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Study on Spatial Evolution of Chinese Green Building

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Study on Spatial Evolution of Chinese Green Building

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Abstract. Green building is an important part of ecological civilization construction in China, which is also a significant reflection of national developing under a new type of urbanization [1]. Since 2006, the number and total gross floor area of green building has achieved major development with the promulgation and implement of national and local standards and promotions of green building. However, this rapid development shows an obvious regional difference and imbalance. This paper conducts a quantitative study by using geospatial statistics theory and geographic information system technique. It aims to explore characteristics and the driven factor of green buildings' spatial evolution so that the development level of green building could be evaluated based on much more scientific and reasonable method. It also aims at providing theory supporting as well as reference for policy making to stimulate green building development in a more balanced way.

1. Literature Review

Green Building is generally considered as one of the most significant strategies to cope with problems regarding global warming and energy crisis in China [2]. In 2006, the first national *Assessment standard for green building standard GB/T50378-2006* was published, followed by gradually increased practical projects on green building. By the time of April 2008, China officially began to adopt the green building evaluation and labelling system [3]. For decades, along with the promulgation and implement of national and local standards and incentive action plans of green building, its scale has been promoted rapidly. Therefore, buildings built according to the related standards and obtained green building certificate have become the mainstream in construction field [3]. In 2017, Ministry of Housing and Urban-Rural Development made stimulating the large-scale development of green building one of the major tasks in the “13th Five-Year Plan of Construction Industry”. It also explicitly set up a goal which required green buildings would account for 50% of the new buildings in urban and rural area by 2020 [4].

From 2011 to 2015, the total amount of green building project that achieves China green building label (hereinafter referred to as green building) throughout the country increased enormously from 352 to 4055¹. As shown in Figure 1, Chinese provinces experienced continuously growth in green building. However, the evaluation of the development of green building mainly depends on preliminary indexes such as projects amount and gross floor area, which is lack of science and rationality in a certain extent[2]. Furthermore, Figure 1 obviously indicates that green building mainly distributes over

¹ This statistic data excludes Hong Kong, Macao, and Taiwan district.



developed eastern coastal district such as Jiangsu, Guangdong, Shanghai and Zhejiang, which leads to an imbalanced development trend around the whole country. Since the development of green building is a process that expends along with time and space, studying its temporal and spatial distribution as well as evolution characteristics helps to measure the development level of green building scientifically and reasonably. More importantly, it also provides reference for further improvement of assessment standard and incentive policy on green building.

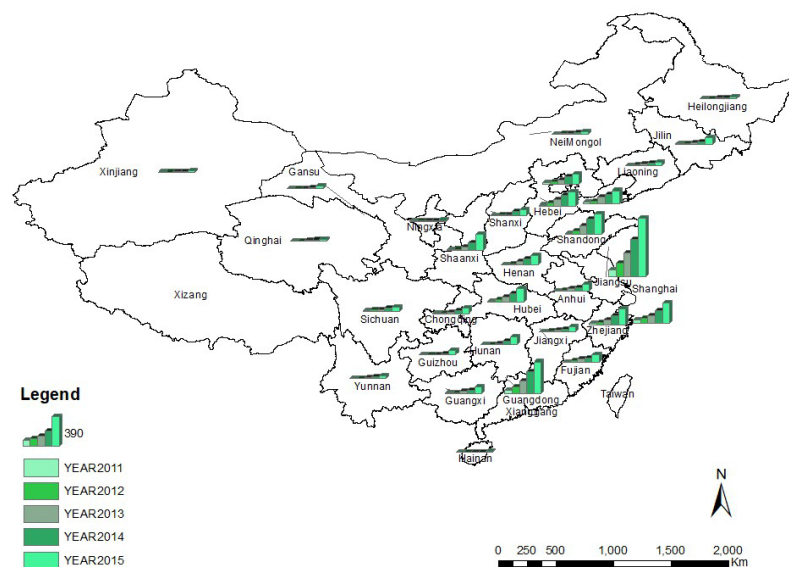


Figure 1. The number of green building in each province from 2011 to 2015; the number of green buildings increased year by year in each province.

In recent years, experts and scholars have begun to explore the geographical distribution of green buildings and its driven factors. But there is still relatively inadequate studies and outcomes on this subject. Stanley Yep conducted research on the geographical distribution of green buildings with different star-ratings as of the end of 2011 and analysed the cause of formation, pointing out that the imbalance geographical distribution of green buildings results from the different market acceptance level in each city. What's more, the variety of market expected value was due to the difference of economy and real estate market between cities [5]. Wei Zhang measured the spatial distribution of green building industry by the end of 2012 with both static and dynamic analyses and found that most green building occurred developing trend from centralized distribution in coastal cities moving further into inland district. His analysis revealed that the main constraint that affected the aggregation of green building industry was GDP and administrative force of the local government, and obviously administrative force played a leading role in the two factors [6]. Yao Jia used Theil Index to measure the spatial difference of the development of various levels of green buildings in China by the end of 2013. In his research, he selected GDP and real estate's added value as weight factors, concluded that green buildings' development level is closely related to the local economic development level. Moreover, Theil Index based on GDP can reflect the spatial difference of green buildings' development in China more clearly [7]. Baoxing Qiu et al. used Coefficient of Variation, Concentration Ratio, Gini Coefficient, Location Entropy, Moran Index and Getis-Ord Gi to calculate the spatial differentiation, overall aggregation and spatial correlation of buildings that achieved China green building label or LEED certificate, which revealed the spatial evolution law of green buildings in China [8].

2. Study Method and Data Source

2.1. Study Method

2.1.1. Global Spatial Autocorrelation Model.

(1) Global Moran's I

In this study, Global Moran's I is used to analyze global spatial autocorrelation. It aims at finding out whether China's green building development has aggregated discrete or stochastic distribution. The calculation method of Moran's I is shown in Formula (1). Its value range is from -1 to 1. When Moran's I is less than 0, it indicates that the development of green building is negative spatial autocorrelation; when Moran's I equals 0, there is no spatial autocorrelation; when Moran's I is greater than 0, it proves green building's development is positive spatial autocorrelation.

$$I = \left(\frac{n}{\sum_i \sum_j w_{ij}} \right) \left(\frac{\sum_i \sum_j w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_i (x_i - \bar{x})^2} \right) \quad (1)$$

Where: n – the total number of location units;

x_i, x_j – observed value of the i -th or j -th unit;

w – space matrix;

\bar{x} – average observed value;

(2) Geary's C

Geary's C is also one of the important indicators for testing global clustering, and its value range is from 0 to 2. When Geary's C is between 0 and 1, the spatial autocorrelation is positive; when Geary's C equals 0, there is no spatial autocorrelation; when Geary's C is between 1 and 2, the spatial autocorrelation is negative. A comparison between Geary's C and Moran's I was used to verify the validity of the conclusion of spatial autocorrelation.

2.1.2. Local Spatial Autocorrelation Model. In order to further analyze the extent of green building's local aggregation, local spatial autocorrelation model called Anselin Local Moran's I was adopted. The calculation method is as the following Formula (2). Results of Anselin Local Moran's I can be divided into four situations: the High-High Cluster (HH), High-Low Cluster (LH), Low-Low Cluster (LL) and High-Low Cluster (HL) zones. HH zone is the high value aggregation area, which means it has only a small spatial difference compared with its surroundings. There is a strong positive spatial autocorrelation in HH zone. LH and HL zones are highly different from their surroundings, which leads to a negative spatial autocorrelation and prominent spatial heterogeneity. LL zone itself and its surroundings are both low values, which means there is not a large spatial difference. LL zone shows a positive spatial autocorrelation, and it's also the blind spot area.

$$I_i = \frac{x_i - \bar{x}}{S_i^2} \sum_{j=1, j \neq i}^n w_{i,j} (x_j - \bar{x}) \quad (2)$$

$$S_i^2 = \frac{\sum_{j=1, j \neq i}^n (x_j - \bar{x})^2}{n-1} - \bar{x}^2 \quad (3)$$

Where : n – the total number of location units ;

x_i, x_j – observed value of the i -th or j -th unit ;

$w_{i,j}$ – spatial weight between i and j ;

\bar{x} – average observed value;

2.1.3. Correlation Analysis. In this study, correlation coefficient is used to measure the intensity of correlation variation between selected macroeconomic indicators and the number of green building projects. The range of correlation coefficient is from -1 to 1. The closer the absolute value is to 1, the stronger the correlation is.

2.2. Data Source

The data of the number of green building projects with certificate was derived from Statistical Report on the Green Building Evaluation Certificate [9–13]. It was also checked based on the website of “Green Building Map” [14] created by China Academy of Green Building Research Shanghai Branch. The macroeconomic data was obtained from the National Bureau of Statistics of China. In view of the procurability of data and computability of the geographic information model, the research period was from 2011 to 2015. Tibet was removed from this study because it did not develop any green building project during that time. Hong Kong, Macao and Taiwan were also excluded in the scope of the study. In addition, considering that the development of green building was a dynamic process and the number of green building projects would increase along with time, therefore the accumulation number of all green building projects by the end of the research year was used in model calculation to represent the total amount of the projects, and the macroeconomic data of each region is from annual statistic generated by National Bureau of Statistics.

3. The Spatial Development Characteristics of Green Building

As Figure 1 shown above, the geographical distribution of green building showed a certain clustering feature. Most of the projects were concentrated in eastern costal developed area, and relatively small part of them can be found in the less developed area such as central and western China. However, the amount of projects with Green Building Evaluation Certificate grew with an increasing speed in central China, which weakened the imbalance between different regions. This study analysed whether the direct geographical distribution imbalance was spatially correlated, and then conduct a deeper research on the causes and relevance of this spatial relationship based on the that.

3.1. The Spatial Correlation of Green Building

By calculation, the Moran's I of green building projects in each year from 2011 to 2015 was shown in Table 1. It can be concluded from the analysis that the provinces with large scale of green building development on the provincial scale were randomly distributed in space, and their spatial correlation between other provinces was not large.

Table 1. Global Moran's I results of green building projects in each year from 2011 to 2015.

Year	Moran's I	Z score	P value	Geary's C	Z score	P value
2011	0.0147	0.9246	0.3552	0.5340	2.0462	0.0407
2012	0.0470	1.6489	0.0992	0.5642	2.6652	0.0077
2013	0.0706	2.1498	0.0316	0.5747	3.1064	0.0019
2014	0.0661	2.0120	0.0442	0.5553	3.1030	0.0019
2015	0.0541	1.7894	0.0735	0.5406	3.0909	0.0020

3.2. Positive Spatial Correlation of Green Building

In this study, Anselin Local Moran's I was used to find out the local spatial correlation of the number of green building projects, and Figure 2 and 3 are the result of each province from 2011 to 2015. First, it is not hard to tell from the Figure, Jiangsu and Shanghai are both in the HH zone, which means the two had a strong positive spatial correlation and maintained a good development during the research period. They not only had an increasing number of green building of their own but also achieved a synergy development with each other. Second, Shandong started to appear in the HH zone in the year of 2013. As can be seen in Figure 4, the total amount of Shandong's green building projects grew up to 109 and ranked the third in China in the same year. The reason for its fast development was due to the promulgation of *Implementation Opinions on Promoting Green Building Actions* in 2013, which positively pushed the development of green buildings in Shandong. Then in the year of 2014, it became mandatory that all the new built government office buildings and large public buildings had to meet the

requirements of lowest level of green building rating system, one-star label. This regulation and a series of supporting incentives greatly promoted the rapid development of local green building scale. Third, the only high value area that was surrounded by low value area was Guangdong. Over years, its own green building development had kept a good growth rate. However, the calculation results proved that the advantage of Guangdong did not drive the development of its neighbouring area such as Guangxi, Hunan, Fujian and Jiangxi very well. There was no obvious synergistic or driving effect among them.

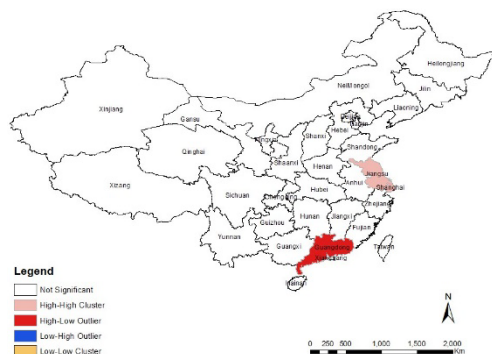


Figure 2. Local spatial correlation analysis of the number of green building projects in 2011 and 2012.

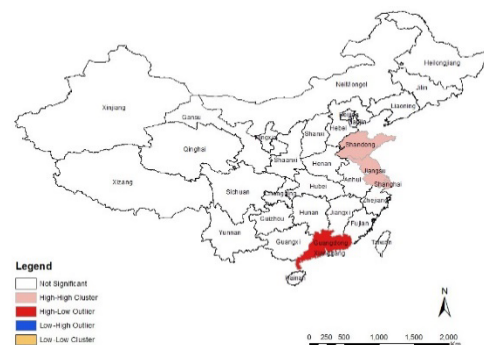


Figure 3. Local spatial correlation analysis of the number of green building projects in 2013, 2014 and 2015

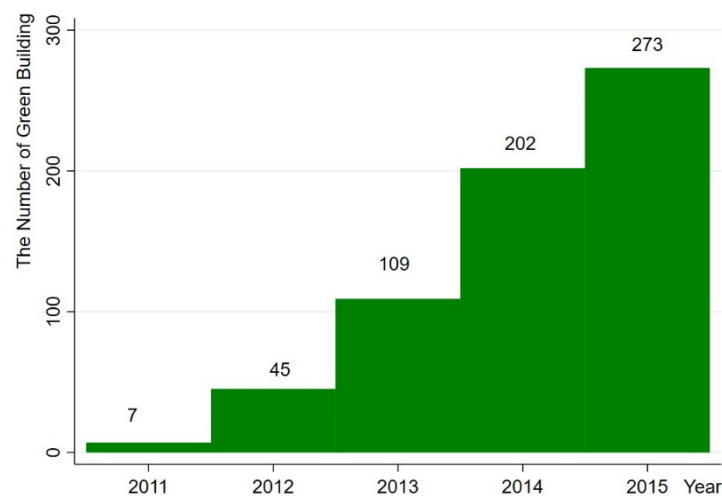


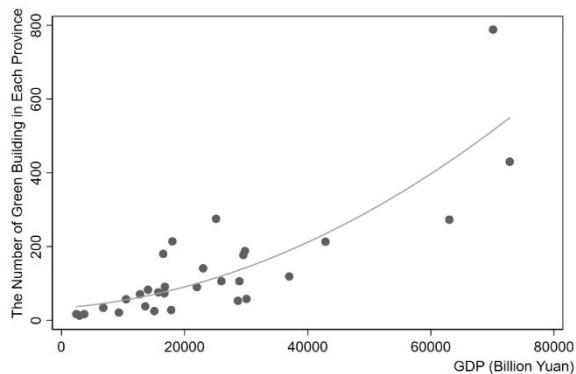
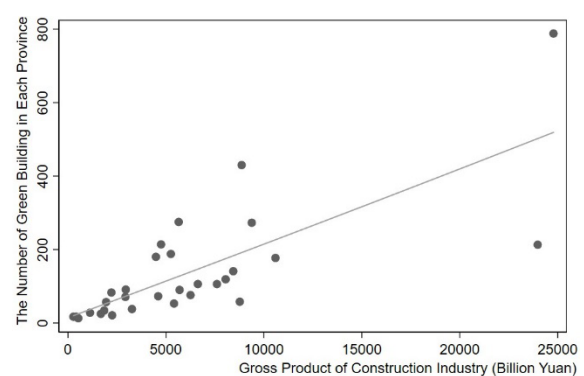
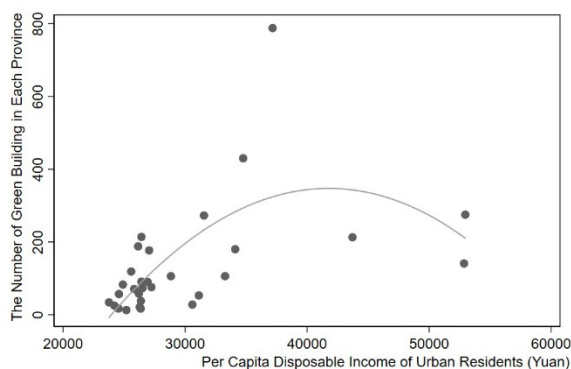
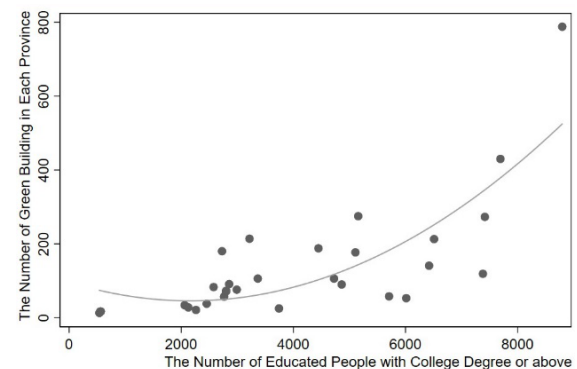
Figure 4. The number of green building in Shandong from 2011 to 2015.

3.3. Driving Factors of Green Building's Spatial Distribution

Four macroeconomic and social factors were selected in this study, including gross national product (GDP), gross product of construction industry, per capita disposable income of urban residents, and the number of educated people with college degree or above, to analyze if they were related to the spatial distribution of green building. According to the correlation analysis model, the relationship between the number of green building projects and those 4 factors were measured respectively. The correlation coefficients are listed in table 2. Taking 2015 as an example, the results are shown in Figure 5 to 8.

Table 2. The correlation coefficients of relative relationship analysis between 4 social and macroeconomic factors and green building number

Year	Correlation coefficients value			
	GDP	Macroeconomic factor Gross product of construction industry	Social factor Per capita disposable income of urban residents	the number of educated people with college degree or above
2015	0.72	0.57	0.41	N/A
2014	0.76	0.55	0.43	0.67
2013	0.71	0.56	0.44	0.51
2012	0.70	0.54	N/A	0.61
2011	0.50	0.49	N/A	0.49

**Figure 5.** Relative relationship between the number of green buildings and GDP in 2015; the correlation coefficients was 0.72.**Figure 6.** Relative relationship between the number of green buildings and gross product of construction industry in 2015; the correlation coefficients was 0.57**Figure 7.** Relative relationship between the number of green buildings and per capita disposable income of urban residents in 2015; the correlation coefficients was 0.41.**Figure 8.** Relative relationship between the number of green buildings and the number of educated people with c in 2014 (no data could be found in 2015 therefore herein use data in 2014.); the correlation coefficients was 0.67

As shown from Figure 5 to 8, the 4 chosen factors have a positive correlation with the number of green buildings to a certain extent. First, from the perspective of regional economic development level, GDP

and the gross product of construction industry were strongly correlated with the number of green building projects, and the correlation coefficients were 0.72 and 0.57. It was due to green building projects' incremental cost compared with conventional projects. When a city had stronger economic strength and more well developed industries, it can support the construction of green building better. Thus, this kind of regions usually had relatively larger amount of green building projects. GDP normally represented the overall economic strength of a region. By the same token, the total production value of the construction industry showed the scale of production in the industry. The Figure 9 reflects the geographical distribution of GDP of different provinces in 2015. It could be found directly how GDP's spatial asymmetry influenced the spatial distribution of the number of green building projects. For example, green building projects were more concentrated in places that had high GDP such as Beijing-Tianjin-Hebei, Yangtze River Delta and Pearl River Delta.

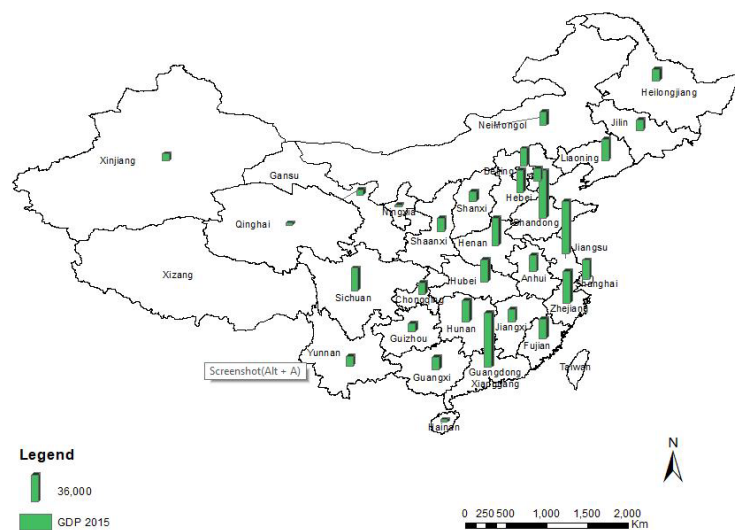


Figure 9. GDP in each province in 2015.

Besides, from the view of residents' living standard and overall education level, per capita disposable income of urban residents and the number of educated people with college degree or above were both positively correlated with green building's development. The latter one had a closer relationship with green building because its correlation coefficient was up to 0.67. The conclusion showed that due to the reason that green building had not yet been marketized, even if the per capita disposable income of urban residents had increased year by year, people were less willingly to choose green building actively, which meant its market acceptance was expected to be improved. The conclusion also reflected that the higher the overall education level was; the easier people can accept the concept of green building. Therefore, they'd love to pay for it more possibly, which simulated the development of green building largely.

4. Conclusion and Suggestion

4.1. Conclusion

By exploring the spatial difference of China's green building development, the following findings were summarized: (1) at the provincial scale, the provinces with better green building development were randomly spatially distributed, and their spatial correlation with other provinces was not strong. (2) most positive correlation of green building scale was observed in the Yangtze River Delta, which this district generated significant synergistic and diffusion effect. Although Guangdong developed rapidly, its neighbouring provinces had low value clusters, which means development in surrounding provinces may be more restricted by economic and technical conditions. (3) differences in economic conditions and the development level of the construction industry between various provinces were important factors affecting the development of green buildings on a large scale. The disposable income and education level of residents would also influence the acceptance of green buildings and its market expectancy,

which in turn led to a significant spatial distribution difference in green building amount of all provinces. (4) national and local government's policy guidance and promotion were still the main driven force for green building development, and the market's promotion role under market economy conditions was still relatively not obvious.

4.2. Suggestions

First, the development of green building is a continuous temporal and spatial expansion. Therefore, the measurement of green building's development level shouldn't depend on only simple indicators such as projects' quantity or gross floor area. Much more attention should be paid to the issue of spatial imbalance and the behind driven factors. A proper goal needs to be set based on the local social and economic development levels. Second, government's policy has a great impact on the green building development in China. It is recommended to scientifically formulate standards and reasonable incentives based on a comprehensive analysis of local economic and social development levels. Third, we suggest to gradually improve the market mechanism and turn green building from a government-led to a market-driven behaviour. At last, it is recommended to enhance the overall quality of the local residents by strengthening public education and awareness, so that residents can easily understand green building benefit and be willing to pay for environmental protection. Furthermore, it will increase market demand and promote green building development on a large scale in China.

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