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Links between the pandemic and urban green spaces, a perspective on spatial indices of landscape garden cities in China

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1. Introduction

1.1. Background

Since the birth of cities, humanity’s struggle with pandemics has been an important factor guiding the enhancement of the environment of urban settlements and the sustainable development of society. Throughout human history, cities have been plagued by disease and urban disasters, reinventing themselves gain and again during crises with vitality and resilience (Pearson, 2021). Currently, the urban environment is characterised by rapid economic growth and yearly improvements in material living standards. However, managing the relationship between urban environments and public health to achieve sustainable urban development is still a daunting task for most municipal governments (Sauvé, Bernard, & Sloan, 2016). Though there is now a growing consensus among governments and urban residents that urban green spaces and public open spaces can have positive physiological, psychological and social impacts on human health, pandemic outbreaks, such as COVID-19, still greatly challenge urban sustainability and social development (AILA, 2016; Organization, 2016; Shorfuzzaman, Hossain, & Alhamid, 2021). As cities around the world react to the spread of COVID-19, urban dwellers around the world have reduced their mobility, which may incidentally be keeping people away from green spaces. Surprisingly, studies have shown that many cities around the world have seen a surge in the use of green spaces (Lu, Zhao, Wu, & Lo, 2021). This has also inspired many cities to create new solutions in urban planning that still allow for more housing in the city, but do not increase residential density too much, and allow for urban green spaces to revitalise neighbourhoods. It can be said that, pandemics could also be seen as opportunities for urban policy-makers and residents to become aware that upgrading urban habitats should continue to receive attention and needs to be deepened. This upgrading is one of the key ways to contribute to urban resilience and keep cities socially sustainable.

1.2. The emergence of NLGCC policy

China is one of the most populous and densely urbanized countries in the world. At the end of 2021, there were 684 cities in the mainland of the People’s Republic of China (PRC), accounting for a total population...
proposed the urban development concept of the landscape city (Ye, Wu, & Wang, 2011). Based on the results of these experiences, the Chinese government launched the NLGCC designation in 1992. This new project marked the beginning of China’s long road to “eco-city” development (Chang, Leitner, & Sheppard, 2016). However, the construction of an eco-city cannot be achieved overnight. The ultimate goal is to form a highly stable urban context and a sustainable human society in a natural-economic-social urban ecosystem (Su, Fath, & Yang, 2010). The NLGCC is the foundational stage in eco-city development. Assessing the current status of the implementation of NLGCC policy in the context of the COVID-19 pandemic shows that the policy has proven to be a useful attempt at responding to the public safety crisis through the development of urban green spaces and public open spaces.

1.3. Literature review & aim of the research

Since the outbreak of COVID-19, a great deal of research has been conducted and evidence obtained about the development of urban green spaces and public open spaces in relation to the prevention and control of the disease. For instance, a growing number of studies show that the use of urban green infrastructure increased significantly during COVID-19 (Korpilø, et al., 2021). People have expressed a strong need to spend time in urban green spaces, which are seen as places of comfort, rest, exercise and relaxation (Ugolini, et al., 2020). Green spaces have played an essential role in people’s health and well-being (Bérdejo-Espinola, et al., 2021; Olzewska-Guizzo, Fogel, Escoffier, & Ho, 2021). Early studies have shown significant differences in the effects on physical and mental health of people who have access to green spaces during quarantine compared to those who do not (Pouso, et al., 2021). It has also been argued that the presence and inclusion of urban green spaces in urban planning should be seen as a social and public health investment, and an opportunity to restore the relationship between inhabitants and nature and to provide protection and preparedness for future epidemics (Geary, et al., 2021). Moreover, equitable availability and accessibility have been shown to need further consideration when planning green spaces to improve urban resilience (Suárez, et al., 2020). In addition, studies have shown that it is important to explore changes in the use of public open spaces, as the COVID-19 pandemic has been expected to bring about substantial changes in the design, use and perception of public spaces in the future, and further attention, thus, needs to be given to the quality and flexibility of these spaces (Honey-Rosés, et al., 2020; Sepe, 2021). Scholars have also shown that, during the COVID-19 pandemic, low urban density provided resilience to urban dwellers with reduced physical activity (J. Wang, et al., 2021).

In summary, existing research has established that developing urban green spaces and public open spaces is important to enable the ability to resist the pandemic and develop urban resilience and sustainability. However, most existing studies have focused on European and North American countries and have been dominated by meso- and microscale case studies. In a country with a large population base and high urban density, such as China, there have not been enough studies on the development of urban green spaces and public open spaces from a macro policy perspective. Research on the NLGCC is an excellent point of entry to identify capabilities in this area.

Existing research on the NLGCC was conducted before the COVID-19 pandemic. It focused mainly on three aspects. First, it focused on the policy attributes of NLGCC and provided an overview of the origin, development and direction of the policy (Miao, 2019); second, it focused on the analysis of its index evaluation system (Huang, Huang, Wang, & Zhou, 2018); and third, scholars have conducted several case studies on planning and development strategies in the cities selected for the list (Hu, Chang, & Syrbe, 2020). In addition, the popularity of information technology, such as remote sensing (RS), geographic information system (GIS), and global positioning system (GPS), has also led to studies on NLGCC (T. Li, et al., 2018). For example, RS has been used to assess the relationship between urban river transformation and

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**Table 1**

Comparison between the Garden City Movement and the NLGCC policy.

| Differences | Garden City Movement | NLGCC policy |
|-------------|----------------------|--------------|
| The new social structure of urban and rural integration | The new social structure of urban and rural integration | Emphasis on the coordination of urban green space, public open space and urban spatial structure |
| Suitable for building new cities on vacant land | Suitable for building new cities on vacant land | Suitable for building new cities on vacant land |
| Lacked the basis for large-scale practice and has certain historical limitations | Lacked the basis for large-scale practice and has certain historical limitations | Lacked the basis for large-scale practice and has certain historical limitations |

**Similarities**

- They are directly impacted by the deterioration of ecological and human habitats.
- Studied the city as a whole, emphasising the harmonious development of society, economy and nature.
the Landscape Garden City Movement in a number of Chinese cities (S. Shi, et al., 2018). Nevertheless, while there have been numerous research outputs as a result of these studies, it is critical to note that ongoing studies continue to be dominated by small-scale theories, countermeasures, and case studies (Joss & Molella, 2013; Xu, Yang, & Yao, 2012; H. Zhang, Wen, Xu, Luo, & Li, 2018). The current spatial distribution of NLGCC in China has lacked a macrogeographic scale analysis. Moreover, no research has delved into the relationship between NLGCC and urban green spaces and public open spaces, nor provided a meaningful discussion of the logic behind some of the solutions that have succeeded in improving urban resilience in the face of the pandemic. That is, there is still no clarity about how these cities used their existing resources and conditions and leveraged government enforcement to build urban green spaces and public open spaces to meet the NLGCC selection criteria and provide actionable ideas for other cities.

In light of these findings this study used ArcGIS 10.2, and the Google Earth and SPSS platforms to examine the NLGCC policy changes and implementation status before and after COVID-19 and to analyse the spatial distribution patterns and development driving factors in all cities that have appeared on the NLGCC list thus far. This study also analyses how China is currently building an open and porous urban fabric through NLGCC policy to produce a more resilient city to face challenges such as the COVID-19 pandemic. For example, the NLGCC policy offers a healthy way to build urban green spaces, thus effectively avoiding the possibility of virus transmission and promoting urban health. It is hoped that the findings will provide policy lessons for high-density cities elsewhere in the world about how to improve their overall resilience and develop more sustainably not only at the scale of the city itself, but also at the national scale for an overall more sustainable society in the future.

2. The in-depth analysis of NLGCC policy

2.1. Evolution of the selection criteria

Since the full version of the NLGCC came about in 2000, its selection criteria have focused on the expanse of green space and other environmental infrastructure in cities. In 2010, factors such as energy savings and emission reduction were added to the selection criteria. After the breakout of COVID-19 in 2022, the Chinese government realised the necessity of developing urban green spaces and public open spaces (Zhu & Xu, 2021). It has been critical to reflect on the lessons of COVID-19 and adjust the NLGCC selection criteria to meet global calls for sustainable and resilient cities. As a result, the current selection criteria include 1) city resilience, 2) quality of urban environmental amenities, such as green spaces and public open spaces, 3) ecological protection and low-carbon behaviours, and 4) urban style and landscape character. The shifting in NLGCC selection criteria from quantity to quality shows that the Chinese government increasingly understands the need to foster a harmonious human-nature relationship (Fig. 1). By constantly adjusting the NLGCC selection criteria, the Chinese government illustrates the progressive nature of the policy in the development of sustainable and resilient cities.

2.2. Significance and benefits

In line with similar theoretical illustrations, the NLGCC is ideal as a development model to be applied to ecological and systemic principles for protecting, planning, building and managing of cities. Building the NLGCC is an important means to promote urban habitat and enhance urban resilience and an important symbol reflecting the goal of sustainable urban development.

1) The NLGCC policy advocates a green and low-carbon development philosophy and a resource- and energy-efficient development model. Promoting the NLGCC policy is important in addressing ecological and environmental crises. For example, the heat island effect in many NLGCCs has been significantly mitigated in recent years due to the selection criteria that require the protection of water bodies and green areas, the construction of urban breezeways and the protection of ecological cooling sources, such as existing forests. According to the latest data released by the China Meteorological Administration, which were included in the NLGCC list in 2002 and 2005, there has been an overall decreasing trend in the zones impacted by the heat island effect in central urban areas. In particular, Wuhan’s intense heat island in its main city was 33.5% lower in 2018 than in 2009, and its air quality had improved significantly (Tang, Lan, & Feng, 2018).

2) The NLGCC policy also offers ideas for optimising the green spatial pattern of high-density cities arising from rapid urbanisation. For example, in Xuzhou City, which was selected for the NLGCC list in 2005, green spaces in the main city of Xuzhou increased from a total area of 3,606.07hm$^2$ to 7,793.41hm$^2$ between 2004 and 2014, and the proportion of green spaces out of the total city area increased from 37.49% to 41.13%. Along with this increase in quantity, the structure of green spaces also changed significantly: the most obvious change occurred in protective green spaces, which increased from 5.21% to 21.19% of the total green space area, followed by green space in units and residential areas, which increased from 30.46% to 37.22%. The NLGCC policy has helped restructure
Xuzhou’s urban green space system (Liang, Ji, Guo, & Meng, 2021). This modification has also benefited the public’s physical and mental health and helped create amicable social interactions in open spaces.

3) NLGCC policies have also encouraged the development of disaster-proof composite spatial systems. During the COVID-19 pandemic, city resilience became increasingly popular in urban planning and research (Chen, Guo, Pan, & Zhong, 2021; Chu, Cheng, & Song, 2021). The spatial resilience of cities reflects their ability to respond to emergency disasters, return to normal operations quickly, and achieve quality development after disasters (Meyer & Auria Combe, 2019). Since the NLGCC policy requires high-level assessments for constructing urban risk-averse green space systems, to some extent, it has pushed many Chinese cities to build disaster-proof composite spaces to enhance city resilience. For example, all cities on the NLGCC list are required to keep the percentage of disaster-avoidance green spaces meeting national standards at 85% or more, providing valuable emergency space for responding to COVID-19. For example, temporary medical complexes can be erected on open lawns to serve as emergency medical sites.

3. Data sources and research methodology of spatial analysis

3.1. Data sources

The statistics in this study were based on a list released by the PRC Ministry of Housing and Construction (https://www.mohurd.gov.cn/) in March 2022. A total of 391 cities in 21 batches have been listed on the NLGCC so far (Fig. 2). Social institutions or organisations publish similar lists, but the PRC being a socialist country (Yang, 2022), the list issued by the central government via its ministry is most authoritative for urban construction data (Feng, Bao, Yang, & Fu, 2021). The geospatial coordinates for the cities on the list were calibrated with the help of the Google Map Coordinate Picker, which selected the centre point of each city’s municipal government premises as the coordinate picker; and the data were then imported into the ArcGIS 10.2 software (Geographic Information System Company, Environmental Systems Research Institute, West Redlands, CA, USA) (Boyang, Weidong, & Dunford, 2014).

The NLGCC database was constructed using the ArcGIS10.2 technological platform. The socioeconomic data for each administrative region were also imported as attribute links based on government working reports and statistical yearbooks that were last updated in late 2021. When they appeared in the database, items that were repeated or cancelled because of regional changes in administrative regions were reorganised. The final data used for this research were reintegrated into 373 location coordinate points to generate the NLGCC spatial distribution map.

3.2. Research Methodology

This research studies the NLGCC using spatial software and indices. Fig. 3 shows a flowchart specific to the research methodology. The nearest neighbour index, geographic concentration index, and imbalance index are used to differentiate the NLGCC spatial distribution type and degree of aggregation (J. Zhang, Cenci, Becue, & Koutra, 2022). Kernel density analysis is used to analyse the spatial distribution intensity of the NLGCC. The Pearson correlation coefficient is used to measure the impact of specific factors on the distribution of the NLGCC.

3.2.1. Nearest neighbour index

The point set elements are usually cohesive, random, and uniform in regional space (Pommerening, Szmyt, & Zhang, 2020). The formula is:

\[ NNI = \frac{D_0}{D_e} = \frac{1}{n} \sum_{i=1}^{n} d_i = \frac{0.5}{\sqrt{n}} \quad (1) \]

where NNI is the nearest neighbour index. \( D_0 \) is the average distance between the target element and its nearest neighbour essential mass centre. \( D_e \) is the average distance of the random distribution of the element. If the NNI value is greater than 1, the NLGCC is spatially randomly distributed; if the NNI value is less than 1, the NLGCC is agglomeratively distributed.

3.2.2. Geographic concentration index

The geographic concentration index is an index used to measure the degree of concentration in the spatial distribution of the research object (Dumais, Ellison, & Glaeser, 2002). Taking the value of 0-100, the larger the G value is, the more concentrated the distribution; the smaller the G value is, the more discrete the distribution, calculated as follows:

\[ G = 100 \times \sqrt{\frac{1}{\sum_{i=1}^{T} \left( \frac{X_i}{T} \right)^2}} \quad (2) \]

where G is the geographical concentration index. \( X_i \) is the number of NLGCCs in each province and city; \( T \) is the total number of NLGCC; and \( n \) is the number of provinces and cities.

3.2.3. Imbalance index

The imbalance index is used to reflect the balanced degree of distribution of NLGCCs in different regions (J. Zhang, Cenci, Becue, & Koutra, 2021), calculated by the formula as:
where \( NLGCCs \), \( k \) denotes the kernel function, and \( r \) the distribution of NLGCCs. It is calculated as follows:

3.2.5. Pearson correlation coefficient

The formula can be used to measure the impact of specific factors on the distribution of NLGCCs. It is calculated as follows:

\[
S = \frac{\sum_{i=1}^{n} Y_i - 50(n + 1)}{100n - 50(n + 1)} \tag{3}
\]

where \( n \) is the number of provincial and urban areas, and \( n = 34 \), \( Y_i \) is the cumulative percentage of the number of NLGCCs in the \( i \)th urban area in the province to the total. Where \( 0 \leq S \leq 1 \), if \( S = 0 \), it means that NLGCCs are evenly distributed across all provincial urban areas; if \( S = 1 \), all NLGCCs are concentrated in a certain provincial urban area; the greater the value of \( S \) tends to 1, the more unevenly distributed NLGCCs are.

3.2.4. Kernel density estimation

The kernel density estimation method can be used to determine the aggregation status of NLGCC on a national scale (Wang, Zhang, Cenci, et al., 2022), which is calculated by the formula as:

\[
f_k(x) = \frac{1}{nh} \sum_{i=1}^{n} k \left( \frac{x - X_i}{h} \right) \tag{4}
\]

where \( f_k \) denotes the kernel density estimate, \( n \) denotes the number of NLGCCs, \( k \) denotes the kernel function, and \( x - X_i \) denotes the estimated point \( x \) to the sample \( X_i \) distance, and \( h \) denotes the search radius.

3.2.5. Pearson correlation coefficient

The formula can be used to measure the impact of specific factors on the distribution of NLGCCs. It is calculated as follows:

\[
r_{xy} = \frac{\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n} (x_i - \bar{x})^2 \sum_{i=1}^{n} (y_i - \bar{y})^2}} \tag{5}
\]

In the formula, \( n \) is the number of provinces and cities with NLGCC distribution; \( x \) and \( y \) are the averages of the two variables and the sample values to be analysed there. The value range of \( r_{xy} \) is [-1, 1]; the greater the absolute value is, the stronger the correlation between variables, and vice versa.

4. Results

4.1. Overview of the research subjects

After sorting and statistical analysis, the NLGCCs were found to be concentrated across the country, but scattered in 31 different administrative regions. The specific results of the index calculations are shown in Table 2.

### 4.2. Analysis of the spatial structure characteristics of the NLGCC

#### 4.2.1. Spatial distribution pattern

While the scale of individual cities varies, their distribution can be abstracted into point elements for spatial type analysis at the country’s macro-geographic scale (Fig. 4a). The nearest neighbour index reflects the mutual proximity of point set elements in regional space (Quistberg et al., 2022). Using the spatial analysis tool in ArcGIS10.2 software to measure the nearest neighbour index for the NLGCC, we obtained the average nearest neighbour index \( R = 0.79 < 1 \). This result demonstrates that the spatial distribution of the NLGCC is a certain number of clusters in the regional space.

#### 4.2.2. Balanced spatial distribution

1) The degree of spatial distribution concentration

According to Formula (2), after calculating and analysing the data in Table 3, the geographical concentration index \( G = 23.10 \) for NLGCC could be calculated. Theoretically, the 373 NLGCCs were evenly distributed across the provincial units, Hence, the geographical concentration index \( G = 17.15 \) was significantly smaller than the geographical concentration index of the actual distribution. Thus, the distribution of NLGCCs is concentrated at the provincial level, mainly in Shandong, Henan, Hubei, Zhejiang, and Jiangsu.

#### 4.2.3. Balanced spatial distribution

1) The degree of equilibrium in spatial distribution

Based on geography, economy, culture and other related factors in each of its province, China has generally been divided into seven regions: North, East, Central, South, Northeast, Southwest, and Northwest (C. Zhang, et al., 2022). The NLGCC spatial distribution varies significantly across these geographic divisions. The main distribution occurs in eastern China, followed by central China, where the total NLGCC accounts for more than half of the country. The distribution of NLGCCs across the seven geographic divisions is shown in Table 4.

The NLGCC imbalance index \( S_{NLGCC} = 0.46 \) could be calculated using the mutual proximity of point set elements in regional space (Quistberg et al., 2022).
Formula (3) to measure the degree of balance in the administrative distribution of NLGCC. This finding indicates that the NLGCC is unevenly distributed across provincial units throughout the country. The Lorenz curve (Fig. 5) for the distribution of NLGCC in each provincial unit was drawn from the data. The graph shows that half of the NLGCCs are distributed across the seven provinces: Shandong, Henan, Hubei, Zhejiang, Jiangsu, Guangdong and Anhui.

4.2.3. Spatial distribution density characteristics

This research employed the kernel density tool in ArcGIS10.2 to reveal the aggregation of the NLGCC, and the results are shown in Table 5.

The following pattern characterises the spatial distribution of the NLGCC: “two cores, three centres, multiple scattered points and stretches” (Fig. 4b).

1) The two cores are the two core-density zones. One is the core-density zone centred on Henan Province and radiating to Shanxi and Shaanxi provinces; the other is the core-density zone of the Yangtze River Delta, centred on Jiangsu, Shanghai and Zhejiang provinces and radiating to Anhui Province.

2) The three centres represent three high-density zones: one with Shandong as its single core; another with Hubei as its core, comprising the three provinces of Sichuan, Chongqing, and Guizhou; and another with Guangdong as its core, comprising the two provinces of Guangxi and Hainan.

3) Multiple scattered points and stretches refer to some medium-density and low-density zones: the medium-density and low-density zones in the eastern region act as a continuous zone of high-value zones, showing a belt-like distribution with decreasing kernel density values; the distribution of medium-density and low-density zones in the central, southern, northeastern and northwestern regions are mainly in the form of scattered points.

Overall, the NLGCC spatial distribution is generally characterised by more of them in the east than in the west, a denser concentration in the south than in the north, and less of them inland in the northwest than on the southeast coast, mainly concentrated in the economically developed and natural resource-rich eastern region.
5. Factors influencing the spatial distribution of NLGCC

5.1. Natural environmental factors

5.1.1. Terrain and altitude

According to geographical classification, China’s topography can be divided into three main zones: plains, basins and plateaus (Zhou, Tian, & Jiang, 2018). Plains are generally well-watered and low in elevation; plateaus are wide and relatively flat; basins have high elevations around their rims and low in their centre. By overlaying the NLGCC with China’s altitude topographic maps (Fig. 6a), it can be found that: NLGCCs are mainly concentrated in plains at lower elevations, while there is almost no distribution in areas above 4,630m above sea level. This study shows a strong negative correlation between elevation and NLGCC spatial distribution. The elevation differential directly leads to the uneven spatial distribution of NLGCCs.

5.1.2. Hydroclimatic conditions

Climate significantly impacts human production and life and the formation of NLGCCs. In this research, China was divided into five major climate types, which were correlated with the spatial distribution characteristics of NLGCCs for analysis (Fig. 6b).

The subtropical and temperate monsoon climate zones have become the main geographical areas for the distribution of NLGCCs. With their relatively superior heat conditions and high precipitation, these zones also experience rain and heat in summer at the same time, which is conducive to afforestation and green space construction and provides better water and heat conditions for the development of urban gardening (H. Zhao, et al., 2019). The reasons for the low distribution of NLGCCs in other climatic zones vary: the alpine plateau climate zone is characterised by its high altitude, insufficient temperature accumulation and short period for plants to grow (Song, et al., 2015); the tropical monsoon climate zone, despite its abundant heat resources, accounts for a modest proportion of the total land area and has a small number of cities (Tian, Qiao, & Zhang, 2012); the temperate continental climate zone is characterised by dryness, low rainfall, sizeable inter-annual precipitation variations, and a lack of water resources limiting the expansion of green spaces in urban areas (Qu, Wang, Lin, Yu, & Yuan, 2020).

This configuration shows that the geographical differentiation of hydrothermal and climatic conditions is a fundamental factor in determining the NLGCC distribution pattern and presents strong constraints for the direction of spatial spread and the geographical scope of NLGCC expansion.

5.2. Socioeconomic factors

5.2.1. Population

The population geographic dividing line (Hu population division line) indicates China’s population development pattern from ancient
times to the present (North, 1994; Pan & Lai, 2019). The spatial distribution of NLGCCs is closely related to this dividing line (Fig. 6c), with a general pattern of decreasing distribution from east to west and concentrated distribution in local areas. According to the latest and seventh census data published by the China Statistics Bureau in 2020, the population of China is concentrated in the provinces of Shandong, Henan, Jiangsu, Zhejiang and Hubei, and a strong positive correlation can be seen when comparing a large number of NLGCCs in these provinces (K. Liu & Lin, 2019). The still growing population brings greater cultural exchanges and integration to the area. The history of migration and warfare has impacted the local culture, bringing about greater cultural development and the establishment of NLGCCs.

5.2.2. Historic garden heritage

NLGCCs constitute a new model of urban ecological civilisation reflecting Chinese specificities and the legacies of a traditional garden culture, whose development is rooted in history and influenced by the extent to which gardens have historically been successful in the region at stake. Using the Pearson’s correlation coefficient ($r_1 = 0.382$, significant at the 0.04 level), the number of heritage gardens and NLGCCs in each province were found to be moderately correlated. The scatter plot (Fig. 7) also shows an apparent spatial coupling between the distribution of NLGCCs and that of heritage gardens in China. South of the Yangtze River, the provinces of Jiangsu and Zhejiang are famous for their private gardens.

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Fig. 6. Overlay of NLGCC’s spatial distribution and driving factors. (a) Terrain and altitude; (b) Climate type zones; (c) Population density; (d) Urban agglomerations.

Fig. 7. Scatter plot of the number of historic gardens versus the number of NLGCCs by province.
of garden types and a high number of gardens, are famous as the main clusters of NLGCCs (Y. Shi, Ge, Chang, Shao, & Tang, 2013). Historic garden resources strengthen the material and cultural foundation of cities to build NLGCCs and cultivate the unique characteristics of each urban landscape.

5.2.3. Differences in the number of cities at the provincial scale

Local municipalities have to declare NLGCCs. The larger the base of cities in a given region is, the greater the number of potential NLGCCs to be named. By calculating the Pearson correlation coefficient for cities at the provincial scale and the number of NLGCCs, the study obtained a result of $r_2=0.841$ (significant at the 0.01 level), showing a strong correlation. In addition, spatial consistency between highly populated urban regions and the main distribution of NLGCC areas can be seen in a scatter plot (Fig. 8) and the overlay of the NLGCC and national urban agglomeration pattern map (Fig. 6d). The main urbanised areas, such as the Bohai Sea, the Yangtze River Delta and the Pearl River Delta, are as well as the agglomeration areas of the NLGCC. To some extent, the aggregation of NLGCCs is also shaped by the uneven spatial distribution of Chinese cities.

4.2.3. Level of economic development

Regional differences in economic development are also important factors influencing NLGCC spatial variations (F. Li, et al., 2018). To assess the impact of economic forces more precisely, the 2020 percentage of NLGCCs and per capita gross domestic product (GDP) in each province were selected as variables to measure the closeness of the linear relationship between the two (Table. 6). The Pearson correlation coefficient $r_3 = 0.573$ (significant at the 0.01 level) was calculated using SPSS software, indicating a strong correlation between the spatial distribution of NLGCCs and the level of economic development. This was due to two reasons:

1) In recent years, the criteria for selecting the NLGCC have shifted away from strictly controlling green space construction, which involves a large amount of capital investment, to integrating relevant resources. Economically developed regions have a clear advantage over less developed regions in terms of financial strength, and they benefit from better market mechanisms and a relatively high level of urban governance in the construction of their NLGCCs (Qi, Ma, Zhang, & Li, 2008).

2) To a certain extent, residents’ high level of income and consumption in economically developed areas, as well as their high demand for quality human environments, has contributed to the creation of NLGCCs in these areas.

6. Discussion

After introducing the origins and selection criteria of the NLGCC policy, this study first discussed empirical evidence on the importance and benefits of the NLGCC policy after its implementation. The study then used a combination of quantitative and qualitative approaches to analyse the NLGCC spatial distribution characteristics and the factors driving the policy.

Although there has been much research conducted on the importance of green space and open space in cities under COVID-19 conditions, studies have not covered actionable macro-policy experiences that have already led to relevant policy implementation. Therefore, this study has analysed the NLGCC policy, one of the most critical development models for urban habitat construction implemented in China over the last 30 years, and dissected the changes occurring in its selection criteria and in its implementation benefits after COVID-19. The results show that it is precisely the implementation of the NLGCC policy that has had a significant effect on the response to the ecological and environmental crisis and on its potential benefits for the prevention and control of public safety crises (O. Y. Liu & Russo, 2021). However, together with public open spaces, urban green spaces are found to be essential for building sustainable and resilient cities and for providing essential social benefits for the health and well-being of urban residents (Beckmann-Wübbelt, et al., 2021; K. Liu & Lin, 2019; Schrammeijer, van Zanten, & Verburg, 2021). Therefore, in its latest edition of selection criteria (issued in March 2022), the Chinese government added an up-to-date assessment of the spatial resilience of cities. Hopefully, this new data will encourage both additional city governments, which are not on the list yet, and those already there to further focus on the creation of composite spaces for disaster prevention and ecological environment protection in their future urban development to maximise the role of urban management capacity in responding to sudden disasters. Importantly, because policy formulation is closely related to the political characteristics and institutional features of a particular country, the Chinese experiment cannot be fully replicated nor applied in other countries. For example, previous research has shown that, on an international scale, countries have begun to generally recognise access to green space as an environmental justice issue (Wolch, Byrne, & Newell, 2014). In China’s specific national context, it is the central government that takes primary control over the supply of land, supplemented by necessary market incentives and the involvement of civic organisations. However, the building of resilient and sustainable cities through policy guidance is feasible and necessary worldwide. Policy-makers should formulate sustainable development policies according to their specific national conditions.

The NLGCC spatial distribution characteristics and driving factors analysis carried out in this study shows that the construction and spatial distribution of the NLGCC is the result of an interactive coupling of natural binding forces, socioeconomic driving forces and government administrative forces. Specifically, the constraint emerging from geographical differences in natural conditions, such as water, heat, climate and altitude, frame the basic pattern of NLGCC spatial distribution. Socioeconomic drivers such as historical garden resources, differences in the number of cities at the provincial level, and population base, further reinforce the unevenness of the basic pattern. The standard-setting and accreditation powers of the authorities and the decision-making and organisational power of lower-level city governments together constitute the administrative power of the government to adjust the spatial distribution and creation of NLGCCs. This finding provides policy-makers and implementers worldwide with a practical example of how policies can guide cities in the development of green
space and public open space according to local conditions.

This study also provides several policy implications for constructing settlement areas in China. Results show that differences in economic power are an important factor in the uneven spatial distribution of NLGCCs, which is due to China’s high regional development inequality (Jain-Chandra, et al., 2018). The eastern region is more developed than the central and western regions. This observation suggests that the lagging economy of the central and western regions has become a barrier to the promotion of green spaces and the creation of public open space. Therefore, improving habitat and building resilient cities in the central and western regions requires promoting economic development and alleviating economic inequalities between regions.

This study still has many shortcomings:

1) It does not go far enough in analysing the selection criteria and postimplementation benefits of the NLGCC policy. In the future, as China’s NLGCC policy continues to advance, quantitative analysis can be used to further assess its relevance.

2) The driving factors influencing the distribution of NLGCCs are still mainly explored qualitatively. However, different driving factors can show spatial heterogeneity across provinces, with some of them even having synergistic or antagonistic effects. In subsequent studies, the combined analysis of the contribution each factor makes to the spatial distribution and construction of NLGCCs can be increased to enhance the quantitative analysis.

3) The level of awareness, motivation and mobilisation of local governments and their key leaders will often affect the creation of NLGCCs. For example, Xinjiang is located in the inland arid zone of northwest China. In such a particular geographical context, the spatial distribution of Xinjiang’s cities is determined by its unique natural environment. Because of these urban development characteristics, Xinjiang’s government has strongly supported the development of a unique oasis-city model since the last century. This policy has helped numerous cities in Xinjiang build urban green infrastructure and accede to the NLGCC list. As the NLGCC nomination process continues, the cities on the NLGCC list will be explored in more detail to reveal the policy-driven mechanisms behind the overall distribution pattern of NLGCCs and the evolution of intracity landscaping patterns.

7. Conclusions

The NLGCC is one of the most vital development models for improving the urban ecological environment and promoting habitat construction in China. This research discussed the selection criteria, importance, and benefits of the NLGCC policy after implementation. It used GIS spatial analysis methods and SPSS analysis tools to analyse the factors driving the NLGCC by exploring their spatial distribution characteristics. The conclusions follow:

1) The NLGCC policy selection criteria evolved from the initial focus on urban green growth and landscape indicators to an increasingly diverse and comprehensive assessment content that now encompasses urban ecological and environmental quality, habitat livability, spatial resilience, and the uniqueness of urban landscapes. This new orientation reflects China’s increased emphasis on the harmonious development of nature, economy and society in the urbanisation process, as well as its continued pursuit of increased urban resilience and sustainable development.

2) The significance of the NLGCC and the benefits of its implementation are discussed in terms of energy savings and emission reduction, the protection of ecosystems, the improvement of the construction of green space and public open space systems, and the improvement of disaster prevention capacity in cities. The NLGCC policy can provide a solution for other high-density cities to deal with ecological and public safety crises.

3) The spatial distribution of NLGCCs is uneven, showing prominent spatial clustering characteristics. On a national scale, the NLGCC is bounded by the Hu population division line, with a cohesive distribution of dense in the east and sparse in the west. The eastern side of the Hu population division line accounts for 90.08% of the total. The NLGCC is distributed in contiguous areas at the regional scale, forming two core-density areas with the most extensive radiation range, three high-density areas with larger radiation ranges, and several low-core areas. At the regional scale, the NLGCC spatial distribution density varies greatly, with Zhejiang, Jiangsu and Henan showing higher distribution densities. In contrast, Tibet, Inner Mongolia and Xinjiang show lower distribution densities.

4) The formation and evolution of the spatial pattern of the NLGCC are driven by a combination of socioeconomic and natural environmental factors. Among the socioeconomic factors, population and city density, per capita GDP and the number of heritage gardens are the main influencing factors; among the natural environmental factors, topography, hydrology and climate also influence the spatial structure characteristics of the NLGCC to varying degrees.

With the establishment of the NLGCC, China’s urban greening has progressed significantly in quantity and quality, while also demonstrating diversity and richness in greening effectiveness. Along with its continued urbanisation, China is also making other theoretical and practical innovations in urban ecological governance. Historically, each public health and environmental crisis has brought about a shift in values and a rethinking in the construction of human settlements. While the COVID-19 pandemic is still a serious matter, it is essential to research...
the NLGCCs and other experimental urban development sites to generate new ideas and responses for cities worldwide to better address ecological and public safety crises.

From a macroscopic perspective, this research analyses the spatial distribution characteristics and driving factors behind the NLGCC at several geographical scales and is essential for the scientific understanding of the geographic and spatial distribution of NLGCCs. The study provides practical knowledge for other high-density cities to improve their urban resilience and move towards the goal of sustainable development.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

The authors do not have permission to share data.

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