Comparing urbanization patterns in Guangzhou of China and Phoenix of the USA: The influences of roads and rivers

Guangjin Tian\textsuperscript{a,\ast}, Jianguo Wu\textsuperscript{b,c}

\textsuperscript{a} State Key Laboratory of Water Environment Simulation, School of Environment, Beijing Normal University, Beijing 100875, China
\textsuperscript{b} Center for Human-Environment System Sustainability (CHESS), State Key Laboratory of Earth Surface Processes and Resource Ecology (ESPRE), Beijing Normal University, Beijing 100875, China
\textsuperscript{c} School of Life Sciences and School of Sustainability, Arizona State University, Tempe, AZ 85287, USA

**Abstract**

Examining the similarities and differences in urbanization pattern between cities in developed and developing countries may enhance our understanding of urbanization processes and mechanisms. Using a buffer analysis approach, we compared the long-term spatiotemporal patterns of urbanization between Guangzhou of China and Phoenix of the United States during the 20th century, with a particular emphasis on the impacts of major roads and rivers. The development of Guangzhou was relatively compact, whereas the development of Phoenix was much more dispersed. The two metropolitan areas were characterized mainly by two types of urban expansion processes. Guangzhou experienced a diffusion-coalescence process, whereas Phoenix experienced a diffusion-coalescence process. The buffer analysis indicated that the impacts of roads and rivers on the urbanization of Guangzhou and Phoenix were similar in terms of urban area, the number of urban patches, the mean patch size, but different in terms of the complexity of urban patches. The urban area declined with increasing distances to roads, but it increased when the distance was close to the rivers and then declined with the increment of distances to rivers. In general, the impacts of roads are stronger in Phoenix than in Guangzhou, while the impacts of rivers are greater in Guangzhou than in Phoenix. These similarities and differences between the two metropolitan regions are reflective of those in both physical conditions and land use policies in the two countries. By comparing these similarities and differences, we can improve our understanding of the urbanization processes in both developed and developing countries, which is necessary for achieving global urban sustainability.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

With the continuing increase in the world’s urban population, cities have also become centers of environmental concerns. The urban population is expected to account for 70% of the world population by 2050 (\textit{United Nations, 2007}), which is a sign of improved civilization of our society. The increasing urbanization is also thought to be an important cause of rapid loss of cropland, hydrological disturbance, species extinction, and biotic homogenization etc. (\textit{Paul and Meyer, 2001; Grimm et al., 2008a,b; Tian et al., 2002, 2005, 2011a,b}). The increasing urban population and the associated land use and cover change will be major cause. Hence, it is crucial to study the patterns of urbanization (\textit{Antrop, 2000, 2004; Kaufmann et al., 2008; Seto and Shepherd, 2009}).

The U.S. and China are two of the most powerful countries in the world today, and, consequently, many similarities and differences can be seen between these two countries’ urbanization processes. Urban agglomeration of developing world is more compact and dense than their counterparts in either Europe or North America (\textit{Wu et al., 2014}). The urban dynamic pattern of Phoenix and Las Vegas in U.S. has been compared (\textit{Wu et al., 2011}). The shape, size and growth rates of the four cities of Guangzhou, Dongguan, Zhongshan and Shenzhen in China exhibit common patterns and a convergence toward a standard urban form despite the different economic development and policy histories (\textit{Seto and Fragkias, 2005}). But systematic comparison of urbanization process between the developed and developing countries has been lacking (\textit{Huang et al., 2007}). The comprehensive comparison of the urban dynamic pattern is needed to enhance our understanding of urbanization processes and mechanisms.

Quantifying the spatial and temporal patterns of urbanization is an important step to understand the effects of urbanization on...
environmental change and ecological processes in different places (Jenerette and Wu, 2001; Luck and Wu, 2002; Alberti, 2005; Wu et al., 2011; Tian et al., 2011a,b). The gradient analysis provides an effective way of understanding the structural and functional differences of cities in the temporal and spatial contexts. The combination of landscape metrics with the gradient approach has been considered a useful tool to study the spatiotemporal dynamics of urbanization (Wu et al., 2000; Luck and Wu, 2002; Xie et al., 2006; Zhu et al., 2006; Xu et al., 2007; Yu and Ng, 2007; McDonnell and Hahs, 2008).

Urbanization exhibits expanding patterns across time and space (Winsborough, 1962; Dietzel et al., 2005; Wu et al., 2011). Dietzel hypothesized that urban growth could be characterized as two distinct processes of diffusion and coalescence, integrating the development waves and growth phases (Dietzel et al., 2005). Diffusion that spreads urban growth from existing centers to new development areas and coalescence that is characterized by outward expansion and gap infilling of existing urban areas (Dietzel et al., 2005). The landscape metrics and gradient analysis can help to identify the distinct processes. Generally, three basic types of urban growth are commonly found in many cities: infilling, edge expansion and spontaneous growth (Berling-Wolff and Wu, 2004; Xu et al., 2007). The infilling and edge expansion can be identified as the coalescence process while the spontaneous growth can be identified as the diffusion process.

The spatial pattern of an urban area and growth typology are a consequence of the interaction of physical and socioeconomic factors (Bürgi et al., 2004). Roads and rivers are the important corridors for urban expansion too. The road influenced urban growth has been identified as linear development or branching (Clarke et al., 1997; Camagni et al., 2002; Wilson et al., 2003). In particular, roads are an important part of the bone structure of the city and often play a key role in the development of the urban landscape since they serve as conduits for flows of goods and services. Before the invention of automobiles, cities developed along rivers and coastlines because waterborne transportation was so important. Rivers are important natural corridors. Our study areas are the Guangzhou metropolitan area of China and the Phoenix metropolitan area of the US. Guangzhou and Phoenix are both located in the South of their countries and have become the fastest growing major cities. The similar latitudinal of Guangzhou and Phoenix will make the comparison more convincing. Their rapid urban expansion has substantially altered the composition and spatial structure of the landscape (Wu et al., 2000, 2002; Luck and Wu, 2002). Therefore, we chose those two cities to compare the urbanization process. The primary objectives of this study are to compare the spatiotemporal patterns of two fast growing cities in China and the US, and to examine the influences of major roads and rivers on the urbanization pattern of the two cities.

2. Study areas, data source and methods

2.1. Study areas

Guangzhou is located between 22 26′N–23 56′N and 112 57′E–114 3′E, with an area of 7434.4 km²; it is located in the central Guangdong Province, north of the Pearl River Delta (Fig. 1). The city also lies close to the South China Sea, Hong Kong and Macao. As the capital of Guangdong Province, Guangzhou is the center of its politics, economy and science. It has ten administrative districts and two county-level cities. The ten districts are Yuexiu, Liwan, Haizhu, Tianhe, Baiyun, Huangpu, Huadu, Panyu, Nansha, Luogang, while the two county-level cities are Zengcheng and Conghua (Fig. 1). Guangzhou is also the key transportation hub of the southern China. There are three highways passing the whole city, Guangzhou–Cong highway, Guang-Hui highway and Guang-Shen highway (Fig. 1). The Pearl River is the third largest river in China. Spanning eight provinces, the Pearl River is composed of four river systems including the West River, North River, East River and Liuxi River (Fig. 1). The four river systems converge in Guangzhou and flow into the South China Sea.

Phoenix is located at 33 27′N, 112 4′W in the southwestern U.S. It is located in the Salt River Valley, or “Valley of the Sun” in central Arizona (Fig. 2). It is the capital and the largest city of Arizona State, as well as the sixth largest most populated city in U.S. It lies at a mean elevation of 340 m, in the northern reaches of the Sonoran Desert. This region is characterized by a hot and dry climate. The average summer temperature is 30.8 °C, the average winter temperature is 11.3 °C, and the annual precipitation is about 180 mm. The freeway and expressway are the arterial roads of Phoenix metropolitan area (Fig. 2). The Salt River runs westward through the Phoenix metropolitan area (Fig. 2). The riverbed is often dry or a trickle due to upstream dams.

Guangzhou and Phoenix metropolitan areas had 6.93 million (Guangzhou Statistics Bureau, 2008) and 3.07 million population respectively in 2000. Although Guangzhou had 2.255 times of population of Phoenix, its urban land was only 18.79% of Phoenix. Hence, the urban land of Phoenix per capita was twelve times of that of Guangzhou metropolitan area. The difference of economic development between Guangzhou and Phoenix was dramatic. The per capita income of Guangzhou was 12,018 Chinese Yuan (equally 1455 US dollars) (Guangzhou Statistics Bureau, 2008). The per capita income of Phoenix was 28,663 US dollars. The per capita income of Phoenix was 19.7 times of that of Guangzhou. In Guangzhou, the service industry made the largest contribution to GDP (Gross Domestic Product) for 59.02% and also provided the largest number of employment. It became the backbone of the economic development. In Phoenix metropolitan area, the third industry of Phoenix was 89.9% of GDP while that of Guangzhou was only 52.35% (Guangzhou Statistics Bureau, 2011). Therefore,
the percentage of the third industry in Phoenix was much higher than that of Guangzhou. In summary, the geographical location and socio-economic role of Guangzhou matches Phoenix, although Phoenix is more developed than Guangzhou.

2.2. Data sources

The historical land use data set with six time periods (1912, 1934, 1955, 1975, 1995 and 2000) for Phoenix metropolitan area was obtained from CAP-LTER (Knowles-Yanez et al., 1999). Four general land use types were classified as urban land, agricultural land, recreation land and desert land. The historical land use of Guangzhou metropolitan area included six time periods (1900, 1923, 1954, 1977, 1995 and 2000). The land use of Guangzhou metropolitan area before 1977 is digitalized from the historical map and there was only urban land and non-urban land in those periods. After 1990, the land use was classified into forest, cropland, grassland, water body, built-up land and unused land. The built-up land was classified into urban land, rural residential land and other construction land.

Based on the available land use datasets for Guangzhou and Phoenix, we compared the urbanization patterns of the two metropolitan areas in three time periods. For Guangzhou, three phases are divided as 1900–1954, 1954–1977, 1977–2000. For Phoenix, three phases are divided as 1912–1955, 1955–1975, 1975–2000. The time ranges do not match completely because of the data limitations. For Guangzhou, the first period was before the liberation of China (1949) and the first five-year plan (1953–1957), and for Phoenix was from 1912 to 1955. The second phase had the first through fourth five-year plan in China. During this period, the planning economy dominated and the urban development was disturbed by the Cultural Revolution (1966–1976). For the third phase, China had implemented the open policy and the planning economy was transformed to market economy.

2.3. Measures for quantifying urbanization pattern

Developed in the late 1980s, landscape metrics are used to quantify the spatial and temporal patterns of urban dynamics (Jenerette and Wu, 2001; Tian et al., 2007a,b, Tian et al., 2011a,b; Wu et al., 2011). In order to compare the urbanization process between Guangzhou and Phoenix, the time series of spatial metrics were calculated using Fragstats software (McGarigal and Marks, 1995). Through the analysis of landscape metrics, we compared the spatial and temporal pattern of urbanization process in Guangzhou and Phoenix.

In this study, we used the buffer analysis approach and also examined the buffers of roads and rivers on rural–urban transects. Specifically, the buffers of roads and rivers were defined for 10 intervals of 0.5 km each for Guangzhou and Phoenix metropolitan areas. The individual buffer zones are 0–500, 500–1000, 1000–1500, etc. The spatial metrics of these buffers were calculated. Through the buffer analysis of major roads and rivers, the impact of road corridors and river corridors on the urbanization patterns of Guangzhou and Phoenix metropolitan areas were compared.

The spatial metrics describe the size, connection between the urban patches and complexity of urban form. These metrics of different times of Guangzhou and Phoenix can help to trace the trend of the dynamic change of landscape pattern during the urbanization process. We selected urban area (UA), number of urban patches (NP), mean patch size (MPS), area weighted mean patch fractal dimension (AWMPFD) and aggregation index (AI) to compare the urban dynamic patterns between Guangzhou and Phoenix (see Table 1). UA is the urban land area in the buffers. NP is the number of urban patches. MPS describes the relative size of urban patches. AWMPFD measures the complexity of urban patches. AI measures the adjacency degree of urban patches and indicates the aggregation between the urban patches (He et al., 2000). It provides a quantitative basis to correlate the spatial pattern of a class with a specific process.

The roads are the major infrastructure of the cities. Road corridors can exist as axes of infrastructure, economic development, and urbanization or of institutional development (Chapman et al., 2003). The construction of roads can stimulate the urban expansion along the road corridors. The roads are one of the driving factors of urban expansion (Luck and Wu, 2002; Li and Liu, 2006, 2008). The major roads of Guangzhou and Phoenix were ring and radial. The freeway and expressway are the major roads of Phoenix metropolitan area. There are two ring roads (Route 101 and Route 202). Routes of 10, 17, 51, 60 and 303 are the five interstate major roads. These roads compose the road system of Phoenix. In Guangzhou there is the ring expressway for the city and the national highway is from Guangzhou to Foshan, Zhuhai and Qingxin for the inter-urban region. The ring and radial roads constitute the major roads of Guangzhou. The urban expansion of Guangzhou was along radial corridors from city center to the outsides (Fan et al., 2009). All the mentioned roads had been considered in the buffer analysis.

![Fig. 2. The administrative districts and counties of Phoenix metropolitan area.](image-url)
Table 1  
Landscape metrics for the comparison of Guangzhou and Phoenix.

<table>
<thead>
<tr>
<th>Metrics</th>
<th>Description</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>UA</td>
<td>Urban area is a measure of landscape composition. Specifically, how much of the landscape is comprised of urban land.</td>
<td>( UA = \sum_{i=1}^{n}</td>
</tr>
<tr>
<td>NP</td>
<td>Number of patches of a particular patch type is a simple measure of the extent of subdivision or fragmentation of the patch type.</td>
<td>( NP = n_i )</td>
</tr>
<tr>
<td>MPS</td>
<td>The average area of all patches in the landscape.</td>
<td>( MPS = \frac{\sum_{i=1}^{n} A_i}{n} )</td>
</tr>
<tr>
<td>AWMPFD</td>
<td>Area weighted mean patch fractional dimension averages the fractional dimensions of all urban patches by weighting the area of urban patches. Its values range between 1 and 2.</td>
<td>( AWMPFD = \sum_{i=1}^{m} \sum_{j=1}^{n} \left( \frac{2 \ln(0.25</td>
</tr>
<tr>
<td>AI</td>
<td>Aggregation index is calculated from an adjacency matrix, which shows the frequency with which different pairs of patch types (including like adjacencies between the same patch types) appear side-by-side on the map.</td>
<td>( AI = \sum_{i=1}^{m} \left( \frac{P_i}{\text{mean}</td>
</tr>
</tbody>
</table>

The rivers are the important natural ecological corridors of the cities. The river corridors have a great potential for increased diversity, transmission of nutrients and continual exchange (Cook, 2002). Hence, the river corridors are prohibited to be developed for the ecological safety. The overall urban expansion pattern was determined, to a large extent, by physical factors such as the rivers and mountains. The national and provincial forest parks and nature reserves also have an impact on the expanding direction of the city.

The buffers of the Salt River in Phoenix and Pearl River in Guangzhou were calculated to compare their patterns. Through the buffer analysis of rivers in Guangzhou and Phoenix, the spatial metrics were calculated to examine the impact of river corridors on the rapid urbanization process.

3. Results

3.1. Urbanization patterns of Guangzhou and Phoenix

During the first period, Guangzhou experienced the unstable growth period. Urban land of Guangzhou was 598 km² in 1900 and 1348 km² in 1923 while the urban land of Phoenix was 2027 km² in 1912 (see Fig. 3a). The annual growth rates of urban land in Guangzhou and Phoenix were 3.41% and 6.55%, respectively. Hence, urban area growth rate of Phoenix was much faster than that of Guangzhou. In 1900, the urban land of Guangzhou concentrated in Yuexiu district with only one compact urban patch. Subsequently, the number of urban patches (NP) of Guangzhou and Phoenix experienced a trend of low-level sustained growth (see Fig. 3b). The mean patch size (MPS) of urban land in Guangzhou and Phoenix increased and then declined (see Fig. 3c). Area weighted mean patch fractional dimension (AWMPFD) of both cities and their urban shape became more irregular and complex (see Fig. 3d). The urban land usually spread toward its nearest urban cores. Aggregation index (AI) of both cities, measuring the degree of clumping of patches that pertains to configurationally aspects of landscape pattern, decline in this period (see Fig. 3e). The decrease of AI indicates the diffusion process of both cities.

During the second period, the urban land of Guangzhou and Phoenix increased dramatically and the annual urban growth rates of Guangzhou and Phoenix were 7.09% and 4.67%, respectively (see Fig. 3a). The urban expansion of Guangzhou concentrated in Yuexiu, Haizhu and Liwan districts and the urban expansion encircled the old center continuously. NP of urban patches in Guangzhou decreased while MPS increased dramatically in 1977 (see Fig. 3b and c). In the 23 years, urban land in Guangzhou sprawled around the existing centers. The new urban areas and the old centers joined together, thus the configuration of urban land became continuous. NP of urban patches in Phoenix increased dramatically while MPS witnessed a dramatic decline for Phoenix from 1955 to 1975, indicating the diffusion process (see Fig. 3c). AWMPFD showed that the urban patch shape became more complex and irregular for both cities (see Fig. 3d). AI shows also differences for the two cities: Guangzhou underwent a small and stable increase, suggesting coalescence process of urban patches; Phoenix showed dramatic decrease of AI, suggesting dramatic diffusion process of urban expansion (see Fig. 3e).

For the third phase, the urban areas of both cities increased dramatically and the annual urban growth rates of Guangzhou and Phoenix were 3.65% and 5.62%, respectively (see Fig. 3a). During this period, NP of Guangzhou increased dramatically after 1995 and MPS declined rapidly (see Fig. 3b and c). NP of urban patches in Phoenix increased dramatically and MPS increased a little (see Fig. 3b and c). The increment of AWMPFD of both cities indicated the shape complexity became larger and more irregular with the rapid urban development (see Fig. 3d). AI of Guangzhou decreased dramatically between 1977 and 1990 and then increased a little between 1990 and 2000 (see Fig. 3e). The urbanization of Guangzhou was in the process of diffusion after the implementation of reform and open policy (see Fig. 3e). However, the urban growth was more rapid between 1990 and 2000 than that between 1977 and 1990 (see Fig. 3b). Since the setting up of Nansha Economic and Technological Development Zone in 1993, several new policies were enacted to facilitate economic development and foreign investment. More than 200 foreign companies were established in Nansha to boost the economic development (Fan et al., 2009). The urban expansion of Guangzhou was stable with coalescence process between 1990 and 2000. AI of Phoenix increased dramatically, indicating the coalescence process of urbanization (see Fig. 3e). Its urban areas began to expand to the surrounding region, such as Avondale, Carefree, Chandler, Fountain Hill, Gilbert, Goodyear, Peoria and Surprise in order to ease the traffic and infrastructure load in old city centers, such as Phoenix, Tempe and Mesa.

The urban land had increased by 66.61 times in Guangzhou from 1900 to 2000, and by 148.76 times in Phoenix from 1912 to 2000, with annual urban growth of 4.3% and 5.86%, respectively. Therefore, Phoenix extended more rapidly than Guangzhou. According to the landscape metrics, Guangzhou experienced diffusion–coalescence–diffusion–coalescence process while Phoenix experienced diffusion–coalescence process. The periodical dynamic pattern of Phoenix can be explained by the processes of diffusion and coalescence: the urban expansion was diffusion between 1912 and 1975 and coalescence between 1975
and 2000. There were four periods for Guangzhou urban expansion. For Guangzhou, its urban growth was diffusion before 1954 and 1977–1990. In these periods, the dispersed and small urban patches resulted in the diffusion model. Its urban growth process was coalescence in 1955–1975 and 1990–2000. In these periods, the urban patches expanded dramatically and condense. Hence the coalescence process dominated. The law can be demonstrated in the Yangtze River urban growth too (Tian et al., 2011a). Although both cities had expanded within the urban core and on the fringes, they had different phased characteristics.

3.2. Impacts of major roads on urban expansion

Urban land area (UA) of Phoenix and Guangzhou declined gradually with distance from a major road in 2000 (see Fig. 4a). Number of urban patches (NP) and the mean patch size (MPS) of urban land in Phoenix declined gradually while those of Guangzhou exhibited a peak when the buffer was 1 km and then declined from the urban center outward (see Fig. 4b and c). AWMPFD of Phoenix and Guangzhou indicated that the shape complexity of urban patches decreased slowly with the increment of buffer radii (see Fig. 4d). The decline of aggregation index (AI) with increasing distance from a major road indicated a reduction in adjacency between urban patches (see Fig. 4e). From the above analysis, the impact of roads on urban development was obvious.

There were bigger gaps of landscape metrics of Phoenix than those of Guangzhou between 1995 and 2000, suggesting more dramatic urban expansion in Phoenix than in Guangzhou. In these 5 years, the rapid urban expansion of Phoenix had resulted in increase of NP, MPS, AWMPFD and AI for different buffers (see Fig. 4a–e). However, Guangzhou’s urban sprawl was slow in this period and the change of NP, MPS, AWMPFD and AI was little (see Fig. 4a–e). In this period, the urban expansion of Guangzhou was slow. It can be demonstrated in eastern China region (Tian et al., 2005, 2007b, 2011a).

The impact of roads on urban expansion is obvious and the spatial patterns of landscape metrics of Guangzhou and Phoenix were similar. But the shape of urban pattern in Phoenix was more irregular than that of Guangzhou (see Fig. 4d). With increasing distance from the major roads, the urban area, number of patches and mean patch size of urban land declined and the urban patches of Guangzhou and Phoenix became smaller and more dispersed.

3.3. Impacts of river on urban expansion

The urban land area (UA) of Guangzhou and Phoenix increased and reached a peak where the buffer distance was 1 km and 1.5 km from the major rivers, respectively (see Fig. 5a). After the peak, the urban land area declined gradually from the major rivers outward. Therefore, the restraint of rivers was obvious when the land was very close to them. NP of urban patches in Guangzhou declined while that of Phoenix reached a peak when the buffer was 1.5 km and then declined (see Fig. 5b). MPS of Guangzhou and Phoenix increased and reached a peak when the buffer distance was 4.5 km and 1.5 km respectively, then both declined (see Fig. 5c). AWMPFD of Guangzhou and Phoenix increased slowly with the increment of
buffer distance and reached and then declined (see Fig. 5d). It indicated the urban shape became more complex and irregular with the increment of buffer distance. AI increased stably in Guangzhou, but increased and reached a peak in Phoenix when the buffer distance was 1.5 km and then declined slowly (see Fig. 5e).

UA of Guangzhou had a little bigger gap than that of Phoenix between 1995 and 2000 (see Fig. 5a). It indicated the urban expansion of Guangzhou was more dramatic than that of Phoenix along the major rivers. In the 5 years, NP, MPS, AWMPFD and AI of Guangzhou showed the contrary trend to that of Phoenix. For Guangzhou, NP and AWMPFD declined while MPS and AI increased. In contrast, NP and AWMPFD of Phoenix increased while MPS and AI declined.

From above analysis, the general impacts of rivers on urban landscape of Guangzhou and Phoenix were similar. UA, NP, MPS and AI increased at first, reached a peak and then declined from the major rivers outward. The urban expansion was prohibited by the natural buffer of close to rivers. When the buffer distance from rivers is more distant, the urban expansion declined too.

### 4. Discussion and conclusions

The spatiotemporal patterns of Guangzhou and Phoenix show different characteristics. This research has examined the characteristics of three different urban development phases for the two cities using multi-temporal land use datasets and landscape metrics. The two metropolitan areas have two types of urban expansion processes. Guangzhou experienced a diffusion–coalescence–diffusion–coalescence process while Phoenix was characterized by a diffusion–coalescence process. For Phoenix, its urban growth met with the Dietzel et al.'s (2005) hypothesis and was diffusion process before 1975 and then coalescence process after that. For Guangzhou, its urban growth was diffusion before 1954 and 1977–1990 and coalescence in 1955–1975 and 1990–2000. Although both cities expanded within the urban core and on the fringes, they had different characteristics of developmental phases.

Buffer analysis indicated that the impacts of roads and rivers on the urban expansion of Guangzhou and Phoenix were similar in terms of the urbanized area, number of urban patches, mean patch size, area weighted mean patch fractal dimension and aggregation index. The landscape metrics declined with increasing distance from major roads and rivers. The urban area declined with the increment of distance to roads, but it increased when the distance was close to the rivers and then declined with the increment of distance to rivers. However, the complexity of urban patches declined with distance from major roads, but increased with distance from major rivers. These similarities and differences in the impacts of...
roads and rivers on urbanization are reflective of both physical and socioeconomic driving forces in the two cities.

Generally speaking, the impacts of roads in Phoenix are more obvious than Guangzhou, and the impacts of rivers in Phoenix are less obvious than Guangzhou. The phenomenon further verifies the natural factors and socio-economic conditions of two cities. First, Phoenix is the developed country and has more private cars than Guangzhou, so the dependence on the roads is stronger than Guangzhou in the distant region. Second, rivers in Guangzhou are not only water resources but also transportation corridors, and thus their impacts on urbanization are quite important – more pronounced than in Phoenix. Through the comparison of the urban development patterns and their underlying drivers for the two major metropolitan regions from China and USA, our study provides new insight into urban dynamics as influenced not only by biophysical factors but also socio-political regimes.

Acknowledgements

This study was funded by National Key Technology R&D Program of China during the Twelfth Five-Year Plan Period (2012BAC13B01). JW’s research in China was supported partly by the Chinese Ministry of Science and Technology through the National Basic Research Program of China (2014CB954303, 2014CB954300).

References


Web reference