improve informal food systems by involving informal food production and marketing in spatial planning. In this paper, informal food systems, which refer to the combination of food chains that contain informal activities, are identified based on the Chinese social background. The spatial typologies of production, marketing, and consumption in informal food systems are summarized. Typomorphology is applied to analyze the typology evolution of spaces for informal food systems in the Qinhua District in Nanjing. The results show that the morphological regions for food production changed more than construction land in 58 superblocks from 2005 to 2019. Agricultural land decreased, and the most common types of change were from fragmented agricultural land (Type P2) to fragmented and temporary arable land (Type P3) to construction land with isolated vegetable plots (Type P4). In this evolution process, the informal food system reflects the deviation between diversified needs in cities and urban planning. A bottom-up structure is necessary to protect vulnerable groups, especially those involved in small-scale urban food production.

1 | INTRODUCTION

Food systems consist of a series of activities from production to consumption. Informal food systems refer to the combination of food chains that contain informal activities. These activities exist in different parts of the food chain such as informal food production and informal food marketing. In recent years, the crisis of China’s food systems has gradually emerged, which lies in the contradiction between urban expansion and agricultural land use. Urban construction land increases at the expense of agricultural land. From 2010 to 2018, the government expropriated 1,794.71 km² of land from farmers each year (National Bureau of Statistics of China, 2018). The rapid land transformation resulted in some property developers not utilizing the land resources, which they
received from the government, rationally and on time. Some of these lands were redistributed or abandoned during construction. At present, there are ~16,187 km² of idle land in China, accounting for 5.8% of the existing urban construction land (Qu et al., 2020). This means not only less formal arable land but also more dispossessed farmers needing to find jobs in cities. However, many cities are unable to create enough formal employment opportunities. Therefore, some migrant workers and the urban poor rely on informal food production on abandoned land and informal food vending for survival.

It is a common phenomenon that food systems involve the informal sector in developing countries (Argenti et al., 2005). The primary driving force behind this phenomenon is rapid urbanization, which combines with a gradual shift of poverty from rural to urban areas (Ravallion, 2002). Although all countries appear to be making efforts toward a more sustainable direction, the characteristics of food systems in different social contexts can vary widely. Small-scale urban food production and traditional food markets are attractive for low socioeconomic population groups in developing countries (Food & Agriculture Organization of the United Nations, 2004). Low-skilled rural migrants exist in all Asian countries, and most of them are engaged in the informal sector, especially in countries like Bangladesh, Cambodia, and Vietnam, which do not have a strong industrial base (Bhowmik, 2005). Compared with livestock farm holders, vegetable producers in urban and peri-urban areas tend to have low- or middle-income status in some rapidly growing countries such as India and Nepal (Padgham et al., 2015). A study on informal food bazaars in urban Hanoi showed that customers prefer to visit these informal markets rather than formal ones because they are more concerned about price and convenience (Maruyama & Le Trung, 2010). In cities in southern Africa, small farmer production and informal food marketing play a significant role in employment generation for the urban poor and food accessibility for urban households (Crush & Frayne, 2011). Although informal urban agriculture initiatives contribute to alleviating poverty and food insecurity, there are still many challenges. Poor quality of available water supplies, soil quality, availability of farming tools, and community self-organization are barriers to scaling up informal food production activities (Bisaga et al., 2019).

Identification of informal food systems contributes to distinguishing different issues of the formal sector from the informal sector. It helps to integrate temporary or segmented agri-food activities into a systematic structure. Informal food systems, which are spontaneous activities based on social, cultural, and economic development, play a significant role in the urban space. Though it has its benefits, it is difficult to define the informality of food systems. Previous research has not differentiated formal food systems from informal ones in the spatial planning dimension. This paper aims to improve informal food systems by considering informal food production and marketing in urban space systems.

Typomorphology is the method used to analyze urban spatial changes and the development process. It combines the typological concept of the Italian School of Saverio Muratori and the urban morphological theory of the British Connellan School (Chen, 2008). The relationship between informal food systems and urban space systems is interactive and dynamic. The framework of typomorphology contributes to proposing suggestions for spatial planning by analyzing the urban space typological process. Based on the social background of China, this research applies the typomorphology method to study the coupling of informal food systems and urban space systems. The following questions were answered: (a) What are the components and characteristics of urban informal food systems? (b) What are the spatial typologies of urban informal food systems? (c) How can we analyze the typology evolution of urban spaces for informal food systems through typomorphology? and (d) How can we improve informal food systems and propose suggestions for urban spatial planning?

## 2 IDENTIFICATION OF INFORMAL FOOD SYSTEMS

The informal sector plays a significant role in income generation and social development in low-income countries. It is made up of informal production units or informal sector enterprises (typically small and nonregistered enterprises) including informal agricultural production units (The United Nations Task Team on Habitat III, 2016). The sector has three primary characteristics: (a) The main aim of the units engaged in production and services is to generate employment opportunities and incomes; (b) household enterprises are considered the main features of production units in the informal sector; and (c) informal sector activities are different from the illegal or underground economy, and they do not deliberately intend to evade tax payment or social security contributions (International Labour Organization, 1993). The concept of the informal sector is enterprise based, while informal employment is job based. People are considered to have informal
jobs if the employment relationship does not accord with the national labor legislation, income taxation, and social protection (International Labour Organization, 2003). There are several situations such as lack of contract or informal contract, casual jobs, short-duration jobs, wages below the minimum standard, and employees in the household.

Food systems consist of production, processing, marketing, consumption, recycling, and various transformations of food. As they are complicated, formal and informal activities get entangled in food chains. Materializations of food systems into space can be described according to each stage such as food production in agricultural land, food marketing in open-air markets, and consumption in domestic settings (Salvador, 2019). Waste management takes an essential role in closing the nutrient cycles, which could operate in a decentralized framework including domestic and community composting, agro-composting in peri-urban farms, and distributed plants for composting (Simon-Rojo & Duží, 2018). However, it is still a very immature system in China since the mandatory waste classification in urban communities, led by Shanghai, began in 2019. Waste management cannot distinguish informal food systems from formal food systems in China, so it is not included in this research. Informal sectors in production and marketing decide the components of informal food systems in China. Consumers’ preferences and food accessibility are also crucial factors. Therefore, this study emphasizes activities in production, marketing, and consumption in informal food systems.

2.1 Production

The legality of land use depends on its property and ownership in China, so informal food production refers to farming on nonagricultural land. There are three types of land when it comes to land management: agricultural, development, and unused (Ministry of Justice of the People’s Republic of China, 2019b). Food production in built-up areas without permission is a type of informal activity. The unique rural industrialization process in China has resulted in a landscape where new residential compounds, abandoned farmland, and scattered industrial areas are mixed in dense urban areas (Verdini et al., 2016). Therefore, agricultural activities in nonagricultural land provide employment opportunities for dispossessed farmers, migrants, and low-income urban residents. Urban food cultivation in informal food systems aims at not only own consumption but also income generation.

Peasants produce food legally on their farmland. In China’s land tenure system, the rural collective has ownership of agricultural land, and local leaders allocate the collectively controlled land to peasants who hold the rural household registration. Urban residents who hold the urban household registration cannot be allocated farmland. They can engage in agricultural production only by renting land from peasants or a rural collective (Han, 2017). Rapid urban growth has attracted a significant number of rural dwellers (Bisaga et al., 2019). This social phenomenon has led to an increase in large-scale farms and fragmentation among marginalized small-scale urban agricultural producers. Farmland is allocated according to households; therefore, young people as the primary labor force in rural areas move to cities, the elderly who stay in the countryside can only cultivate a small part of the land, and the remaining land is leased to the contractor. At present, ~80% of young people from peasant families live in cities, and their parents stay at home to earn income from farming (He, 2013). In peri-urban areas, small-scale vegetable plots are abundant. These producers directly sell food as itinerant vendors or in open-air markets.

2.2 Marketing

Small-scale farmers and the urban informal food producers make a living through vegetable farming and directly sell their food in open-air or wet markets. Itinerant food and market vendors are informal employment groups because of their self-employed characteristics. Street vending is considered an unstandardized, unregulated, and disorderly form; it is a stopgap measure for dealing with urban unemployment (Hanser, 2016). In China, 36% of women and 30% of men in the labor force have informal jobs (The United Nations Task Team on Habitat III, 2016).

The requirements and necessity of food vendor licenses vary according to the region, and the regulation of public space for vendors is generally vague. Urban space under the aim of urban development is organized to maximize social production, so street vendors are absent in modern space planning (Cross & Morales, 2013). Some cities allow unregistered vendors to sell their food in specific areas and during certain times. In contrast, some local authorities tend to move vendors out of the streets because they block traffic, disrupt pedestrians, and compete unfairly with retail outlets. Although supermarkets and hypermarkets are becoming increasingly popular in modern cities, traditional food marketing channels, including private fruit and vegetable shops, street vendors, and wet markets, still occupy market shares of over 80% (Zhang & Pan, 2013). Supermarkets are popular for processed and packaged food, but consumers tend to purchase fresh produce from vendors in open-air markets or wet markets daily (Si et al., 2016).

2.3 Consumption

Urban residents are target customers for street vendors, and residential areas have primarily influenced the spatial
distribution of food markets. In low-income communities, food vendors provide fresh and affordable agri-food for households, and this helps mitigate the impact of healthy food disparities (Larsen & Gilliland, 2009). Usually, tools from vendors are very simple such as carrying poles, bicycles, and tricycles. These tools make them easy to move, but they can only carry a small amount of agri-food. Fresh food vendors often gather in open residential areas to get more passenger flow. This informal food market can not only improve the food accessibility for residents but also strengthen the connection between food producers and consumers. The elderly are their regular visitors. Aging parents reside with their married children has been a prevalent living arrangement in China because the fast-paced lifestyle prevents the young couple from working and taking care of their families simultaneously (Shen et al., 2016). The older people are now responsible for grandchild care and food preparation to reduce a young couple’s pressure. Vendors do not need to find opportunities from restaurants and other institutes because of sufficient individual customers in residential areas.

Public space in gated residential compounds is inaccessible for itinerant vendors and open-air markets. These communities are equipped with wet markets where vendors can rent a food stand for retailing. In some traditional wet markets, itinerant vendors can only pay the management fee to access the inside open space or public space around the market. They do not have a fixed pitch license, and they need to pay it daily. Therefore, communities have different forms of food vending. According to a survey from the Hungry Cities Partnership in Nanjing, 23.6% of households purchase food from street vendors and 15.8% visit them 5 d a week. A total of 92.6% of households visit wet markets for food, and 75.2% visit at least 5 d a week (Si et al., 2016). Wet markets are responsible for urban residents’ food supply, whether they are run by a private company, state-owned enterprises, or governmental agencies. As the supporting facility of residential areas, the wet market should be no less than 1,000 m² for every 50,000 m² of newly constructed neighborhood residences (Nanjing Government, 2003).

3 | MATERIALS AND METHODS: A FRAMEWORK FOR TYPOMORPHOLOGY ANALYSIS

Typomorphology is a critical tool for analyzing and understanding the evolution of urban forms. It emphasizes the typological contribution to the morphological analysis of urban fabric (Gurer, 2012). The Italian school of Saverio Muratori first put forward the typological theory and linked it to urban morphology, and the French school contributed to the evolution of the urban fabric and the organization of the plot’s structure (Leite & Justo, 2017). Typomorphology combines these two essential and complementary studies to understand the evolution process of urban form by analyzing the built landscape with location, time, and scale (Chen & Thwaites, 2013). This indicates that history and human spontaneity are essential to the development of architecture and urban forms. The city is an organism, and the spatial type generated in each specific period and region represents the local social, technological, economic, and cultural requirements at that time. For example, some morphological types that have remained unchanged after a long period of social development can adapt well to social change. Some types are easily affected by social change. Some returned to the original type after evolving into other types, which means that they lost their function in a certain period but are now needed again. Comparing spatial types in a region in different periods can reveal the evolution direction of the urban form. This method can analyze how informal food systems can adapt to urban spatial changes. It includes the following steps for analyzing the spatial types of informal food systems (Figure 1): (a) the study area is selected to ensure that it can contain all sectors and types of informal food systems; (b) the morphological regions are divided based on the features of urban spatial organization and informal food systems; (c) morphological development is divided into different periods by analyzing historical factors that can cause significant morphological changes: and (d) the types and land use in each morphological region and each period are refined and summarized to determine how morphology develops in consecutive time phases. Whether the final type could adapt to the current spatial structure can be analyzed by judging whether the spatial form and land-use types are continuous. Finally, based on the above morphological analysis, this framework provides suggestions for improving the current informal food system in the spatial planning dimension.

3.1 | The study area and map data

To figure out the typology process of informal food systems, Nanjing was chosen for the case study. It is a second-tier city and the capital of Jiangsu Province, China. According to statistics, at the end of 2019, Nanjing had a permanent population of 8.5 million, including 7.1 million as registered. The area is 6,587.02 km² (Nanjing Government, 2019c). Four administrative levels make up Nanjing: municipal, district, subdistrict, and neighborhood. There are 11 districts, 100 subdistricts, and townships (Nanjing Government, 2019a).

The collection of Nanjing urban spatial data combines field research and literature. The field survey aims to study the typologies of current urban informal food systems in Nanjing and select the district suitable for urban typology process analysis. The field survey in Nanjing was conducted in August and September 2019. To identify and document informal food chains, the interviews started with the street vendors who were
-selling vegetables in central areas of Nanjing, and then production sites were traced by following food supply chains. At this stage, interviews refer to simple contact that aims at finding suitable production sites. Many vendors refused to tell their production locations because of their informality. But the interviews were easier to conduct with some vendors who were nearby villagers with legal arable land. Street morning market (open-air market along the street with the opening time from 6 a.m. to 8 a.m.) in Xiaolingwei and itinerate vendors in the Old Town South and Maqun are involved in this article. Six vendors were eventually selected and traced to production sites, including Banqiao, Guli, Qilin, Maqun, Shiziba, and Huadian, and the last three were informal food production (Zhao, 2020). Face-to-face semistructured interviews were conducted with ∼60 consumers to record their residential areas and their preference toward space for food vending. The consumers of the street morning market in Xiaolingwei were contacted on site. Eighty percent of respondents are women. Most people are middle-aged and elderly, and 60% of customers are over 50 yr old. It shows that 40% of consumers visit vendors for fresh vegetables every day. The morning market only operates 2 h a day in the morning, and customers are usually retired older people who stay at home to prepare food for grandchildren and the young couple. The interview results show that these consumers who visit the morning market all live in the Xiaolingwei subdistrict, which means they are reluctant to travel a long distance to vendors in other residential areas.

The literature mainly focuses on the historical development of its urban space. Nanjing statistical yearbooks provide data on construction land, agricultural land, and urban green land (Nanjing Municipal Bureau Statistics, 2005, 2013, 2019), and the Land Expropriation Plan Announcement shows the information about the land that is being converted from agricultural land and rural construction land to other uses (Nanjing Municipal Bureau of Planning & Natural Resources, 2021). After the field research for typologies of informal food systems, Qinhuai District was selected to analyze spatial evolution; it is divided into 58 superblocks according to the distribution of main roads (Figure 2). Its land has various types of uses, and its spatial morphology has changed significantly in the past 20 yr under the influence of urbanization. Qinhuai District is southeast of Nanjing’s central city. It is one of the four main urban areas of Nanjing (49.11 km²). The registered population in the area is 716,200, and the permanent population is 1.032 million. There are 106 communities and six administrative villages (Government of Qinhuai District, Nanjing, 2020). This article summarizes
the typological process of Qinhuai District from three periods, which is combined with map observation. The map information was derived from Google Earth Pro.

3.2 Typologies of informal food systems

The spatial distribution of informal food systems comes with a pattern that is influenced by urban growth. The characteristics of production, marketing, and consumption differentiate formal food systems from informal ones. These three sectors correspond to agricultural land, urban public space, and residential areas. The spatial patterns of current cities are characterized by high densities and small public space; high competition for land pose a threat to space for food (Roggema, 2017). Many plots of agricultural land face the challenge of being transferred to the construction segment. Increasing urbanization is the main reason informal food systems primarily exist in China. With the progress of land transformation, food production goes through different phases: (a) Continuous large-scale farmland is owned by farmers; (b) land use changes in suburban areas result in fragmented farmland; (c) the local government has already expropriated some arable land, but it remains undeveloped; (d) some green and construction land in built-up areas is abandoned, and urban residents have cultivated vegetables. These different phases or types of land indicate different groups of stakeholders and location of urban spaces. Figures 3, 4, and 5 show the spatial typologies of production, marketing, and consumption in informal food systems.

Street vendors have long been marginalized and are considered a social problem because of their occupation of public space (Cross, 2007). Itinerant vendors do not have a fixed position in public space, and they tend to choose space with a high concentration of their target consumers (Gao & Zhong, 2015). Nanjing has not incorporated food vendors into urban planning, and many public squares prohibit food vending, so planar-shaped space for open-air food markets are not common. In comparison, there are many linear-shaped spaces for vendors, such as the sidewalk (Zhang & Pan, 2013). Besides, some itinerant vendors sell agri-food around the traditional wet markets, and some choose to pay for the wet markets to get the internal space. Consumers in the informal food system are urban residents, and food markets are in the vicinity of residential areas. There are many gated residential quarters in China, and it is not easy for residents to have access to food vendors. In contrast, open residential quarters could provide more public spaces for food vending.

3.3 Time phases and morphological region

Economic development and social changes have led to the transformation of the urban form in China, which has discontinued the traditional urban spatial organization (Chen & Thwaites, 2013). In nearly 20 yr, rapid urbanization has caused an enclave sprawl of urban and farmland fragmentation (Long et al., 2018). The urban built-up area increased by 78.5% from 2003 to 2013. This article aims to explore how urban space has changed in recent years. Three periods were selected: 2005, 2013, and 2019 (Figure 6). In the process of urban development, informal food systems adapted to changes in the space form. From 2005 to 2019, both construction and production land underwent a process of mutual
### FIGURE 3  Typologies of food production in informal food systems

| Small-scale farms | Vegetable plots |
|-------------------|-----------------|
| 1. Farming in contiguous agricultural land | 3. Temporary gardening |
| 2. Farming in fragmented agricultural land | 4. Abandoned land gardening |

| Location of production land | Rural areas and peri-urban areas | Peri-urban areas | Urban areas | Urban areas |
|-----------------------------|----------------------------------|------------------|-------------|-------------|
| Producer                    | Farmers                          | Farmers          | Dispossessed farmers, migrants, and low-income urban residents | Dispossessed farmers, migrants, and low-income urban residents |

| Typologies of food production (green area) | P1 | P2 | P3 | P4 |
|-------------------------------------------|----|----|----|----|
| ![Image of Typologies of food production (green area)](image1) |

| Features                                                                 |
|--------------------------------------------------------------------------|
| Large-scale agriculture base, small farms, and villages                  |
| Fragmented agricultural land, villages, and urban residential quarters   |
| Fragmented and temporary arable land; new urban residential quarters     |
| Isolated vegetable plots inside urban residential areas or other abandoned land |

### FIGURE 4  Typologies of food marketing in informal food systems

| Outlets: food mainly flow to | Open-air market / itinerant vendors in streets/ itinerant vendors in wet markets |
|-----------------------------|---------------------------------------------------------------------------------|
| Typologies of food marketing (red area) | M1 | M2 | M3 | M4 |
| ![Image of Typologies of food marketing (red area)](image2) |

| Features                                                                 |
|--------------------------------------------------------------------------|
| Itinerant vendors; Scattered spots; no fixed position and no fixed time  |
| Open-air markets; planar-shaped spaces; vendors sell along with the street; fixed time and fixed position |
| Open-air markets along with the street; linear-shaped spaces; fixed time and fixed position |
| Wet markets with itinerant vendors; Ancillary space; no fixed position and no fixed time |


transformation. Therefore, this period can reflect the changes in space for informal food systems in the process of rapid urbanization. The morphological region refers to a specific area with a homogeneous plane, building, and land-use types. In an individual district, morphological regions can be considered superblocks. These are involved in multiple functions including production, marketing, and consumption. This study extracts 58 superblocks in Qinhuai District in Nanjing for analyzing the spatial and land-use types according to the main roads’ distribution.

| Consumers | Urban residents |
|-----------|-----------------|
| Typologies of food consumption (white and grey areas) | C1 | C2 | C3 | C4 |
| Residential areas in the vicinity of production sites; high accessibility for food cultivation | Open residential areas, easily accessible roads, and public spaces; high accessibility for vendors | Open residential areas and gated residential compounds; relatively high accessibility for vendors | Gated residential compounds; public spaces inside the community; low accessibility for vendors |

4 | RESULTS

This article adopts an analytical framework for the evolution of the Chinese urban form. It focuses on transforming the typology process into design guidance by analyzing how the spatial form and types change (Chen, 2010). By refining and summarizing the types of each morphological region, this article identifies the morphological evolution process from 2005 to 2019 including food production and food consumption.

4.1 | Typological process

The typological process describes how urban space changes in a certain period to meet people’s needs. According to different land uses in informal food systems, three types of space are marked by colors and patterns in Figure 7 and Figure 8, containing open blocks, gated residential communities, and spaces for food production. Other spaces that are colored in white are not distinguished, including waters and low mountains. The marketing sector is not considered in the
typological process because the space use of food vendors is generally informal or illegal, which is difficult to track.

In this article, spaces for food production refer to agricultural land and urban leftover space that do not include urban green space systems such as green belts, parks, and public flower ponds. Qinhuai District is very close to central urban areas where large-scale farms do not exist. Therefore, small farmers and informal food producers are all involved in informal food systems. In the process of land transformation, there remains some idle land, expropriated agricultural land, and abandoned construction land that could be cultivated by urban residents. Since informal production spaces are a challenge to trace and confirm, the production sites are meant to be interpreted as leftover space or idle land that are available for food production.

In contrast, urban open blocks and gated residential areas are easier to identify. After analyzing the maps for three periods, 58 superblocks were divided into two parts. The spatial form and land-use type of 30 superblocks did not change from 2005 to 2019 (Figure 7). Figure 8 shows that the space-use types of 28 superblocks have changed during this period, and some of the changes have been changing back and forth.

### 4.2 Suggestions for morphological regions

Figure 9 shows that food production contains 25 morphological regions, of which, four regions’ type remained unchanged from 2005 to 2019, including P1 (contiguous agricultural land) and P2 (fragmented agricultural land), while the other morphological regions have changed. Contiguous agricultural lands in three superblocks were still cultivating food. Spatial types of fragmented agricultural land in 20 superblocks have changed. The most common types of changes are from fragmented agricultural land (P2) to fragmented and temporary arable land (P3) to construction land with isolated vegetable plots (P4); this includes nine morphological regions. It follows the urbanization process in which urban villages with fragmented agricultural land are easily transformed from the urban periphery to central locations (Kochan, 2015). Six morphological regions’ types changed from 2005 to 2013. Then they have remained unchanged from 2013 until now. Although many agricultural lands are being converted to construction lands, six superblocks have added abandoned land for food production from 2005 to 2019. More morphological regions with construction land have retained their original functions and spatial forms, including gated residential compounds (18

| 2005-2019 | 1 | 2 | 3 | 4 | 5 | 6 |
|-----------|---|---|---|---|---|---|
| 2005-2019 | 8 | 9 | 10 | 11 | 12 | 13 |
| 2005-2019 | 14 | 17 | 20 | 21 | 22 | 24 |
| 2005-2019 | 25 | 26 | 31 | 32 | 33 | 34 |
| 2005-2019 | 38 | 39 | 47 | 50 | 51 | 54 |

**Figure 7** Morphological regions that the urban form and types remain unchanged in Qinhuai District from 2005 to 2019

| 2005-2019 | 1 | 2 | 3 | 4 | 5 | 6 |
|-----------|---|---|---|---|---|---|
| 2005-2019 | 14 | 17 | 20 | 21 | 22 | 24 |
| 2005-2019 | 25 | 26 | 31 | 32 | 33 | 34 |
| 2005-2019 | 38 | 39 | 47 | 50 | 51 | 54 |
FIGURE 8  Morphological regions that the urban form and types have changed in Qinhua District from 2005 to 2019
| Elements       | Morphological regions | Types† | Typological process | Suggestions                                      |
|---------------|-----------------------|--------|---------------------|--------------------------------------------------|
| Production    | 50, 51, 54            | P1     | P1                  | Protect urban farming                             |
|               | 55                    | P1     | C2                  | ×                                                 | Could provide space for open-air markets         |
|               | 47                    | P2     | P2                  | ×                                                 | Protect urban farming                             |
|               | 37                    | P2     | P2                  | ×                                                 | Ensure availability of time for urban gardening  |
|               | 49                    | P2     | P2                  | ×                                                 | ×                                                 |Could provide space for open-air markets         |
|               | 36, 40, 41, 42, 43, 45, 46, 48, 58 | P2 | P3 | P4 | × | × | × | Could provide space for urban gardening, such as community gardens |
|               | 57                    | P2     | P3                  | ×                                                 | ×                                                 | ×                                                 |Ensure availability of time for urban gardening  |
|               | 53                    | P2     | P3                  | ×                                                 | ×                                                 | ×                                                 |Wet markets could provide space for local food producers |
|               | 56, 15                | P2     | C3                  | ×                                                 | ×                                                 | ×                                                 |Wet markets could provide space for local food producers; Could provide space for open-air markets |
|               | 44, 52                | P2     | C4                  | ×                                                 | ×                                                 | Wet markets could provide space for local food producers |
|               | 28                    | P2     | P2                  | ×                                                 | ×                                                 | Could provide space for open-air markets         |
|               | 19, 35                | P2     | C2                  | ×                                                 | ×                                                 | ×                                                 |Need suitability evaluation for urban gardening |
| Consumption   | 1, 2, 5, 6, 8, 9, 10, 11, 12, 13, 14, 17, 20, 24, 31, 32, 33, 38 | C4 | C4 | C4 | Wet markets could provide space for local food producers |
|               | 7                     | C4     | C1                  | ×                                                 | ×                                                 | Need suitability evaluation for urban gardening |
|               | 18                    | C4     | C1                  | ×                                                 | ×                                                 | Wet markets could provide space for local food producers |
|               | 3, 4, 21, 22, 25, 26, 34, 39 | C3 | C3 | C3 | Wet markets could provide space for local food producers; Could provide space for open-air markets |
|               | 16,                   | C3     | C1                  | ×                                                 | ×                                                 | Need suitability evaluation for urban gardening |
|               | 23, 27, 30            | C3     | C3                  | ×                                                 | ×                                                 | Need suitability evaluation for urban gardening |
|               | 29                    | C2     | C2                  | ×                                                 | ×                                                 | Need suitability evaluation for urban gardening |

†: means the typology process is interrupted; →: means the typology process continues

**FIGURE 9** Morphological regions with changed types of Qinhuai District in Nanjing. *Characteristics of each type are detailed in Figure 3. When it comes to morphological regions: P1, superblocks where the entire area is for food production; P2, superblocks where production land and open blocks are mixed; P3, superblocks that mix residential compounds and fragmented production land; P4, areas that contain small and isolated production land; C1, part of the construction land has been converted into land for food production; C2, open blocks; C3, mixed open blocks and gated residential compounds; C4, gated residential compounds.
morphological regions) and mixed areas of gated residential compounds and open residential neighborhoods (8 morphological regions).

The results of the typology process of superblocks can guide spatial planning suggestions. Continuous agricultural land in superblocks is farther away from the city center, so they are less affected by urban expansion. Regions for urban farming should be protected because these small farms in urban and peri-urban areas could not only cultivate food but also provide multifunctional services such as urban greening and leisure activities (Haberman et al., 2014). These areas have always been used for food production, as they have unpolluted soil and accessible irrigation facilities, which are difficult to achieve in many newly added urban agriculture areas (van Averbeke, 2009). The government tends to expropriate arable land to make urban construction in the city master plan. However, it may take several years for the expropriated land to be constructed (China Net-Donghai Information, 2012). These temporary and isolated green space can be used for urban gardening. Superblocks that have changed to temporary production sites need available time to have their gardening use be ensured. Urban leftover spaces are available for food production if they have changed to small and isolated gardens. For example, allotment and community gardens could be embedded in urban areas at a small level, though they have a limited income-generating function. In comparison, social farms emphasize promoting disadvantaged people’s rehabilitation and creating employment opportunities (Lohrberg et al., 2016).

There are not many changes in the morphology of residential areas. These changes are mainly concentrated in the increased abandoned land that has changed from construction land to food production plots. Different space and surroundings require different types of urban agriculture (La Rosa et al., 2014). Fertile soil and clean water are significant for newly transferred urban gardens. Therefore, these superblocks need suitability evaluation for food cultivation. The spatial structure of food consumption influences space for food marketing. The gated residential compounds are equipped with wet markets as the food supply infrastructure, but most agri-food comes from wholesale markets (Wang & Mingjun, 2013). These government-operated wet markets are necessary to provide part of the space for small local food producers. Some public spaces in wet markets can be leased to part-time vendors at low prices to adapt their flexible gardening and selling time. Open residential areas have high accessibility of public space for open-air markets that can provide meeting spaces for local communities and encourage commercial activities for low-income groups (Madanipour et al., 2013).

5 | DISCUSSION

The evolution of land-use types in the above results is affected by many factors, such as social development and planning policy. In this evolution process, the informal food system reflects the deviation between diversified needs in cities and urban planning. Traditional food systems with local food production and direct marketing are gradually transferred into modern food systems that emphasize distribution and retailing. Informal food systems, as a positively functional part of traditional food systems, are marginalized by growing food companies and complicated modern logistics (Smith, 2012). Urban planning neglects food production and marketing in informal food systems; it even regards them as a sign of urban backwardness.

Agricultural land protection policies in China have largely limited the transformation from farmland to construction land, but it is still a challenge to integrate urban farming into the urban environment with diversified functions. The concept of ‘permanent basic farmland protection’ was proposed and designed in 2008 to ensure food self-sufficiency according to China’s population and socioeconomic development’s demand for agricultural products (Ministry of Land & Resources, 2008). Urban agriculture as an initiative to improve food security in China is still a government-led pattern (Cai et al., 2011). The development goal of urban farming in Nanjing is to promote larger production scale, modern equipment, diversified functions, and well-organized farmers (Nanjing Government, 2019b). In fact, the roles of these urban farms in cultural and social aspects are limited. The city’s facility agriculture and high-standard farmland account for 20 and 60% of the cultivated land, respectively (Nanjing Government, 2016). Despite the fact that government-led urban food planning has achieved great success in promoting food self-sufficiency and economic development outcomes for local officials, urban farming in some regions is improved through leasing farmland to immigrant farmers or companies by village committees. The peasants are pushed off the land with little compensation (Lang & Miao, 2013). These large farms, with the rapid expansion of greenhouse cultivation, have provided some employment opportunities for local farmers, but the trust of consumers toward food safety and quality is challenging agricultural industrialization (Zhong et al., 2020). Urban farmland has the advantage of being close to the densely populated areas so that it can be planned and designed in diversified forms and scales to contribute to biodiversity conservation and ecological benefits and provide leisure and recreation activities for urban residents (La Rosa et al., 2014). With expanding cities and a growing population, planners must pay attention to unorganized, small-scale urban farming and its potential to improve food security and other social benefits.
The dualistic land ownership system in China has caused some unique phenomena in informal food production. This system is based on the land tenure law that land in urban areas is owned by the state, and land in rural areas is owned by rural collectives. The village committees are responsible for periodically allocating agricultural land to peasant families according to the family’s population or labor ratio (Ministry of Justice of the People’s Republic of China, 2019a). The fast-growing cities encroach surrounding rural villages by government land expropriation. These rural families within a village are wholly resettled in new urban housing districts as urban residents. As compensation, they usually get the ownership of one or more apartments for free (Xu et al., 2016). The transformation from rural agricultural land to urban construction land is an important source of revenue for municipalities (Lang & Miao, 2013). This land transformation process may take many years because of various reasons, for example, compensation issues. Some dispossessed farmers support their families by informal food production on temporary idle lands. Although these lands have lost the attributes of agricultural land, the soil and water sources still maintain the formal arable land’s high standard of safety. Dispossessed farmers also have an intricate knowledge of vegetable properties, utilized recycled materials, fertilization of the soil, and other professional cultivation skills (Luehr, 2019). This is different from illegal urban agriculture in South Africa, where squatter gardening largely exists in informal settlements because of the severe housing shortage and high unemployment. Besides, individual gardeners, particularly women, produce food within any form of leftover space in proximity to their dwellings such as road verges (Hardman et al., 2018). Abandoned land gardening is also common in informal food systems in China. It is similar to illegal urban agriculture in many developing countries where urban low-income residents colonize fallen building sites without permission (Hardman & Larkham, 2014). Producers do not only support their own consumption but also increase income by selling agri-food in markets. But poor soil conditions in these plots could be dangerous to human health.

Urban planning is always perceived as a potential barrier for urban food production and legislation of informal food cultivation (Hardman & Larkham, 2014). Urban planning in many cities ignores the time lag between planning policy promulgation and implementation. This makes informal urban food production a gray area, which is complicated with its prohibition and without proper policy support. Temporally abandoned land largely exists in the change from agricultural to construction land. Shiziba Village is an example where most of its farmland was expropriated by the Nanjing government in 2016 and then it remained idle because a few villagers did not reach an agreement with the local authority on relocation compensation issues (Nanjing Municipal Bureau of Planning & Natural Resources, 2016). Currently, the informal arable land accounts for around 11% of the community. The urban poor, not only the producers but also the consumers, can benefit from informal food systems to ensure the region’s stability. It is estimated that 121.4 million people suffer from chronic hunger in mainland China (http://www.fao.org/faostat/en/#country/41). Urban food production in informal food systems provides low-income residents with affordable fresh food. The urban planning department should be responsible for these abandoned lands; how could they be put to good use, and how long could they be utilized? Planners could analyze land use requirements, size, number, and impacts of the community’s land-use patterns on food system activities (Pothukuchi & Kaufman, 2000). Relevant departments could screen idle land that can be used for food production and improve the soil and water that have been polluted (Bisaga et al., 2019).

A bottom-up structure is necessary to protect vulnerable groups, especially for small-scale urban food production, and people’s demand should be the starting point of urban planning and policies (Petit-Boix & Apul, 2018). Informal food systems involve different actors such as informal settlements, food producers, and street vendors. Official planning cannot take all these into account because of the huge population, temporary food production, and changing land markets. Civic organizations could play an important role in improving informal food systems by coordinating the relationship between small-scale food practitioners and the government. For the short-time idle land, these formal or temporary civic associations and grassroots could codesign abandoned public or private (uncultivated) green space to new gardens, and they could try to persuade local authorities to adopt legislation to change the legality of the use of these spaces (Hardman & Larkham, 2014). For long-term idle land suitable for food production, the authorities should specify their plans and the consequent use of time. Government agencies can carry out an inventory of idle land and a land-use plan. Community neighborhood committees can then help low-income settlements apply for land and policy support. Small-scale idle land for urban food production could lease urban unemployment and low-income migrants at a low price as a food welfare mechanism (Daviddova, 2011). A legal allocation of idle land can make full use of natural resources and provide a source of income for the urban poor.

The traditional wet markets in China are being upgraded from gathering places of informal vendors to modern food outlets as the urban infrastructure (Ministry of Agriculture & Rural Affairs of the People’s Republic of China, 2012). Although the wet market is the primary channel for urban food supply, its function for local food support and direct marketing is minimal. The operation of the formal wet market includes government operation and enterprise operation. The local government leases stalls to vendors, while some enterprises tend to sell their agricultural products in markets (Xiong, 2015). Large-scale food distribution and
transportation makes it impossible for small-scale farmers and vendors to connect in local markets directly so that the vegetables go through four-to-five intermediate links from the production site to wet markets (Wang & Mingjun, 2013). Some traditional wet markets rent public space to itinerant vendors daily, but many modern wet markets have excluded these part-time vendors who are also producers. If urban planning cannot provide legal spaces for food vendors, it may increase supervision difficulties for food safety. Regulations and planning policies can eliminate vendors, but it is more resilient to create thriving markets by engaging small-scale food producers in open-air markets and wet markets (Polyak, 2013).

The typomorphology approach provides a new perspective to analyze the spaces of informal food systems. This framework analysis could provide guidance and suggestions for upgrading the informal food system in the spatial planning dimension. It is conducive to prevent the government from blindly removing informal activities in food systems. There is a limited understanding of the illegal or informal occupation of the land and the consequent impacts of urban spatial transformation on informal activities (Thornton, 2009). Urban farming in informal settlements is a common phenomenon contributing to food security and employment in many developing countries (van Averbeke, 2009). Informal food systems can be more complicated when it comes to production, marketing, and consumption in different social backgrounds. The typomorphology analysis framework in this article provides a direction for understanding the informal food system and analyzing its role in an urban spatial organization.

The limitation of this study is that the extraction of spatial types of informal food systems cannot be very accurate because of the lack of historical data records. The results rely heavily on the quality of the land-use data. It is difficult to verify the informal food production sites and street vendor space in the three periods. Therefore, the extraction of space is based on a combination of literature research, map observation, and field investigation. The spatial form extracted in this paper regards both farmland and small green space as available space for food production according to the field research in Nanjing in 2019. The map data comes from Google Earth Pro 7.3.2.5776. Details about the land use data are available in the Nanjing statistical yearbooks online (http://221.226.86.104/file/2005/chengxiangjianshe/index.htm, http://221.226.86.104/file/2013/index.htm, http://tjj.nanjing.gov.cn/material/njnj_2019/).

DATA AVAILABILITY STATEMENT
The map data that support the findings of this study are available in Google Earth Pro 7.3.2.5776. Details about the land use data are available in the Nanjing statistical yearbooks online (http://221.226.86.104/file/2005/chengxiangjianshe/index.htm, http://221.226.86.104/file/2013/index.htm, http://tjj.nanjing.gov.cn/material/njnj_2019/).

AUTHOR CONTRIBUTIONS
Luoman Zhao: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Writing-original draft; Writing-review & editing

CONFLICT OF INTEREST
The author declares no conflicts of interest.

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