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An analysis of spatiotemporal changes of urban landscape pattern in Phoenix metropolitan region

Moquan SHA, Guangjin TIAN *

School of Environment, Beijing Normal University, Beijing 100875, China

Abstract

The recent decades witness the rapid urbanization around the world. Phoenix, as one of the fastest growing city in United States, experienced fast urbanization during the global urbanization tide. This study analyzes spatiotemporal characteristics during the urban expansion in Phoenix metropolitan area by the support of GIS. In this study, we divided the land use of Phoenix into four classes: urban, agricultural land, desert and recreation land, and chose 4 class-level metrics: PLAND, PD, LSI, and LPI and 3 landscape-level metrics: SHDI, AWMPFD, and CONTAG, to qualify the urbanization dynamics of Phoenix. From 1912 to 2000, desert occupied the largest area of land in Phoenix, but its area kept decreasing; the urban area and its shape complexity kept increasing, and its fragmentation increased first and then declined dramatically; the agricultural area increased at first but then large proportion of its area converted to urban use; recreation land also showed a similar pattern to urban area.

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Keywords: landscape metrics; spatiotemporal changes; urbanization; Phoenix

* Corresponding author..
E-mail address: tianguangjin@gmail.com

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1. Introduction

During the 20th century, the world's population increased at a dramatic rate, and the world's population rapid shifted to urban areas [1]. Currently, only 1% to 6% of the earth land is covered by urban areas which support more than half of the world's population [2] [3]. With the large-scale urbanization, more and more rural land converted to urban uses, which had profound impacts on the local and global ecosystems at multiple spatiotemporal scales [4] [5].

Landscape metrics highly concentrate landscape information, and reflect the structural composition and spatial configuration of landscape features. They are widely used in the analysis of urban environment [6]. In recent years, landscape pattern metrics have been used to quantify the spatiotemporal dynamics of urban landscape pattern of an urban area [7] [8], and to describe the regularity of urbanization process [6].

In this paper, by using remote sensing interpretation of land use data of Phoenix from 1912 to 2000 and with the support of GIS, through the landscape metrics analysis of Phoenix, we compared the process of urbanization development in Phoenix during the 20th century to address the following issues:

1) How did different types of landscape in the sample spatially distribute?

2) How did the landscape pattern change during the process of urbanization?

2. Study Area

The Phoenix metropolitan area is a metropolitan area, centered on the city of Phoenix. It is located in the southwestern USA. It includes much of the central part of the U.S. state of Arizona. The 2000 Census reported the population of the metropolitan area to be 3,251,876[9]. Phoenix metropolitan area is the 12th largest metro area by population in the United States.

3. Data source and methods

The land use dataset of Phoenix was obtained from CAP-LTER [10]. According to the land use datasets of Phoenix metropolitan areas, we classified the time periods into five periods: 1912~1934, 1934~1955, 1955~1975, 1975~1995 and 1995~2000.

According to the needs of the calculation of urban and rural landscape metrics, the region was classified into four types: urban, desert, recreation and agriculture. The vector data of land use were converted to raster at spatial resolution of 100m×100m. We applied FRAGSTATS 3.3 to calculate landscape metrics of each class type and total landscape [11]. We chose 4 class-level metrics: Percentage of landscape (PLAND), Patch density (PD), Landscape shape index (LSI) and LPI (Largest Patch Index) and 3 landscape-level metrics: Shannon's Diversity Index (SHDI), Area-Weighted Mean Patch Fractal Dimension (AWMPFD), and Contagion (CONTAG), to qualify the urbanization dynamics of Phoenix.

4. Result

4.1. Overall changes of landscape features in Phoenix

Most of Phoenix metropolitan area was covered by desert during the past century (Fig.1 (a)). In 1912, 90.66% of land was desert. From 1912 to 2000, the area of desert kept declining, but the desert still a dominate class type in Phoenix. From 1912 to 1975, agricultural land occupied the second largest area in Phoenix, with the proportion increasing from 9.16% to 16.07%. But from 1975, large area of agricultural land converted to urban area. Thus urban land started to increase dramatically, and its area exceeded agricultural land. In 1995, urban area covered 18.91% of Phoenix and this number added to 25.52% in 2000. Recreation land occupied the smallest area of Phoenix, and its increasing rate of area is relatively slow. By 2000, the rank of areas was: desert>urban area>agricultural land>recreation land.

From 1912 to 2000, LSI(Fig.1 (b)) of urban area kept growing, indicating during the large-scale of urbanization, urban area kept expand and its shape complexity increased; LPI(Fig.1 (c)) of urban land showed a similar pattern to

LSI, which meant that the core urban patch expanded rapidly and was more and more dominant in the landscape of Phoenix as urban patches were connected, so LPI kept increasing; PD (Fig.1 (d))increased from 1912 to 1995,and decreased from 1995 to 2000.

Desert covers the largest area, but its area kept shrinking, and its area proportion kept declining. Its LPI (Fig.1 (c)) decline by 64.32% from 1912 to 2000, indicating the largest patch area of desert reduced; PD (Fig.1 (d)) decreased from 1912 to 1995, showing the degree of dispersion and fragmentation of desert class rose, but from 1995 to 2000, PD decreased because of the relative concentration of the desert area caused by the shrinking of desert area; LSI (Fig.1 (b)) of desert kept going up in the 20th century, indicating the increment of shape complexity.

PD (Fig.1 (d)) of agricultural land shows similar pattern to that of desert; LPI (Fig.1 (c)) increased from 1912 to 1934, and started to reduce in 1934. LSI (Fig.1 (b)) increased from 1912 to 1995, but showed a declining trend since 1995.

Recreation land occupied a small part of land, and showed a similar develop pattern to urban area.

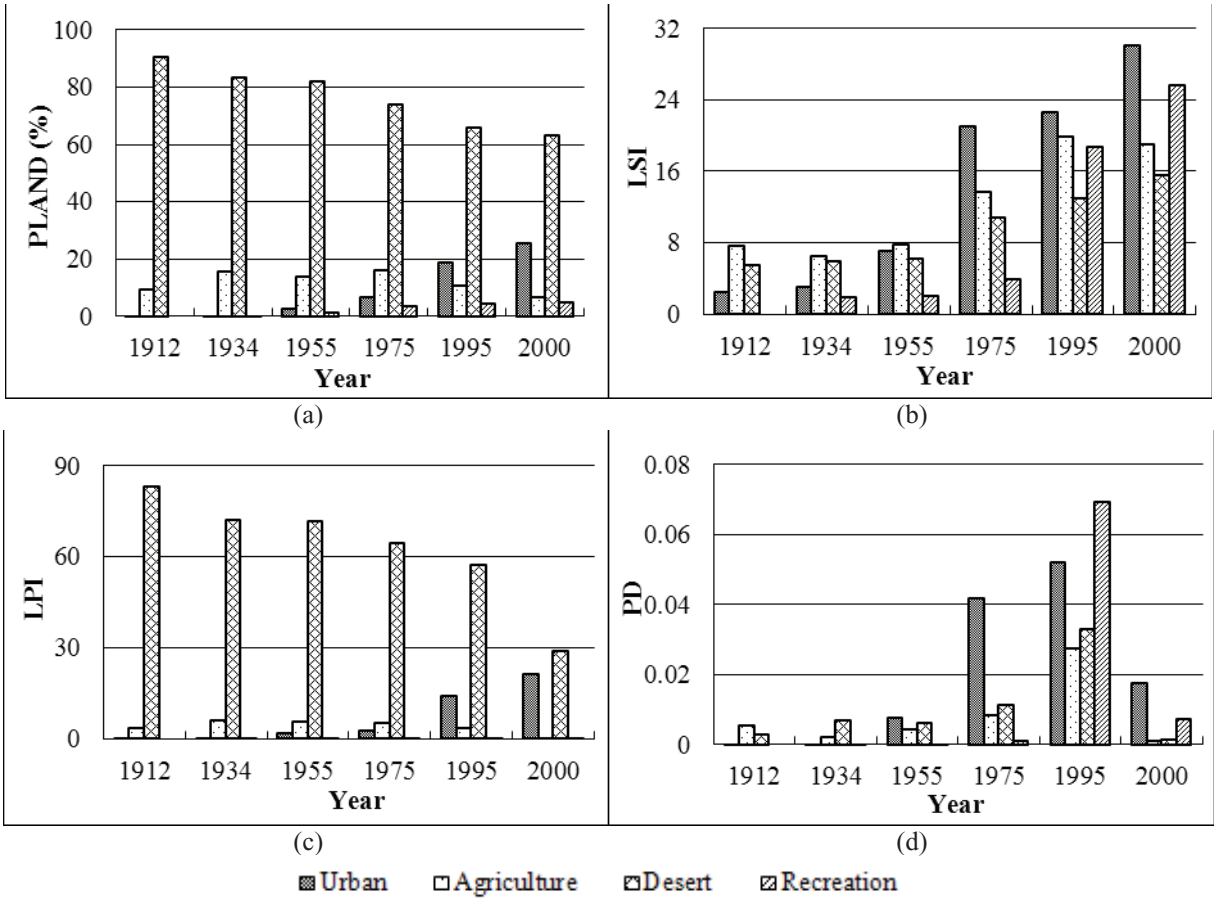


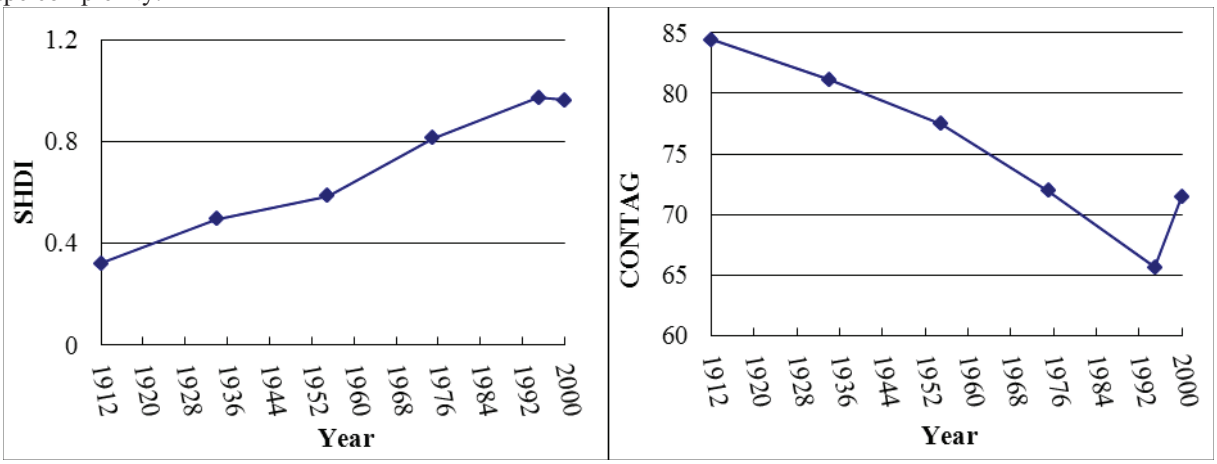
Fig. 1. Synoptic Landscape Characteristic for Phoenix. (a) PLAND (b) LSI (c) LPI (d) PD

4.2. Temporal dynamics analysis with landscape-level metrics

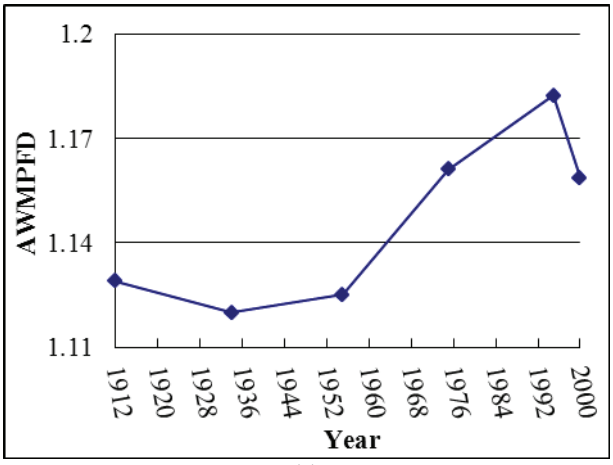
From 1912 to 1995, SHDI (Fig.2 (a)) kept increasing by more than two times, because the area desert kept shrinking and converted to other types of land, especially urban areas. Development of new land-use type made the SHDI increase at a dramatically rate, reflecting the increment of landscape diversity. But from 1995, the rapid expansion of urban area occupied large area of farmland and desert, and made the landscape diversity decrease.

From 1912 to 1995, CONTAG (Fig.2 (b)) dropped dramatically with the large-scale urbanization in Phoenix. This change is relative to the increment of PD of urban land. The rapid development of urban area and the increase of number of urban patches result in the low connectivity of landscape in Phoenix. From 1995 to 2000, CONTAG started to grow, indicating the connectivity of urban patches increased during these five years because the newly-grown urban patches connected with the pre-growth urban area.

From 1912 to 1995, AWMPFD (Fig.2 (c)) kept increasing except a little drop in 1934, indicating the degree of shape complexity continued going during the initial time of urbanization in Phoenix. While from 1995 to 2000, AWMPFD reduced a little, because of the expansion and connectivity of urban area had negative impact on the shape complexity.



(a) (b)



(c)

Fig. 2. Changes in landscape-level metrics. (a) SHDI (b) CONTAG (c) AWMPFD

5. Discussion and conclusion

In the past century, the proportion of urban area kept increasing and its shape complexity also experienced a trend of increasing and decreasing. Large area of desert and agricultural land converted to urban area, and their shape complexity showed similar patterns to urban area. Phoenix is situated in the northern part of Sonoran Desert, so desert occupied the largest area of Phoenix. The desert distributed in the surrounding area of urban land. The agricultural lands were located in the surrounding region, such as Avondale, Carefree, Chandler, Fountain Hill, Gilbert, Goodyear, Peoria and Surprise. But in recent years, the urban area urban areas began to expand to the surrounding regions in order to ease the traffic, infrastructure and housing load in existing city centers, such as Phoenix, Tempe and Mesa. Areas of recreation land also increased in the past century, and distributed around the urban area.

In recent study, the spatiotemporal dynamics of Phoenix and Las Vegas were compared, indicating that the two cities showed similar pattern during urbanization process because of their resemblance in the pattern of population growth and the natural environment. Xu et al. applied landscape metrics to better understand the spatiotemporal dynamics of the urban landscape of the Nanjing metropolitan region [12]. Schneider and Woodcock studied 25 cities around the world indicated that many Asian and African cities showed a similar pattern as Phoenix in urban development within the urban core and on the edges [13].

In this study, we used a long-time series data. But due to lack of data, time interval may be too long and it may result in poor continuity of data and have negative impact on analysis results. Because of the limitations of data sources, we did not do a more detailed analysis on long-time urbanization and did not involve the scale effect. In the next step we will continue deeper study on spatial and temporal changes in urban development process.

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