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Characterize Innovative Space of City Based on Multivariate Data: A Case Study of Guangzhou, China

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Abstract: With the emergence of knowledge economy, innovation has evolved as the principal driver of economic development. In the subjects of economic geography and urban planning, the relationship between innovation and place has been a research focus. The purpose of this research is to explore the method of characterizing the spatial distribution of innovative activities in city. Four types of indexes are selected to characterize the innovative space in city: universities and scientific institutions, high-tech enterprises, incubators and patents, which come from three aspects: innovative actors, innovative carriers and innovative outputs. Using these indices, this research characterizes the pattern of the innovative space in Guangzhou. The findings show that the spatial distribution of innovative activities in Guangzhou forms two centers: Tianhe central area and Guangzhou Science City. In Tianhe central area, there are not only a large number of the actors of original innovation but also a large number of the actors of applied innovation, so its innovative mode is the mixed mode including both original innovation and applied innovation. Unlike Tianhe central area, Guangzhou Science City is a suburban high-tech park, which aims to cultivate the high-tech enterprises to promote the development of high-tech industry, so its innovative activities are mainly applied innovation.

Keywords: Innovative Space, Spatial Distribution, Innovation, Multivariate Data, Guangzhou

1. Introduction

Since the industrial revolution, with continuous innovative activities, human society has gradually entered the era of knowledge economy. The innovation has become the first driving force of development. It can be said that almost all economic growth since the 18th century is ultimately due to innovative activities [1].

In 1911, Economist Schumpeter, J. first put forward the theory of innovation in *the theory of economic development*. He proposed that the innovation is the fundamental driving force of economic development [2]. Therefore, the research of innovation was initially concerned in the field of economics. Then, the research of innovation has been concerned by the field of economic geography and urban planning. As the subject of economic geography and urban planning pay attention to space research, the related researches mainly focus on the relationship between innovation and space.

This research aims to explore the method of characterizing the spatial distribution of innovative activities in city. This research successfully constructs the characterizing method based on multivariate data including innovative actors, innovative carriers, innovative outputs, and takes Guangzhou as a case for empirical research.

2. Literature Review and Research Object

Economist Schumpeter, J. first put forward the theory of innovation in 1911 and identified innovation as the critical dimension of economic change. The innovation is called “creative destruction” by him. According to Schumpeter, J., the "gale of creative destruction" describes the "process of industrial mutation that continuously revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one".[2].

However, until the 1950s, the theory of innovation has not been widely concerned in academic circles. After the 1950s, with the technological revolution brought by

microelectronics, the economy of many countries has experienced long-term and rapid growth. This phenomenon can no longer be simply explained by the elements such as capital and labor that the traditional economic theory emphasizes. Therefore, the economists began to pay more attention to the theory of innovation that Schumpeter J put forward. And, the related researches formed neo-Schumpeterian economics [3, 4].

Neo-Schumpeterian economics develops the theory of innovation into two branches: economics of technological innovation and economics of institutional innovation [5]. They explore the role of innovation in economic growth from different perspectives. The former emphasizes the role of technological innovation [6], while the latter emphasizes the role of institutional innovation [7]. The innovation that is referred in this research is technological innovation, which includes the original innovation for the purpose of scientific research and the applied innovation for the purpose of industrial development [8].

After the 1990s, the research of innovation has been concerned by the schoolers of economic geography and urban planning [9]. As the subject of economic geography and urban planning pay attention to space research, the related researches mainly focus on the relationship between innovation and space. As a result, characterizing the spatial distribution of innovation activities become an important research direction [10].

However, the existing research on the spatial distribution of innovative activities mainly focuses on the macro level, such as the global distribution of innovative activities [11] and the distribution of innovative activities in Europe [12]. For example, 2thinknow constructs the evaluation system of innovative cities, which includes 162 indexes. And every year, it evaluates the innovative achievement of cities all over the world and publishes the report named *Innovation Cities™ Index* (1). According to the level of the innovative achievement, 2thinknow divides cities all over the world into four classes: nexus cities, hub cities, node cities and upstart cities. Based on this, some literatures have studied the global distribution of innovative activities. The researches show that the hub innovative cities are highly concentrated in developed countries such as the United States and Western Europe, and it can't be ignored that the innovative centers of Asia Pacific countries such as China are rising [13, 14].

In recent years, with the development of analysis methods based on big data, some research began to pay attention to characterizing the spatial distribution of innovative activities in city [15]. However, most literature just use the location of patents to characterize innovative space. For example, Duan, D. Z. et al., Zhang, Z. et al. and Ma, S. et al. use the data of patents to characterize the spatial distribution of innovative activities in Beijing and Shanghai [16-18]. However, patents mainly reflect the outputs of innovative activities. If it expands the types of indexes and uses multivariate data for analysis, it can more accurately and richly reflect the spatial distribution of innovative activities in city. Therefore, this research aims to explore the characterizing methods of innovation space in city based on multivariate data.

3. Index and Analytical Method

3.1. Index

According to the characteristics of the national innovation system in China, this research selects the following indexes characterize the innovative space in city: universities and scientific institutes, high-tech enterprises, incubators, patents. These indexes come from three aspects: innovative actors (including the actors of original innovation and the actors of applied innovation), innovative carriers and innovative outputs. (Table 1)

Table 1. *Index types and the quantity in Guangzhou.*

Target	Index	Quantity in Guangzhou
innovative outputs	patents	961,216
the actors of original innovation	universities and scientific institutes	83+189
the actors of applied innovation	high-tech enterprises	7,808
innovative carriers	incubators	405

3.1.1. The Data of Universities and Scientific Institutes

Universities and scientific institutes are the main actors of original innovation. Firstly, obtain the list of universities in Guangzhou by "sunshine university entrance examinations" website of Ministry of Education of the People's Republic of China (MOE) (2). There are 83 universities in Guangzhou, including 37 undergraduate universities and 46 junior universities. Secondly, obtain the list of scientific institutes in Guangzhou by QCC website (3). There are 189 scientific institutes in Guangzhou. Among them, 13.76% are established by the central government, 52.39% are established by the provincial government, 19.04% are established by the municipal government and 14.81% are established by the district government.

3.1.2. The Data of High-Tech Enterprises

Enterprises are the main actors of applied innovation. In China, Ministry of Science and Technology of the People's Republic of China (MOST) establishes the certification system of high-tech enterprises. According to *the management measures for the recognition of high-tech enterprises* issued by MOST, a certified high-tech enterprise needs to meet the following conditions: a) It must focus on the high-tech field advocated by the state; b) It must continue to carry out R&D activities and transformation of science-technology achievements; c) It must have the own achievements protected by intellectual property rights and uses them to do business; d) It must be registered in China for more than one year. MOST recognizes high-tech enterprises every year and forms the

record database. This research selects high-tech enterprises certified by MOST as indexes to represent the actors of application innovation. This research obtains the list of high-tech enterprises in Guangzhou from the science-technology database of Department of Science and Technology of Guangdong Province (4). There are 7,808 high-tech enterprises certified by MOST in Guangzhou.

3.1.3. The Data of Incubators

Incubators are service institutions for cultivating enterprises. In China, the government departments of science and technology establish the certification system of incubators. According to *the management measures for the recognition of incubators* issued by MOST, a certified incubator needs to meet the following conditions: a) It must devote itself to cultivate science-technology enterprises and promote the transformation of science-technology achievements; b) It can provide physical space, shared facilities and professional services for the enterprises. MOST, Department of Science and Technology of Guangdong Province and Guangzhou Municipal Science and Technology Bureau respectively certify national-level, provincial-level and municipal-level incubators. This research obtains the list of the incubators in Guangzhou from the data open platform of the People's Government of Guangzhou Municipality (5). There are 405 incubators certified by the government departments of science and technology in Guangzhou.

3.1.4. The Data of Patents

Patents play important roles in the process of innovative activities, which can directly reflect the innovative outputs. At present, it is a consensus that patents can be used to characterize the spatial distribution of innovative activities. The data of patents used in this research comes from the system of patent search and analysis of China National Intellectual Property Administration (CNIPA) (6). This research obtains the data of patents in Guangzhou from January 1, 2000 to December 31, 2020 by using self-made program. There are 961,216 data in total, including application number, applicant, applicant address and other information.

3.2. Analytical Method

The first step is to add the coordinate information to the indexes. Based on the address of patents' applicants, the name of scientific institutes, the name of high-tech enterprises and the name of incubators, this research uses Amap API (7) to obtain their GCJ-02 geographic coordinate information.

The second step is to establish the database. Use Arc GIS to convert the GCJ-02 geographic coordinate information into the WGS-1984 plane coordinate information and add the data of the administrative boundary of Guangzhou.

The third step is spatial analysis. Use Arc GIS to carry out the analysis of nuclear density or the analysis of grid count, which can intuitively reflect the spatial distribution of innovative activities in Guangzhou.

4. Analysis and Outcomes

4.1. Overview of Guangzhou

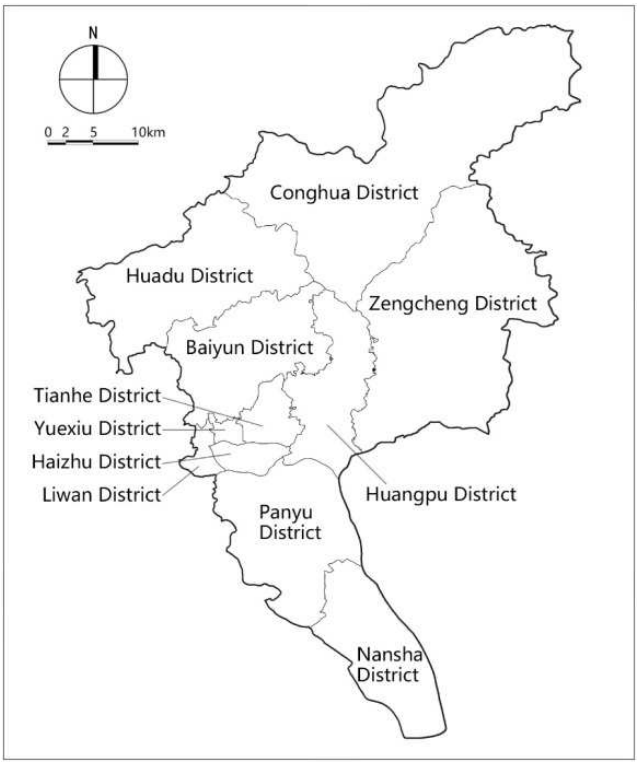

Figure 1. *The Administrative Division of Guangzhou.*

Guangzhou is located in the Pearl River Delta in southern China. Guangzhou is the capital of Guangdong Province and one of the five national central cities in China (Beijing, Tianjin, Shanghai, Guangzhou and Chongqing). By 2021, Guangzhou is made up of 11 boroughs (Figure 1), its land area is about 7,434 square kilometers and its population is about 19 million. In 2021, the GDP of Guangzhou is about 4,280 billion dollars, and its GDP per capita is about 23,000 dollars. According to *the evaluation report on innovative capability of cities in China (2021)* published by Institute of Scientific and Technical Information of China (ISTIC), the innovative ability of Guangzhou ranks third among all cities in China.

4.2. Spatial Distribution of Universities and Scientific Institutes

The universities and scientific institutes in Guangzhou are mainly located in Tianhe District and highly concentrated in Wushan-Shipai area (Figure 2). In the 1930s, Sun Yat-sen promoted the construction of the university town in Wushan-Shipai area, where Sun Yat-sen University (SYSU) was established. After the founding of the People's Republic of China (PRC) in 1949, based on SYSU, the government built a number of universities in Wushan-Shipai area, such as South China University of Technology (SCUT), South China Agricultural University (SCAU), South China Normal University (SCNU), Jinan University (JNU), etc. At the same time, the government has set up a large number of scientific

institutes in Wushan-Shipai area, such as the Fifth Research Institute of Ministry of Industry and Information Technology of the People's Republic of China (MIIT), Guangdong Academy of Agricultural Sciences (GDAAS), Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences (GIEC), etc.

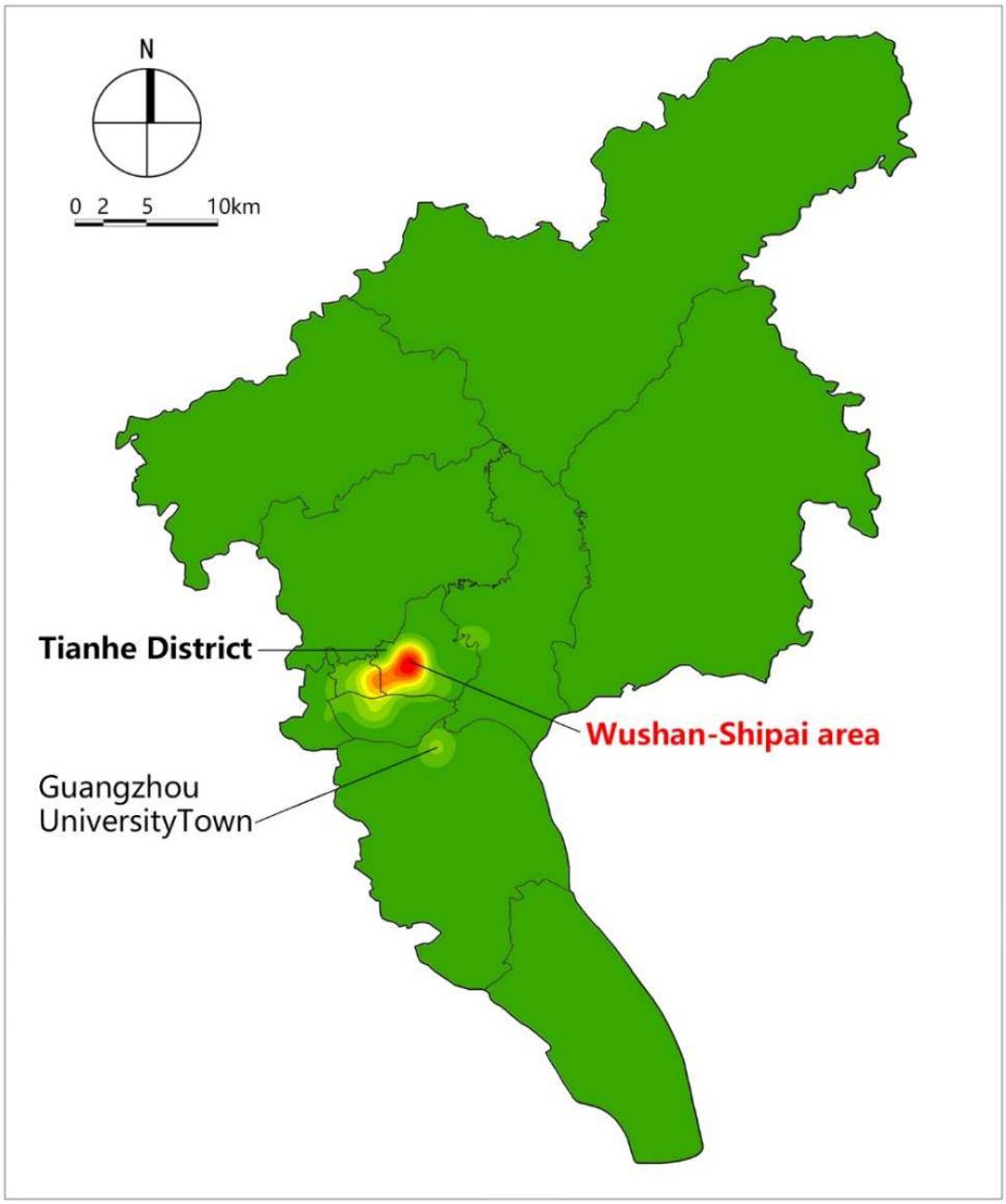

Figure 2. *The Spatial Distribution of Universities and Scientific Institutes in Guangzhou.*

4.3. Spatial Distribution of High-Tech Enterprises

The spatial distribution of high-tech enterprises in Guangzhou has formed two centers (Figure 3).

The first center is Tianhe central area. In 1991, Guangzhou set up Tianhe High-tech Industrial Development Zone and established Wushan Science-technology Street in Wushan-Shipai area. It aims to promote the development of high-tech industry by relying on the R&D resources of universities and scientific institutes in Wushan-Shipai area. After more than 30 years of development, Tianhe central area has become the high concentration area of high-tech enterprises in Guangzhou.

The second center is Guangzhou Science City. Guangzhou Science City is a suburban high-tech park, which the government began to construct in 1998. From the beginning, Guangzhou Science City learned from world-famous high-tech parks such as Silicon Valley and Hsinchu Science Park. Its goal is to cultivate the high-tech industries to promote the development of high-tech industries. After more than 20 years of development, a large number of high-tech enterprises have been successfully incubated in Guangzhou Science City.

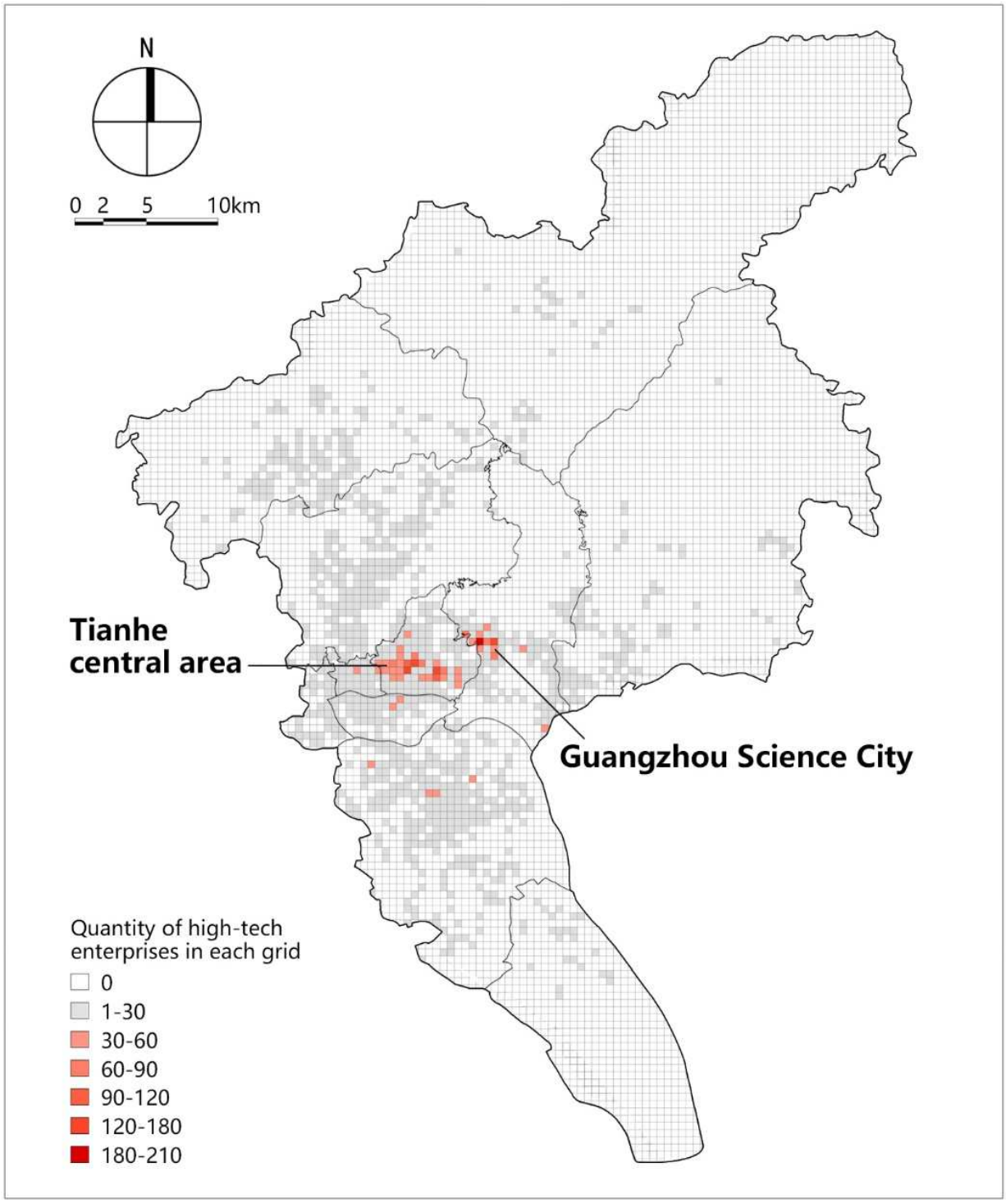

Figure 3. *The Spatial Distribution of High-tech Enterprises in Guangzhou.*

4.4. Spatial Distribution of Incubators

Like the spatial distribution of high-tech enterprises, the spatial distribution of incubators in Guangzhou has also formed two centers: Tianhe central area and Guangzhou Science City (Figure 4). Tianhe central area and Guangzhou Science City are key areas for the government to promote the development of high-tech industries. In these areas, on the one hand, the government has established a large number of state-owned incubators by the financial investment, on the other hand, the government has also actively supported private capital to establish incubators. These incubators incubate a large number of high-tech enterprises, so the spatial distribution of the incubators and the high-tech enterprises presents almost the same characteristics.

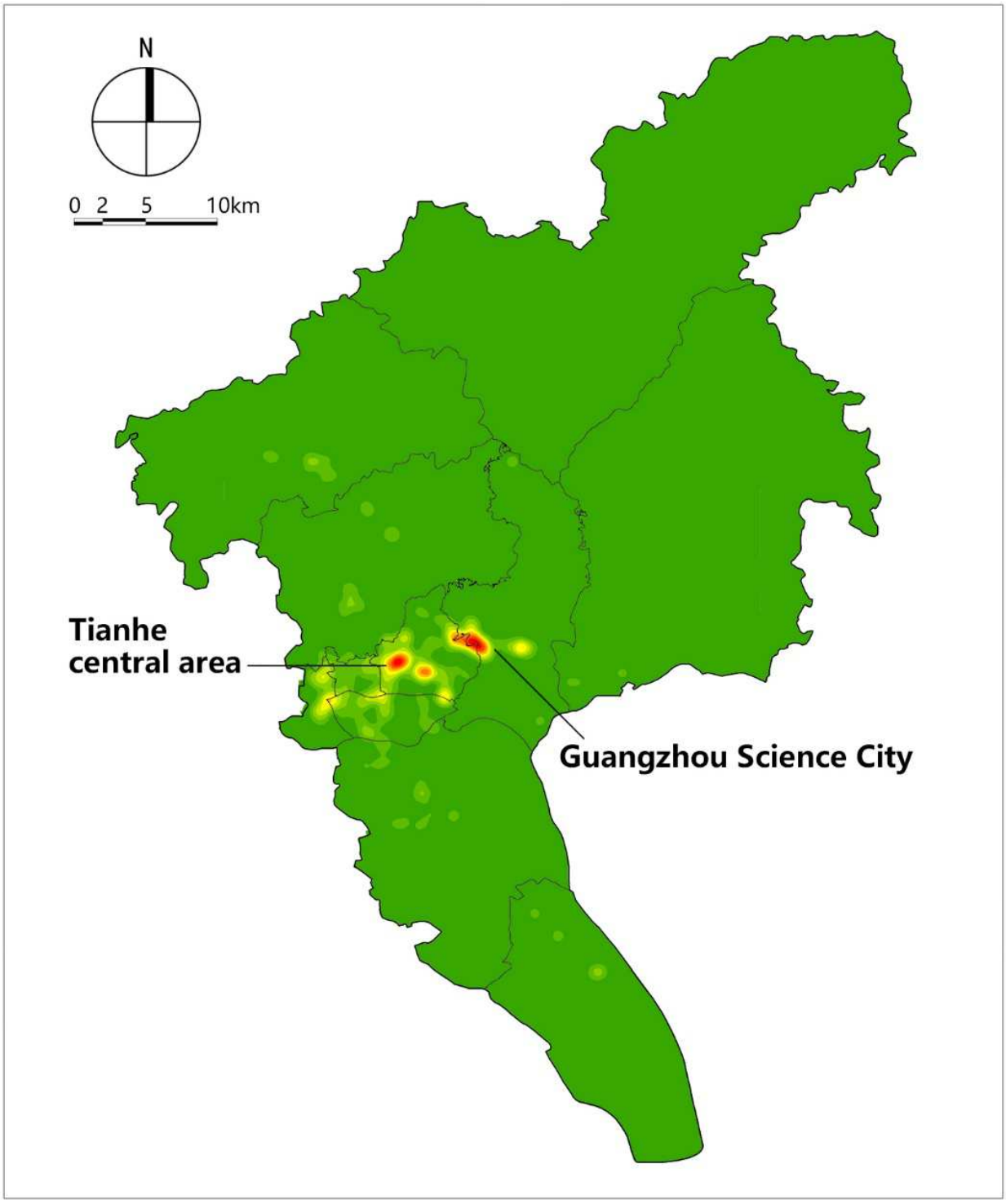

Figure 4. *The Spatial Distribution of Incubators in Guangzhou.*

4.5. Spatial Distribution of Patents

Like the spatial distribution of innovative actors and innovative carriers, the spatial distribution of patents in Guangzhou has formed two centers too: Tianhe central area and Guangzhou Science City (Figure 5). In Tianhe central area, there are not only a large number of universities and scientific institutions, but also a large number of high-tech enterprises. As a result, its innovative outputs are very high, and its innovative mode is the mixed mode including both original innovation and applied innovation. Unlike Tianhe central area, Guangzhou Science City aims to cultivate the high-tech enterprises with the incubators to promote the high-tech industrial development. Therefore, the innovative activities in Guangzhou Science City are mainly applied innovation.

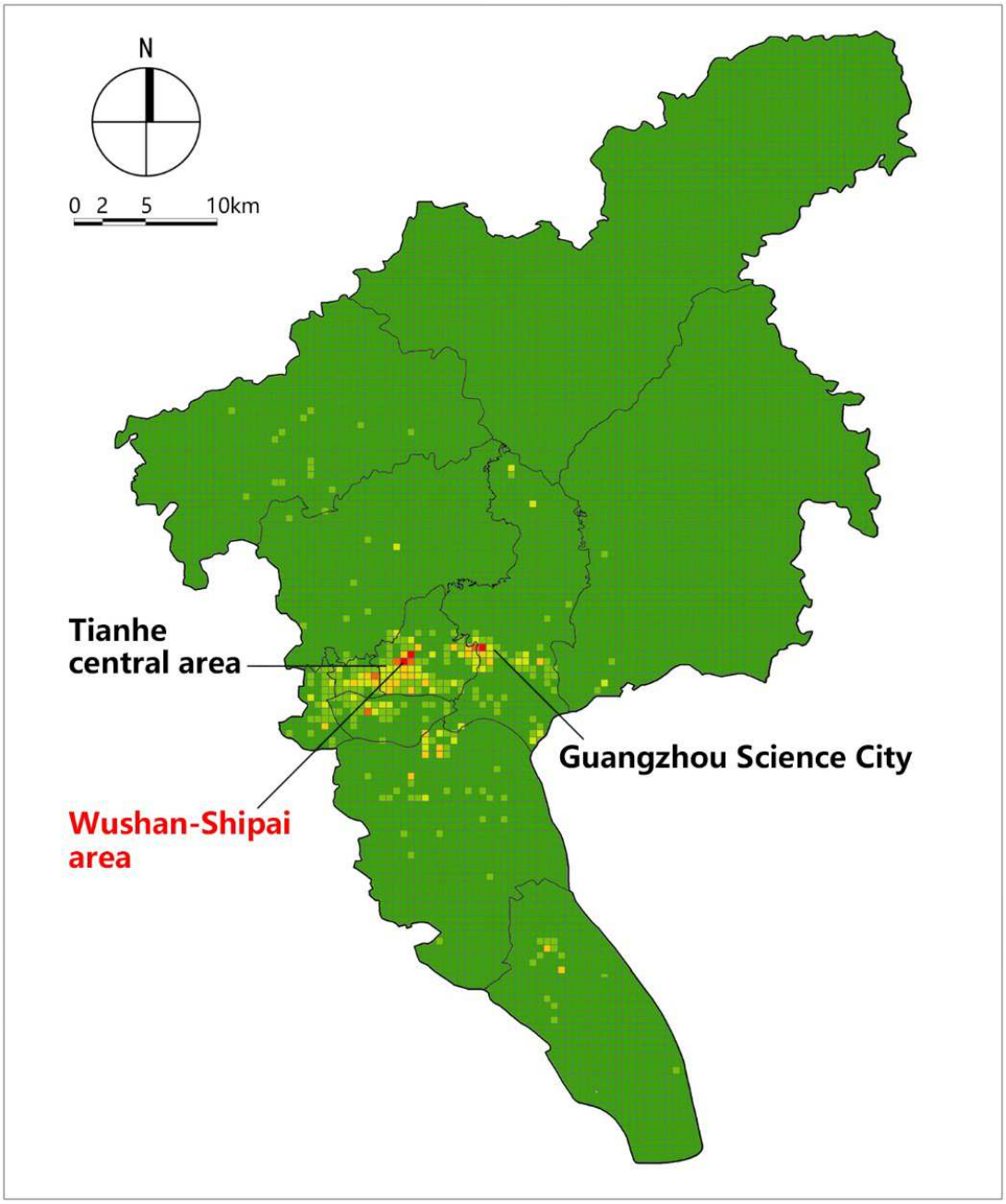

Figure 5. *The Spatial Distribution of Patents in Guangzhou.*

5. Conclusion and Discussion

This research aims to explore the method of characterizing the spatial distribution of innovative activities in city based on multivariate data. Finally, this research draws the following conclusions.

1) This research successfully constructs the method of characterizing the spatial distribution of innovative activities in city based on multivariate data. Four types of indexes are selected to characterize the innovative space in city: universities and scientific institutions, high-tech enterprises, incubators and patents, which come from three aspects: innovative actors, innovative carriers and innovative outputs. And the empirical analysis of Guangzhou verifies the feasibility of the above method. This research believes that compared with the characterizing method based on single data, the characterizing method based on multivariate data can more accurately and richly reflect the spatial distribution of innovative activities in city.
2) Using the above indexes, this research characterizes the pattern of the innovative space in Guangzhou. The analysis results show that the spatial distribution of innovative activities in Guangzhou forms two centers: Tianhe central area and Guangzhou Science City. In Tianhe central area, there are not only a large number of universities and scientific institutions, but also a large

number of high-tech enterprises. Due to the agglomeration of both the actors of original innovation and the actors of applied innovation, the innovative mode of Tianhe central area is the mixed mode including both original innovation and applied innovation. Unlike Tianhe central area, Guangzhou Science City is a suburban high-tech park, which aims to cultivate the high-tech enterprises to promote the development of high-tech industry. Therefore, the innovative activities in Guangzhou Science City are mainly applied innovation.

But this research takes Chinese city as a case, so it has some particularity. It is unknown whether there are statistical records of the indexes similar to China in other countries and whether they can be publicly available. Therefore, whether the method explored in this research can be applied in cities in other countries still needs to be further explored in the future.

Notes

(1) 2thinknow is a data innovation agency. 2thinknow began publishing Innovation Cities Index since 2007. Website: https://www.innovation-cities.com/.
(2) Website: https://gaokao.chsi.com.cn/.
(3) QCC is a service website for querying the information of enterprises and institutions in China. Website: https://www.qcc.com/.
(4) Website: http://sjfb.gdstc.gd.gov.cn/sjfb/#/index.
(5) Website: https://data.gz.gov.cn/.
(6) Website: http://pss-system.cnipa.gov.cn/sipopublicsearch/portal/uiIndex.shtml.
(7) Amap API is a map website provided by AutoNavi Software Co., Ltd. that is a Chinese web mapping, navigation and location-based services provider, founded in 2001. Website: https://lbs.amap.com/tools/picker.

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