



GEOSCIENCES

Gradient analysis of landscape pattern in the core area of the “Zhengzhou and Kaifeng Integration” at the landscape level

FAN QINDONG, LIANG LIUKE & LI HU

Abstract: The analysis of landscape pattern change is an effective way to understand urbanization. Research area is the core area of urbanization, which is between Zhengzhou city and Kaifeng city in China. Geographic information system (GIS) and landscape metrics method are used to quantify the gradient landscape pattern changes in the study area. The results show an obvious gradient change of landscape pattern from 2005 to 2015. The landscape pattern in the eastern and western of the study area experienced larger changes than the middle area. The western end mainly changed in terms of the patch number, patch shape and anthropogenic influence, but the patch types in the east changed more rapidly than those in the west. Landscape pattern change is influenced by policy and location, and human influence is the main driving force. Unlike previous study areas, in which urbanization expanded from the center of a city to its surroundings, our study area spread from two ends (Zhengzhou and Kaifeng cities) to the center of the study area. This study could be used as a typical case for the gradient analysis of landscape pattern changes during urbanization.

Key words: Gradient, landscape level, landscape metrics, landscape pattern.

INTRODUCTION

Over the last several decades, urbanization has played an important role in landscape pattern changes worldwide (Dai et al. 2017). The government can understand the development of the urbanization through the change of landscape pattern. Spatial and temporal changes of landscape pattern can provide essential information for studying the driving forces of urbanization, and the impact of urbanization on social and economic environment. Moreover, because of the landscape dependence of most ecosystem services, landscape pattern change is considered to be a major factor affecting the ecosystem services which human survival and development depend on. (Smiraglia et al. 2015).

At present, urbanization driven by policies is the primary cause of landscape pattern changes especially in developing countries, such as China (Fan & Ding 2016). Monitoring the structure and configuration of landscape pattern changes provides key information for governments to understand the implementation of land policies, and basic information for governments to make environmental policies (Barbati et al. 2013, Salvati 2014).

Landscape indices have been frequently used in landscape pattern analysis (Fan & Ding 2015, Najafabadi et al. 2014). A significant aspect of any landscape analysis is the spatial scale, which has been traditionally understood as the spatial extent and resolution (Myint et al. 2015). Determination a suitable scale is crucial in

geographical and landscape ecological research (Zigmārs et al. 2017, Kupfer 2012). Multiple scales analysis and moving window method have been used to find the optimal scale in many previous studies (Chen et al. 2013, Cushman & Landguth 2010, Fan & Myint 2014, Plexida et al. 2014). Moreover, most landscape metrics are scale-dependent (Wheatley 2010, Wu 2004).

Using only landscape indices is often criticized for its discretization, so gradient analysis was introduced to promote the continuity and directivity of landscape pattern delineation (Hagen-Zanker 2016). Because of the directivity and non-uniformity of urbanization, gradient analysis has more advantages in terms of the landscape pattern analysis of urbanization in some actual cases (Huang et al. 2010, Li & Yeh 2004). Gradient analysis was first introduced by Whittaker in 1967, and then McDonnell & Pickett (1990) stated that environmental variations are ordered in space. Forman and Godron stated that anthropogenic gradients can be described as a specific succession of “natural–managed–cultivated–suburban–urban landscapes”. At present, land use and land cover change, biodiversity conservation, cultural heritage, food provision services, changes in life styles, etc. have become the main topics of urban–rural linkage (Marcheggiani et al. 2013, Zasada 2011). Thus, “urban–rural” gradient analysis has been most frequently used in previous studies (Modica et al. 2012).

As the representative of developing countries, China has experienced rapid urbanization. In China, urbanization is driven by urban agglomeration. However, cases where landscape patterns are influenced by many cities are still lacking. Our study is an “urban–rural–urban” model, and the study area is located in the rural area between the cities of Zhengzhou and Kaifeng, which is the core area of the Zhengzhou and Kaifeng integration region.

The landscape pattern changes in this area are influenced by both Zhengzhou and Kaifeng.

Multiple scale analysis is used to find the optimal scale of the study area. Gradient analysis is used to quantify the landscape pattern changes. In our previous study, the selection of landscape metrics and optimal grain size were present (Fan et al. 2018). This study attempts to explore the gradient landscape pattern change in study area at landscape level. This study can be considered a typical case for landscape pattern change research. Our results will provide useful information for local governments to monitor landscape pattern change under current policies and make the next policies.

MATERIALS AND METHODS

Study area

The study area is the core of the Zhengzhou and Kaifeng integration area, which is the area between Zhengzhou and Kaifeng in Henan province, China. Zhengzhou City is the provincial capital of Henan. Our study area is located to the east of Zhengzhou and the west of Kaifeng. Zhengkai Road is the main thoroughfare thorough the eastern and the western of the study area that connects Zhengzhou and Kaifeng. Zhengzhou and Kaifeng are the main cities of the “Central Henan Urban Agglomeration” policy. Under the policy, Zhengzhou sprawls to Kaifeng and Kaifeng sprawls to Zhengzhou along Zhengkai Road.

The study area extends east to Jinming Road in Kaifeng, west to the Jing-Gang-Ao Highway in Zhengzhou, north to Lian-Huo Highway, and south to 310 National Road. The study area is approximately 47,314 hm². It is located between longitudes 34°72' and 34°85'E, and latitudes 113°81' and 114°30'N (Figure 1).

The terrain of the study area is flat, with an altitude of 68–88m. The study area is a warm

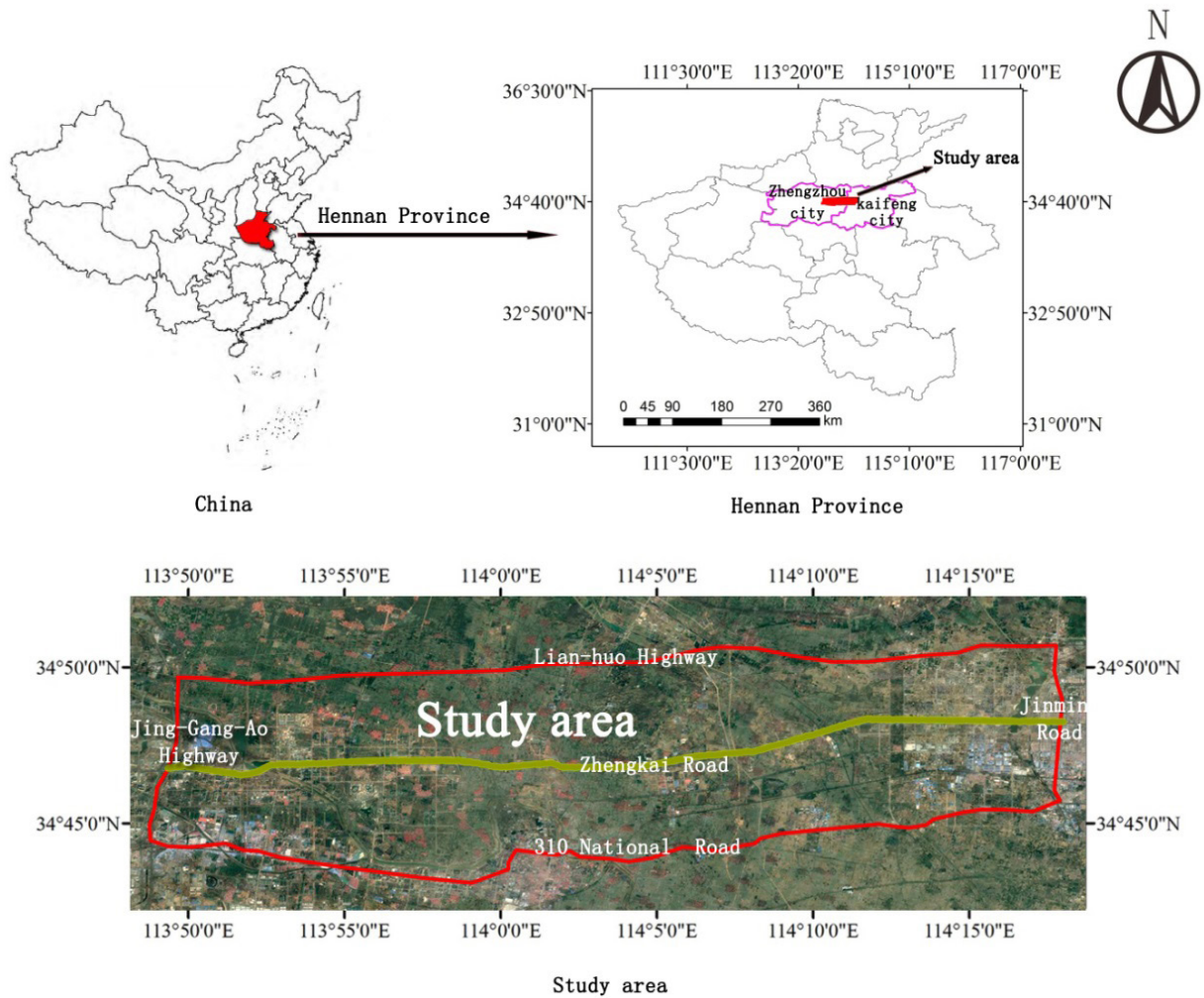


Figure 1. Location and range of the study area.

temperate continental monsoon climate, and experiences a long history of farming. Cultivated land is the main landscape type, and the rural residential areas of different sizes are scattered among them. In addition to the hedges in the field, the forest landscape is mostly patchy scattered in the farmland and around the residential areas. The main tree species are artificially planted poplar. The study area previously belonged to a traditional agricultural landscape. Over the past decade, the implementation of the “Central Henan Urban Agglomeration” policy has considerably changed the landscape pattern of the study area. At present, Zhengzhou

and Kaifeng’s governments wish to determine the landscape pattern changes in the study area under the “Central Henan Urban Agglomeration” policy, which can be used to monitor the progress of this planning policy and provide a necessary reference for future land policies.

Data sources

The data source is based on our previous study (Fan et al. 2018): (1) the remote images of the study in 2005, 2010 and 2015 are downloaded and registered by GIS 10.0, (2) the land type of study area were divided into cultivated land (CL), including irrigated lands and paddy fields, forest

land (FL); water areas (WA), including rivers, ditches, and pools; settlements and mining sites (SMS); and unused land (UL); (3) 5 landscape metrics (SHDI, LPI, NP, TE, and PAFRAC) were selected from 14 through principal component analysis to avoid repetition (Table I), and 20 m was determined to be the optimal grain size.

Methods

The research process can be divided into two steps. At first, the sample plots of gradient analysis were determined. Then, analyzing the gradient change at landscape level by landscape pattern index.

The selection of the plot size and location

Eleven points (P0, P1, P2, P3, P4, P5, P6, P7, P8, P9, and P10) along Zhengkai Road were selected, and the study area was divided into 10 equivalent sections (Figure 2).

Four circles with radii of 250m, 500m, 100m and 1500m were established from the center of each point (from P0 to P10 in Figure 2). That is, four extent sizes were created for analysis. (Figure 3).

Five landscape metrics (SHDI, LPI, NP, TE, and PAFRAC) were calculated in FRAGSTATS 4.2 for each extent size. Then, a comparison figure

of the extent size was generated to find the optimal extent size.

The Gradient analysis of the plot

Based on the optimal extent of each plot, five landscape metrics SHDI, LPI, NP, TE and PAFRAC were used to analyze the gradient landscape pattern spatially and temporally at the landscape level. The analysis process are performed by FRAGSTATS 4.2.

RESULTS

Determining the optimal extent size

The extent sizes of points P0 and P10 were beyond the range of the study area (Figure 2), so the other points (P1, P2, P3, P4, P5, P6, P7, P8, P9) were selected to analyze the extent sizes. The results are shown in Figure 4 (a, b, c, d, and e).

When the extent was 250 and 500m, the sampling was not sufficient to present the landscape's characteristics, and, it is not displayed in Figure 4 (e).

From Figure 4 (a) to Figure 4 (d), the five landscape metrics for the nine sampling points did not change as much when the extent size was 250 and 500 m. That is, the landscape metrics were insensitive to extent size from 250 to 500m

Table I. Five landscape metrics.

Abbreviation	Landscape metric	Definition or formula
SHDI	Shannon's Diversity Index	Proportional abundance of each patch type
LPI	Largest Patch Index	Area of the largest patch in the landscape divided by the total landscape area
NP	Patch Number	Number of landscape patches
TE	Edge Density	Sum of the lengths of all edge segments in the landscape
PAFRAC	Perimeter-Area Fractal Dimension	Factor reflects the shape complexity across a range of spatial scales (patch sizes)

and could not represent the characteristics of the gradient (Zhu et al. 2006). When the extent size was 1500 m, the landscape metrics greatly varied and, thus, could not represent the landscape’s characteristics (Tan et al. 2008).

Here, 1000m was selected as the optimal extent size.

Gradient Analysis

The circles with a radius of 1000m were used as the extent size, and five landscape metrics were calculated at nine sampling points for landscape pattern analysis in 2005, 2010 and 2015. The results are shown in figure 5 (a, b, c, d and e).

According to Figure 5a, the overall NP value of the study area increased over time, indicating that landscape fragmentation became more serious from 2005 to 2015. Meanwhile, the NP number in the western portion of the study area changed more than that in the east, indicating that landscape fragmentation was more serious in the west (next to Zhengzhou). However, the

NP number decreased at sample point P6, suggesting lower landscape fragmentation.

The figure 5(b) shows that the overall change LPI decreased from 2005 to 2015. In our study area, cultivated land was the dominant patch. That is, the large area of cultivated land decreased because of the influence of landscape fragmentation during urbanization. The LPI rapidly decreased from 2005 to 2010, but barely changed from 2010 to 2015. Meanwhile, the LPI in the western portion of study area changed less than that in the east, revealing that the area of the large patch in the eastern portion of the study changed more than that in the west (next to Zhengzhou).

As is exhibited in figure 5(c), the overall TE greatly increased from 2005 to 2015, but remained relatively uniform in space. The TE of the west (next to the Zhengzhou city) was slightly above the east in the study area. Combined with the above analysis from figure 5 (a), the TE increased because of an increase in landscape fragmentation.

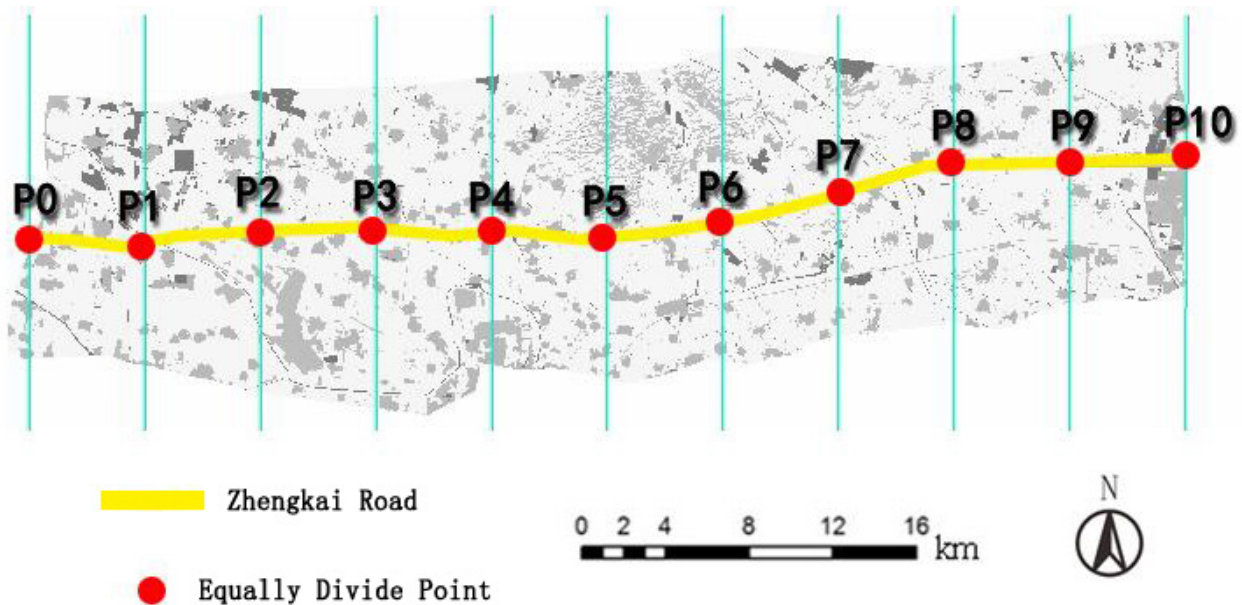


Figure 2. Gradient division of study area.

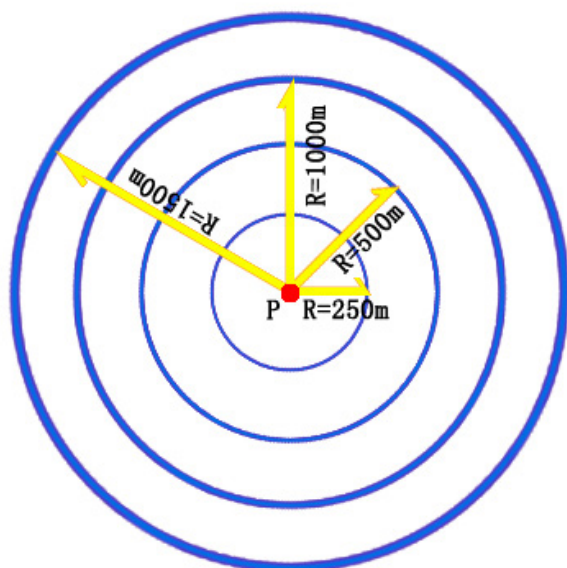


Figure 3. Extent sizes of each point.

According to figure 5d, the overall PAFRAC greatly increased from 2005 to 2015. That is, urbanization policies gradually became more influential from 2005 to 2015. In the Spatial gradient, the PAFRAC change in the western area (next to Zhengzhou) was greater than that in the east of the study area.

As can be seen from figure 5e, the overall SHDI of the study area gradually increased from 2005 to 2015. The SHDI change from 2005 to 2010 was greater than that from 2010 to 2015. Meanwhile, the LPI in the eastern portion of the study area changed more than that in the west (next to Zhengzhou).

From Figure 5, in our study area, the change of landscape pattern shows obvious gradientness. The landscape pattern in the eastern and western of the study area experienced larger changes than the middle area. The gradient change of landscape pattern in the study area is unbalanced. The western end mainly changed in terms of the patch number, patch shape and anthropogenic influence, but the patch types in the east changed more rapidly than those in the west.

DISCUSSION

In the process of rapid urbanization, human driving force is the main reason of landscape pattern change. From the research results, the location of the study area and the relevant regional policies have a great impact on the landscape pattern change in the study. The research results will also vary with different research scales and different landscape pattern index.

Landscape metrics and scale

The extent size is indispensable in landscape pattern analysis (Turner 1989, Saint-Geours et al. 2014). Comparative analysis of multiple extent sizes are widely used in landscape pattern analysis. However, the different scales were discontinuously set in previous studies, and the determination of interval is usually subjective. One scenario is that the optimal extent may not fit the subjective interval. That is, the comparative scale should be determined objectively and continuously in future.

Landscape metrics method is a useful tool for analyzing and monitoring landscape patterns (Uuemaa et al. 2013). Generally, using 5 to 6 metrics is sufficient to express landscape pattern Change (Baldwin et al. 2004). In this paper, five landscape metrics which are selected in a previous article (Fan & Ding 2015) were used to analyze landscape pattern change from 2005 to 2015 at the Landscape level. However, if we analyze the landscape at class level or patch scale, the landscape metrics should be re-selected because of scale dependency (Gao & Li 2011).

Landscape pattern analysis

At present, landscape is driven by urban agglomeration in China. "Urban to rural" is the traditional model for the gradient analysis of

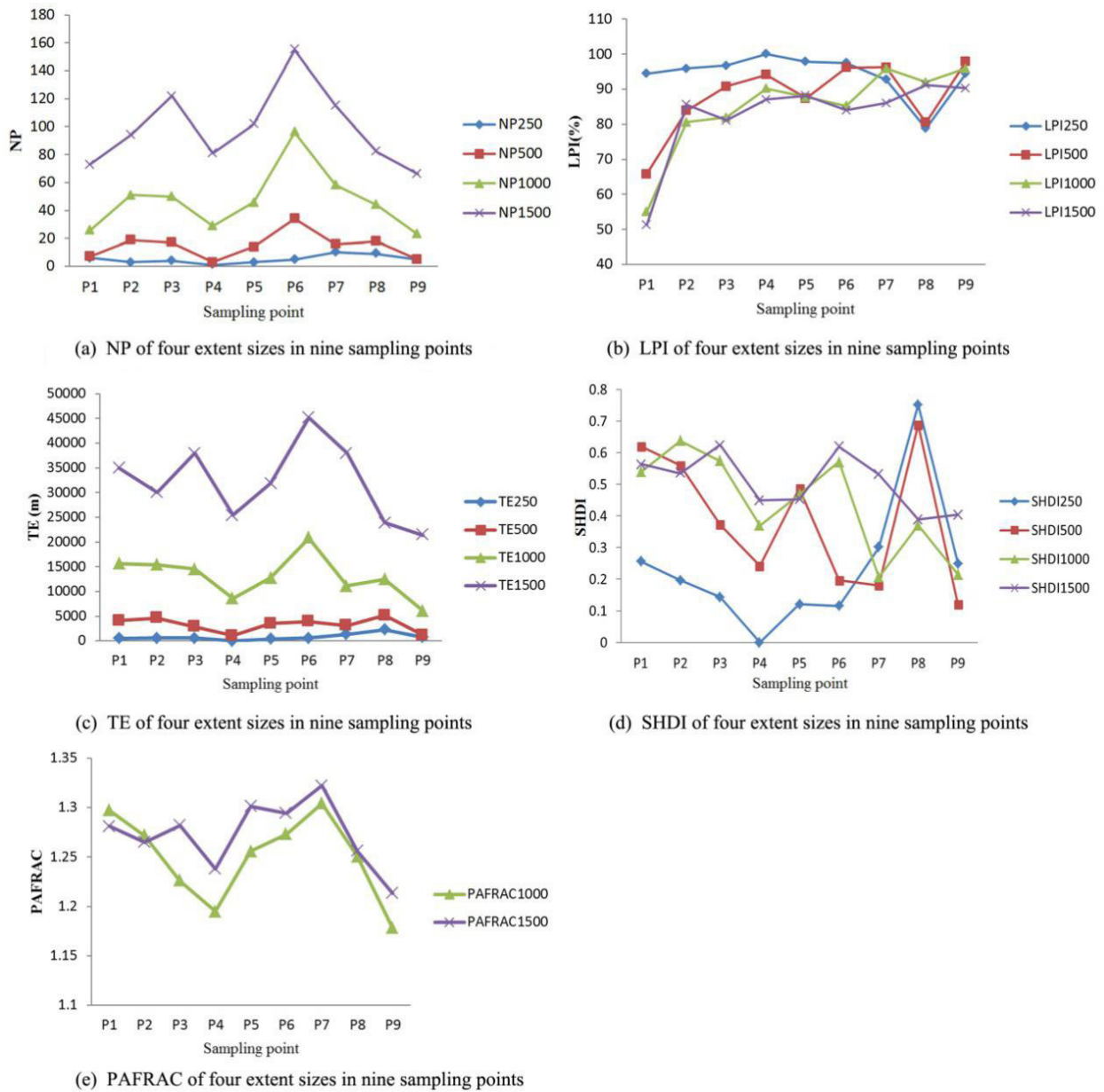


Figure 4. The landscape pattern metrics of four extent sizes in sampling points.

landscape pattern, which cannot determine the influences of many cities. In this paper, we used the specific gradient to show the influence of Zhengzhou and Kaifeng on the landscape pattern of the study area, which follows the “urban-rural-urban” model. This case can compare the influence of two cities on landscape pattern change.

Zhengzhou City is the provincial capital of Henan, which is an obvious policy advantage in terms of urbanization, and the landscape pattern of Zhengzhou changed more than that of Kaifeng. According to figure 5, P6 is an obvious feature point with relatively large NP, TE, PAFRAC and SHDI values. In addition to the “Central Henan Urban Agglomeration” policy, there is a “Guandu Group Plan” in P6.

CONCLUSIONS

Our study analyzed the gradient change in the landscape pattern of the “Core Area of the Zhengzhou and Kaifeng Integration” from 2005 to 2015. The results shown below:

The landscape pattern in the western portion of the study area change more than the

east. The landscape pattern of both the eastern and western ends of the study area changed faster than that of the middle area. The sampling point P6 changed faster because of the “Guandu Group Plan”. In summary, the landscape pattern of the study area near the provincial capital was more influenced than that of the general city.

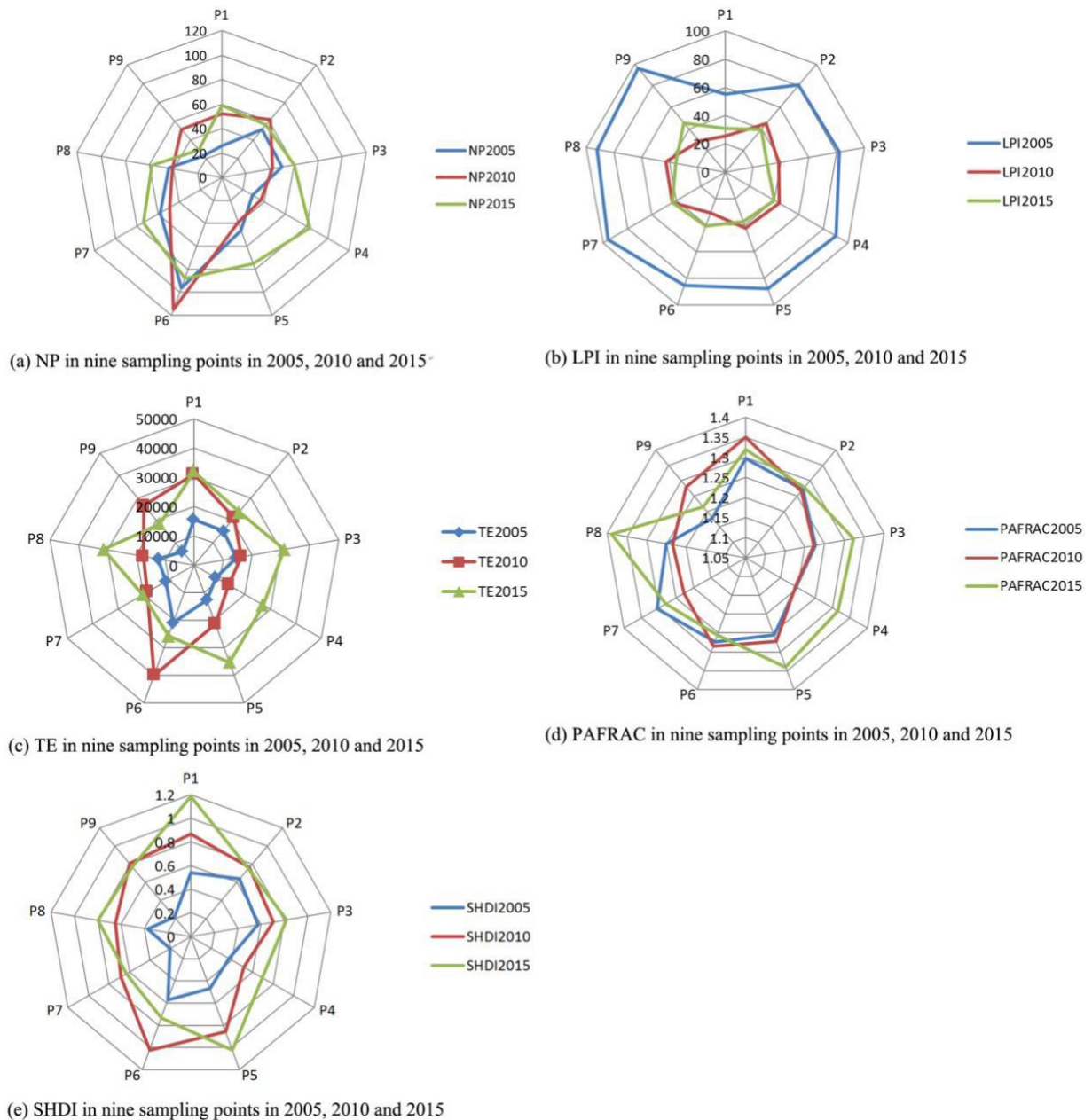


Figure 5. The landscape pattern metrics in nine sampling points in 2005, 2010 and 2015.

City policies exerted important effect on the landscape pattern.

The landscape pattern in the western portion of the study area mainly changed in terms of patch number, patch shape and human influence. However, the patch types in the east changed faster than those in the west. As for the change speed of patch type, this is not involved in the previous landscape pattern gradient analysis.

Location is the basic condition that affects the gradient change of pattern, and policy plays a leading role in urbanization. In gradient analysis, the choice of scale and landscape pattern index will affect the results.

This is an typical case of “urban–rural–urban” urbanization model in china, which differs from previous cases of “urban–rural” model. This new model can better elucidate the influence of agglomerated on landscape pattern, which can provide more accurate information to local governments.

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