

## Spatial Distribution Characteristics and Influencing Factors of Vegetable Markets in Lanzhou City (Postprint)

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### Abstract

Vegetable markets constitute an important component of urban geographical space, and their rational layout is a crucial link in implementing the urban “vegetable basket” project. This study selects vegetable markets in the main urban area of Lanzhou as the research object, utilizing 2020 Lanzhou vegetable market POI data and socioeconomic data, and employing methods such as kernel density analysis, exploratory spatial data analysis, two-step floating catchment area method, and geographical detector to analyze the spatial distribution characteristics and influencing factors of Lanzhou’s vegetable markets from a geographical perspective using big data. The results indicate that: (1) The spatial distribution of vegetable markets exhibits a “northwest-southeast” orientation, with comprehensive large-scale supermarkets being more evenly and dispersedly distributed in Lanzhou’s main urban area compared to other types, while medium and large farmers’ markets and vegetable retail stores show a more clustered distribution. (2) In terms of quantity and scale, vegetable markets display a distribution pattern of “dense in the east and sparse in the west, dense in the south and sparse in the north”; comprehensive large-scale supermarkets exhibit a patchy distribution, medium and large farmers’ markets overall show an island-like distribution with a polycentric pattern, and the spatial distribution pattern of vegetable retail stores appears as spotted distribution. (3) The spatial distribution of vegetable markets demonstrates a strong clustering tendency. (4) The overall accessibility of Lanzhou’s vegetable markets is relatively good, though some streets in Anning District and Xigu District have relatively low accessibility. (5) The spatial distribution of Lanzhou’s vegetable markets is primarily influenced by multi-factor interactions, with main influencing factors including population factors, transportation factors, etc. Finally, the study identifies irrational aspects of the spatial distribution of vegetable markets and proposes relevant recommendations, aiming to provide references for strengthening the rational spatial layout and coordinated development of Lanzhou’s

vegetable markets.

## Full Text

### Spatial Distribution Characteristics and Influencing Factors of Vegetable Markets in Lanzhou City

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#### Abstract

Vegetable markets constitute a crucial component of urban geographic space, and their rational layout is essential for implementing the urban “vegetable basket” project. This study examines vegetable markets in the main urban area of Lanzhou City, employing kernel density analysis, exploratory spatial data analysis, two-step mobile search method, and geographic detector to analyze the spatial distribution characteristics and influencing factors of vegetable markets in Lanzhou from a geographical perspective using big data. The results reveal that: (1) The spatial distribution of vegetable markets exhibits a “northwest-southeast” orientation. Comprehensive supermarkets demonstrate a more balanced and dispersed distribution compared to other types, while large and medium-sized farmers’ markets and vegetable retail stores show greater concentration. (2) In terms of quantity and scale, vegetable markets display a pattern of being dense in the east and south but sparse in the west and north. Comprehensive supermarkets are patchily distributed, large and medium-sized farmers’ markets show an island-like distribution with a multi-center pattern, and vegetable retail stores exhibit a spotted distribution pattern. (3) The spatial distribution of vegetable markets shows strong clustering tendencies. (4) Overall accessibility of vegetable markets in Lanzhou is good, though some streets in Anning and Xigu districts have low accessibility. (5) The spatial distribution of vegetable markets is primarily influenced by multiple factor interactions, with population and transportation being the main factors. Finally, the study identifies unreasonable aspects of the spatial distribution and proposes relevant recommendations to provide references for strengthening rational spatial layout and coordinated development of vegetable markets in Lanzhou.

**Keywords:** vegetable markets; GIS spatial analysis; geographic detector; Lanzhou City

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#### 1. Study Area Overview

Lanzhou City (102°36 ~104°35 E, 35°34 ~37°00 N) serves as an important transportation hub in Northwest China, providing vital support

for economic development in western China. The Yellow River runs through the city from west to east, creating a topographic feature of “two mountains flanking one river.” The city covers a total area of  $3.79 \times 10^3$  km<sup>2</sup> with a permanent population of approximately  $1.31 \times 10^6$ . *Constrained by valley terrain, Lanzhou has difficulty expanding nearby and thus develops along river axes. This study focuses*

Basic information is presented in Table 1.

[Figure 1: see original paper]

**Table 1. Basic information of the central districts of Lanzhou City**

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## 2. Data and Methods

**2.1 Data Sources** The data used in this study include POI data of vegetable markets in Lanzhou’s main urban area, administrative boundary data, population raster data, and road network data. Vegetable market POI data were obtained through web crawler technology from Gaode Maps, capturing attributes including name, detailed address, and coordinates. After data screening, classification, and coordinate conversion, these served as the research data source. This dataset essentially covers all vegetable market entities in Lanzhou’s four districts, with rich content and high precision that meets requirements for current reliability and accuracy of spatial locations.

Administrative boundary data were obtained from the National Geospatial Information Center. Since street-level population data for Lanzhou were unavailable, population data from Worldpop were used after zonal statistics. Road data were sourced from OpenStreetMap, while residential areas and public transportation station data were obtained through web crawling.

Based on Gaode Maps, Python was used for web crawling with four keywords: “supermarket,” “agricultural product market,” “fruit market,” and “vegetable market.” Following the classification system of POI big data and agricultural market research, supermarkets were classified as comprehensive hypermarkets, agricultural product markets as large and medium-sized farmers’ markets, and fruit and vegetable markets as vegetable retail stores. A total of 1,047 POIs were extracted, including 217 comprehensive hypermarkets, 83 large and medium-sized farmers’ markets, and 747 vegetable retail stores. The spatial distribution is shown in Figure 2.

[Figure 2: see original paper]

**2.2 Research Methods** 1) **Standard deviational ellipse:** This method calculates the distribution trend of point groups by computing standard distances in X and Y directions, analyzing the distribution direction and trend of vegetable markets in the main urban area and each district.

2) **Kernel density estimation:** Widely used in spatial analysis, this is the

primary statistical method for extracting spatial distribution characteristics of vegetable markets, reflecting their agglomeration degree. Higher kernel density indicates denser distribution.

**3) Exploratory spatial data analysis:** This method reflects the correlation between the quantity and region of vegetable markets in Lanzhou, analyzing spatial heterogeneity and correlation.

**4) Two-step mobile search method:** The improved two-step mobile search method considers distance decay, using a Gaussian function that best matches residents' travel patterns. Following the *Lanzhou 15-Minute Life Circle Supporting Facilities Planning Research and Guidelines*, the distance threshold was set at 1,000 m. Supply capacity of various vegetable markets was determined through consultation with seven domain experts (urban geography, economic geography) using the Analytic Hierarchy Process (AHP) for weighting (Table 2). After weighting and normalization considering the quantity of vegetable markets within the threshold, accessibility was calculated for each market.

**Table 2. Supply capacity of various vegetable markets**

**5) Geographic detector:** This method detects causal relationships between variables and explores underlying drivers. If an independent variable affects a dependent variable, their spatial distribution patterns will be similar. Factor detection explains the degree to which a factor explains spatial differentiation of the dependent variable, while interaction detection examines combined effects.

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### 3. Results

**3.1.1 Spatial Distribution Direction of Vegetable Markets** Standard deviational ellipse analysis reveals that vegetable markets in Lanzhou exhibit a “northwest-southeast” pattern (Figure 3), primarily due to the city’s band-shaped form constrained by terrain and the northwest-southeast orientation of the Yellow River. The ellipses for all four districts align with this overall direction. Xigu District has the smallest ellipse area while Chengguan District has the largest, indicating more concentrated and fewer vegetable markets in Xigu.

[Figure 3: see original paper]

Figure 4 shows the distribution of three vegetable market types, all constrained by the valley terrain to a “northwest-southeast” pattern. Comprehensive hypermarkets show the largest rotation angle, followed by large and medium-sized farmers’ markets and vegetable retail stores. The latter two have smaller ellipse areas, indicating higher agglomeration than comprehensive hypermarkets. Thus, comprehensive hypermarkets are more balanced and dispersed, while large and medium-sized farmers’ markets and vegetable retail stores are more concentrated.

[Figure 4: see original paper]

**3.1.2 Spatial Agglomeration of Vegetable Markets** Kernel density analysis shows a pattern of “dense in the east and south, sparse in the west and north” with patchy, multi-center agglomeration near commercial centers (Figure 5). Three agglomeration zones exist: Chengguan-Qilihe, Anning, and Xigu. The Chengguan-Qilihe zone shows the strongest agglomeration, while Anning and Xigu are relatively weaker.

[Figure 5: see original paper]

At the street scale, Chengguan District concentrates in Yannan, Yanbei, Weiyuan Road, and Gongxingdun streets; Qilihe District in Xiyuan, Jianlan Road, Xizhan, and Xihu streets; Anning District in West Road, Kongjia Cliff, Yintan Road, and Peili areas; and Xigu District in Xigu City, Fuli Road, and Sijiqing streets.

Comprehensive supermarkets show patchy distribution with broad coverage and uniform distribution across districts (Figure 6). At the street scale, they concentrate in Yannan, Yanbei, Xiyuan, and Jianlan Road streets in Chengguan and Qilihe districts, and in Peili, Kongjia Cliff, West Road, and Shajingyi streets in Anning District near commercial centers. Large and medium-sized farmers’ markets show island-like distribution, mainly concentrated in the Chengguan-Qilihe contiguous area and Xigu District, with less agglomeration in Anning. Vegetable retail stores show spotted distribution, primarily in Chengguan-Qilihe area. Comprehensive supermarkets, offering diverse services, are more evenly distributed, while vegetable retail stores, influenced by residential distribution, show poor adaptation in Xigu and Anning districts.

[Figure 6: see original paper]

**3.1.3 Spatial Autocorrelation Analysis of Vegetable Markets** Global Moran’ s I analysis at the street scale shows strong clustering trends (Table 3, Figure 7). The positive slope in the Moran scatter plot indicates significant spatial clustering. Local Moran’ s I analysis (Figure 8) reveals high-high clusters in Yanbei Street (Chengguan), high-low clusters in Chenping Street (Xigu), low-high clusters in Qingbaishi and High-tech Zone streets (Chengguan), and low-low clusters in Baiyin Road, Jiuquan Road, Gaolan Road, Wuquan, and Railway West/East Village streets (Chengguan).

**Table 3. Global Moran’ s I value of vegetable markets in the central districts of Lanzhou City**

[Figure 7: see original paper]

[Figure 8: see original paper]

**3.1.4 Accessibility Analysis Based on “15-Minute Life Circle”** Following the *Lanzhou 15-Minute Life Circle Supporting Facilities Planning Research and Guidelines*, the improved two-step mobile search method analyzed

street-level accessibility. From a consumer perspective, comprehensive hypermarkets have the strongest supply capacity, followed by vegetable retail stores and large/medium farmers' markets. Using natural breaks, accessibility was classified into five levels (Figure 9). Chengguan District shows the highest accessibility, followed by Qilihe, Anning, and Xigu. Streets with high accessibility include Donggang West Road, Weiyuan Road, Gongxingdun, Donggang, High-tech Zone, Yannan, Yanbei, and Yanchang Road (all in Chengguan). Streets with poor accessibility include Gongjiawan, Peili, Liujiabao, Shajingyi, Xiliugou, Lintao Street, Xigu City, Fuli Road, and Xifeng Road (mostly in Xigu District).

[Figure 9: see original paper]

**3.2.1 Variable Selection** Based on existing research on urban infrastructure distribution, this study selects variables considering data availability: (1) **Population factors:** Vegetable markets serve residents and cluster around populations; (2) **Transportation factors:** Road accessibility and connectivity affect market layout; (3) **Residential area factors:** The number of residential communities influences market quantity and type; (4) **Resident payment level:** Purchasing power directly affects market quantity and layout. Primary and secondary indicators are detailed in Table 4. Distance factors (distance to main roads  $X_{10}$  and distance to residential areas  $X_{11}$ ) were also analyzed for different market types.

**Table 4. Index system of influencing factors of vegetable markets in the central districts of Lanzhou City**

**3.2.2 Influencing Factors Analysis** Geographic detector single-factor results (Table 5) show that residential area density ( $X_5$ ), population density ( $X_1$ ), and distance to residential areas ( $X_{11}$ ) most strongly influence distribution, indicating vegetable markets closely follow population factors.

Multi-factor interaction results (Table 6) show that interaction effects (q-values) are generally higher than single-factor effects, indicating vegetable market distribution results from multiple factor interactions. The interaction between population density and road density ( $q = 0.92$ ) shows markets concentrate in densely populated areas with developed road networks—typically well-developed commercial districts with high shopping demand. Population density and residential area density ( $q = 0.89$ ) confirm markets cluster around large consumer groups. Residential area density and housing price ( $q = 0.85$ ) indicate market quantity relates to both residential density and purchasing power.

Distance analysis for different market types (Table 7) shows that distance to residential areas has stronger explanatory power than distance to main roads. Comprehensive hypermarkets ( $M_1$ ) are closest to residential areas, followed by vegetable retail stores ( $M_3$ ), with large/medium farmers' markets ( $M_2$ ) farthest—likely because farmers' markets prioritize goods distribution near main roads.

**Table 5. Explanatory power of influencing factors of vegetable markets distribution in the central districts of Lanzhou City**

**Table 6. Interacted explanatory power of multiple factors of vegetable markets distribution in the central districts of Lanzhou City**

**Table 7. Explanatory power of influencing factors of vegetable markets distribution of different types in the central districts of Lanzhou City**

**3.2.3 Spatial Coordination Under Influencing Factors** Since public transportation convenience, housing price, population density, road density, and residential area density are primary factors, bivariate local Moran's I analysis examined spatial coordination between vegetable markets and these factors (Figure 10). Results show low-high clustering in many Chengguan streets (Linxia Road, Zhangye Road, Fulongping, Baiyin Road, Jiuquan Road, Gaolan Road, etc.), indicating good regional conditions but insufficient vegetable market distribution. Xiuchuan Street in Qilihe shows high-low clustering—many markets but poorer regional conditions. Overall, vegetable market distribution shows low coordination with regional conditions in most Chengguan streets, with slight imbalance between social development and market allocation.

[Figure 10: see original paper]

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#### 4. Discussion

Based on the research findings and identified layout problems, recommendations include: (1) In spatial layout, future community-level life circle planning should increase markets in streets like Linxia Road and Zhangye Road where needed, while controlling market numbers in Xiuchuan Street. More refined planning should increase markets in residential areas with high demand but low supply to create convenient vegetable shopping circles. (2) In future spatial planning, scientifically plan new markets and optimize layout structure, considering radiation range and functional positioning to guide orderly development.

Big data intuitively reflects spatial distribution characteristics but lacks logistics and area data for deeper analysis. Mobile market location data are difficult to obtain and were excluded. Data limitations prevented inclusion of land price and income data at the street level. Future research should accumulate multi-temporal spatial location data for spatiotemporal evolution studies. With internet development, online vegetable shopping platforms (e.g., Duoduomai, Meituanyouxuan) are emerging, posing challenges to physical markets. The balance between virtual and physical markets warrants attention.

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## 5. Conclusions

- 1) Vegetable markets in Lanzhou show a “northwest-southeast” distribution pattern, consistent across all districts. Comprehensive supermarkets are more balanced and dispersed than other types, while large/medium farmers’ markets and vegetable retail stores are more concentrated.
- 2) Spatial agglomeration shows a pattern of “dense in the east and south, sparse in the west and north.” The Chengguan-Qilihe area shows concentrated block distribution, Xigu shows patchy distribution, and Anning shows sheet-like distribution. Comprehensive supermarkets are patchily and uniformly distributed; large/medium farmers’ markets show island-like, multi-center distribution; vegetable retail stores show spotted distribution, mainly in Chengguan-Qilihe.
- 3) Global Moran’ s  $I$  is 0.36 (significant at 1% level), with positive slope indicating strong clustering. High-high clusters concentrate in Yanbei Street (Chengguan); high-low in Chenping Street (Xigu); low-high in Qingbaishi and High-tech Zone streets (Chengguan); low-low in Baiyin Road, Jiuquan Road, Gaolan Road, Wuquan, and Railway West/East Village streets (Chengguan). Accessibility is highest in Chengguan, followed by Qilihe, Anning, and Xigu.
- 4) Multi-factor interactions have greater influence than single factors. Key interactive factors include population density, road density, residential area density, housing price, and public transportation convenience. Primary single factors are residential area density, population density, and distance to residential areas.
- 5) Overall distribution coordinates with regional conditions—Chengguan has the highest economic level and strongest agglomeration, Xigu the weakest. However, at the street scale, some streets show imbalance: many Chengguan streets (Linxia Road, Zhangye Road, etc.) have good conditions but few markets, while Xiuchuan Street has many markets but poor conditions. Anning and Xigu districts have many residential areas but insufficient markets.

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