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# Changes of Residential Land Density and Spatial Pattern from 1989 to 2004 in Jinan City, China

YIN Haiwei[1], KONG Fanhua[2], ZHANG Xiang[1]

(*1. Department of Urban Planning and Design, Nanjing University, Nanjing 210093, China;*
*2. International Institute for Earth System Science, Nanjing University, Nanjing 210093, China*)

**Abstract:** Urban sprawl is driven by a myriad of factors, the predominant one of which is the development of residential land. Selecting part of Jinan City for a case study, we use the landscape metric of percent of landscape (PLAND) to capture residential land growth and density changes in 1989, 1996 and 2004 to illuminate the dynamic process of residential land development. The results indicate that the moving window method and the landscape metrics method are efficient ways to describe residential land density. The residential land showed the greatest change among the built-up land with 1995.68 ha from 1989 to 2004, which is mainly transformed from agriculture land and green space. The urban center area of study area is primarily covered with medium density residential land, and surrounded by high density residential land. The development pattern of residential land exhibited both fill-in (new growth occurs through infilling the free spaces within the developed area) and sprawl processes, influenced by a series of factors, such as urban development policy, conservation of springs, recreational and aesthetic amenities. The findings of the study will help to guide urban planning with a focus on the management and protection of the environment and resources.
**Keywords:** residential land density; landscape metric; urban sprawl; moving window; Jinan

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## 1 Introduction

With the urban development, the world′s population has become increasingly concentrated in cities. In 1940, only one in eight people lived in an urban center, but this increased to one in three by 1980 (World Commission on Environment and Development, 1987). It is expected that about 60% of the world′s population will live in urban areas by 2030 (UNPD, 2003). Growing population typically requires the development of residential land, along with its accompanying infrastructure, commercial, and industrial development, urban sprawl and land use changes (Hammer *et al*., 2004). The development of residential land often affects the pattern, dynamics and functionality of urban landscapes and ecosystems, because the development of residential land is strongly influenced by individual choices over location and land use (Irwin and Bockatael, 2004; Hammer *et al*., 2004). Factors such as the environmental amenities and the accessibility to infrastructure affect these individual choices (Gordon and Richardson, 1997; Turner, 2005). Especially, scenic natural resources attract development, residential land growth is more likely to occur in areas of particularly high ecological value (McGranahan, 1999), and may eventually cause environmental degradation (Hammer *et al*., 2004; Brueckner and Largey, 2008; Bi *et al*., 2010). Data on residential land development can thus be enormously used to understand the methods and the effects of urban landscape change and thereby influence the formulation of policies to guide future growth. However, the way to quantify residential land development is always a hot issue in recent years.

The land use density is essential to capture urban de-

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Corresponding author: YIN Haiwei. E-mail: qzyinhaiwei@163.com

velopment (Gordon and Richardson, 1997; Torrens and Alberti, 2000; Sudhira *et al*., 2004; Lu and Weng, 2006), and most empirical studies of urban development are based on aggregate measures of density of urban built-up area, which is characterized as impervious land (Torrens and Alberti, 2000; Barnes *et al*., 2001; Epstein *et al*., 2002; Lu and Weng, 2006; Hasse and Nuissl, 2010); however, they usually fail to account for the noncontiguous development patterns that may associate with sprawl at a class level (Carrion-Flores and Irwin, 2004). The studies of residential land density and pattern change could be useful to identify the factors that drive urban sprawl. The land use density is an important index to characterize the urban development, however, it is still contentious as to which is the best variable to represent the urban development density. In this study, we chose the moving window method combined with the landscape metrics to quantify the residential land density and show its spatial pattern characteristics in some districts of Jinan City. The landscape metrics describe the expanding footprints of residential land. Understanding such a residential land density change and spatial pattern will help plan for urban development as well as urban green space protection.

## 2 Study Area

As the capital of Shandong Province, Jinan City (36°32′–36°51′N, 116°49′–117°14′E) is located in the eastern part of China, north of the Taishan Mountain and south of the Yellow River (Fig. 1a and Fig. 1b). At present, Jinan City consists of six districts (Lixia, Licheng, Huaiyin, Tianqiao, Changqing, and Shizhong), three counties (Pingyin, Shanghe, and Jiyang), and one city (Zhangqiu). Jinan has a typical warm-temperate, semi-humid, continental monsoon climate and well-defined seasons. The mean annual temperature is 14℃, and the average mean precipitation is 650–700 mm. Jinan has sprawled greatly in the last 50 years. During 1949–2004, the areal extent of built-up areas has increased from 24.6 $km^2$ in 1949 to more than 200 $km^2$ in 2004 (Jinan Statistics Bureau, 2005). The urban population has also grown dramatically, increasing from $0.6 \times 10^6$ in 1952 to $3.1 \times 10^6$ in 2004, and the share of the total population rose from 19.35% to 52.19% (Jinan Statistics Bureau, 2005). Continuous rural-to-urban migration flows in Jinan have largely contributed to the increase in the urban population and residential land development. The study area in this study includes part of Shizhong, Lixia, Huaiyin and Tianqiao districts in Jinan City (Fig. 1c), that is the entire inner part of the 3rd ring road with approximately 538.11 $km^2$ (Fig. 1d).

Jinan is known as the ′City of Springs′ (Jinan Landscape Bureau, 2001). The mountain region in the south, providing scenery and forests, is the key to protecting the sources of these famous springs. Hence, conservation of the south mountain region is always a key issue in Jinan City (Kong and Nakagoshi, 2006). In recent decades, however, the green space amenities have attracted migrants who have established more and more settlements in the south mountain region, thus encroaching gradually on the scenic forests of the area and posing a very real threat to the fragile ecosystem. In response to growing concerns about the undesirable impacts of sprawl on the south mountain region, a wide range of policy instruments have been developed to manage urban growth and to protect the natural environment from development.

## 3 Data and Methods

### 3.1 Data and processing

Data used in this study include the SPOT 2 images in 1989 (resolution 10 m; panchromatic band), 1996 (resolution 10 m, panchromatic band; and resolution 20 m, 4 bands), and 2004 (resolution 10 m, 4 bands); and the Landsat 5 TM image in 1989 (resolution 30 m, 6 bands; resolution 120m, 1 band). To obtain residential land data as well as other land use information in 1989, 1996 and 2004, the SPOT and Landsat images were rectified and geo-referenced to the Universal Transverse Mercator (UTM) coordinate system, and resampled to the same resolution by using the software of ERDAS Imagine System. The residential land maps were created by visual interpretation based on the ARCGIS, combined with field surveys and ground truthing as necessary. The maps were shown in Fig. 2. The accuracy of the land cover data as determined from the satellite imagery was 88%. These vector data were then converted to raster format with a pixel size of 10 m × 10 m using ArcMap spatial analysis. To capture the general features of the residential land, seven landscape metrics, percent of landscape (PLAND), mean patch size (MPS), patch density (PD), landscape shape index (LSI), largest patch

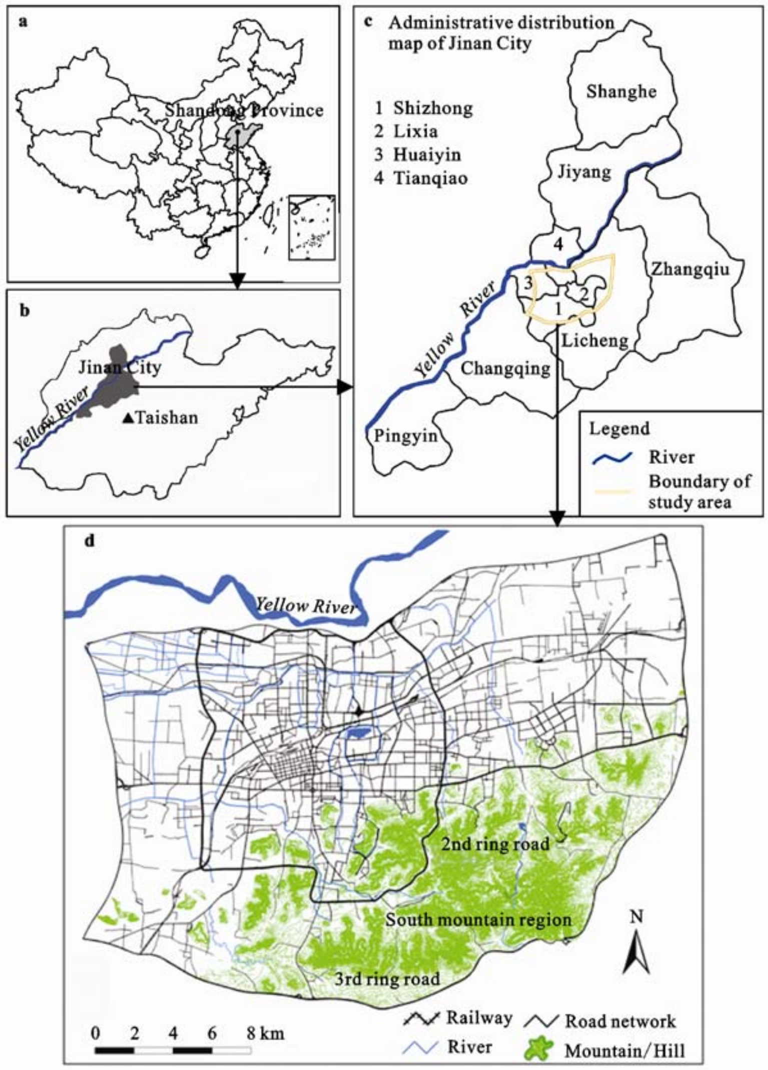



Figure 1 refers to Kong *et al*. (2010)

Fig. 1 Location of Shandong Province (a) and Jinan City (b), administrative distribution map of Jinan City (c) and information of study area (d)

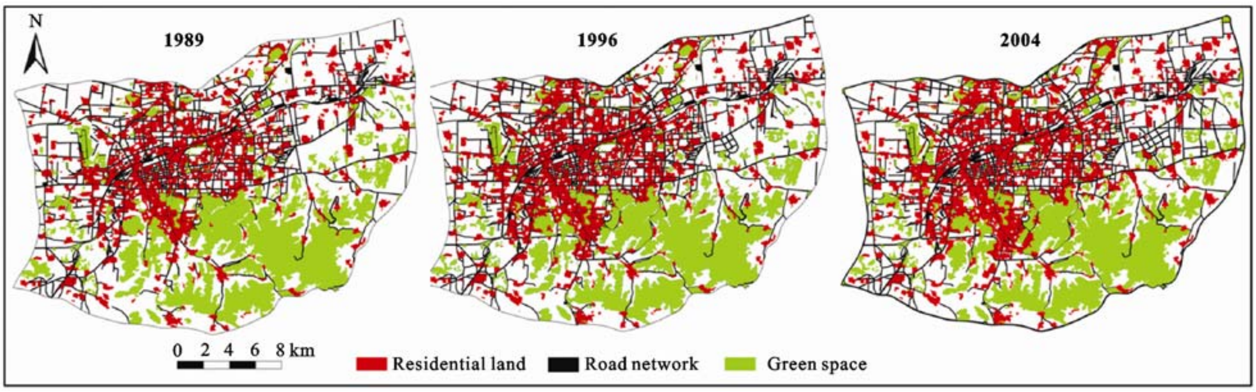



Fig. 2 Distributions of residential land, green space and road in 1989, 1996 and 2004 in study area

index (LPI), Aggregation index (AI) and class area (CA) were calculated using FRAGSTATS 3.3 (McGarigal *et al*., 2002a).

### 3.2 Moving window method and sector classification

To detect the spatial changes of the residential land density, we conducted a 'moving window' analysis supported by FRAGSTATS, which quantified the residential land density using the landscape metric of PLAND. The PLAND metric indicates the percentage of a certain landscape type to the total landscape (McGarigal *et al*., 2002b). In this paper, it was used to indicate the area percentage of residential land in a chosen window size. The PLAND metric was captured by the moving window method with a 500-m-radius window size. Several trials were made to test the impact of window size on the PLAND and to improve the smoothing effect. Results with a 500-m-radius window were proved to reveal its fluctuations well (Kong and Nakagoshi, 2006). FRAGSTATS does not compute the metrics for focal cells when a window not fully contained within the input grid (McGarigal and Cushman, 2002). Then, to minimize the boundary effect, a buffer was first made along the outline of study area and a positive value was given, where the width of this extension is equal to the radius of the window size 500 m. The window moved over the whole landscape, calculating the selected metric within the window and returning a value to the center cell and outputting a new continuous surface grid gradient map for the selected metric (McGarigal and Cushman, 2002; Kong and Nakagoshi, 2006). Consequently, the PLAND value of each cell indicates the percentage of residential land area in the 500-m-radius window size. The grid map of percentage of residential land area accordingly could express the density of residential land across the study area. Thus, the moving window analysis can be used to examine the residential land change process in the local area, and it will contribute to the analysis of potential changes for urban land use.

According to the PLAND value, the residential land densities were reclassified into 4 groups, namely high, medium, low density and others. The classification standard is shown in Table 1.

The residential land changes were not evenly spread across the study area. Consequently, the monitoring of residential land changes includes not only the general analysis of the whole study area, but it also includes local analysis at the separated sectors in the 8 directions, which will help to provide comprehensive information on residential land development.

## 4 Results and Analyses

### 4.1 Dynamic characteristics of residential land from 1989 to 2004

A time-series analysis from 1989 to 2004 with the landscape metrics was conducted to establish a perspective of residential land pattern changes over the past 15 years. The values of landscape metrics are shown in Table 2. Totally, there was a significant gradual increase in the built-up area percentage from 32.12% in 1989 to 38.38% in 1996 to 42.96% in 2004 (Table 2, shown by PLAND). The increase in area is approximately 3368.70 ha and 2459.71 ha in Period I (1989–1996) and Period II (1996–2004), respectively (Table 2, shown by CA). The built-up area increased approximately 5828.41 ha between 1989 and 2004. Among of the built-up land, the residential land area showed the greatest increase of 1995.68 ha from 1989 to 2004. This may indicate a significant change in urban structure caused by residential land development. However, the largest patch index of residential land was 0.27, 0.50 and 0.47, the mean patch size was 15.00 ha, 16.12 ha and 16.69 ha, and the aggregation index was 96.09, 96.12 and 96.18, respectively in 1989, 1996 and 2004. These data indicate that the pattern of residential land development has become

Table 1 Residential land classification based on PLAND landscape metric value

| Class | Abbreviation | Description |
|---|---|---|
| High density residential land | HDR | PLAND ≥ 50% |
| Medium density residential land | MDR | 30% ≤ PLAND < 50% |
| Low density residential land | LDR | 15% ≤ PLAND < 30% |
| Others | Others | PLAND < 15%, including the residential land scattered in the non-built-up area, and all other non-built–up areas |

Note: PLAND, area percentage of landscape

Table 2 Characteristics of urban land use structure in 1989, 1996 and 2004

| Class | Year | CA (ha) | PLAND (%) | LPI (%) | PD | MPS (ha) | LSI | AI (%) |
|---|---|---|---|---|---|---|---|---|
| Built-up land | 1989 | 17286.33 | 32.12 | 27.73 | 2.46 | 13.05 | 34.90 | 97.42 |
| | 1996 | 20655.03 | 38.38 | 35.42 | 2.26 | 17.01 | 33.93 | 97.71 |
| | 2004 | 23114.74 | 42.96 | 40.66 | 2.01 | 21.36 | 35.12 | 97.75 |
| Residential land | 1989 | 9149.95 | 17.00 | 0.27 | 1.13 | 15.00 | 38.37 | 96.09 |
| | 1996 | 10394.3 | 19.32 | 0.50 | 1.20 | 16.12 | 40.47 | 96.12 |
| | 2004 | 11145.63 | 20.71 | 0.47 | 1.24 | 16.69 | 41.30 | 96.18 |

Note: CA, class area; PLAND, area percentage of landscape; LPI, largest patch index; PD, patch density; MPS, mean patch size; LSI, landscape shape index; AI, Aggregation index

increasingly aggregated over the past 15 years. It may further suggest that residential land development is the result of a filling-in (the new growth occurs through the infilling of the free spaces within the developed area and accordingly causes the increase of aggregation degree) (Camagni *et al*., 2002) rather than the result of urban sprawl.

To explore the amount and location of residential land transformation with the other land use types, especially with green spaces, a land use conversion matrix was conducted (Table 3). In general, the results indicate that there was an increase of 19.97 km$^2$ in residential land during 1989–2004. The increase comes predominantly from the agriculture land, accounting for 85.18% of the total area. Another important source is the urban green space, occupied 18.93%. Compared Period I with Period II, the transformation from urban green space has been decreased, which is partly due to the implementation of related policies, such as the ′Great Changes of Jinan in Five Years′ policy (Jinan Planning Bureau, 2003) about conservation of green spaces, especially in the south area. However, from Fig. 3, it can be found that the loss of green spaces occurred over all of the 8 sectors, and most of the lost green spaces are in sectors 3, 4 and 5 (the south of Jinan city), where are mainly the remnant scenery forest and are looked as the ′green lung′, as well as the source of springs in the city. There has been a significant loss of green space relative to the residential land increase in the three sectors in the last 15 years. Consequently, it seems that the conservation efforts in these areas did not lead to a measurable improvement, which may result in serious impacts on the urban ecological environments and other socio-economic attributes.

## 4.2 Description of residential land density change

The residential land density differs significantly across the study area. The distribution pattern of residential land density indicates that the urban center area is primarily covered with medium density residential land where the central business district is located while the high density residential area is established around the center. However, the high density residential area does not make a closed circle, but a gap towards the southeast. This is due to the block of scenic forests. The outside of high-density residential land is then surrounded by medium-density residential land, low-density residential land and others (Fig. 4).

Table 3 Transformation of residential land from 1989 to 2004 (km$^2$)

| 1989 \ 1996 | Residential land | Sum | 1996 \ 2004 | Residential land | Sum |
|---|---|---|---|---|---|
| Residential land | 91.24 | 91.50 | Residential land | 101.06 | 103.95 |
| Industrial land | 0.37 | 29.41 | Industrial land | 0.36 | 38.71 |
| Public facility | 0.00 | 33.44 | Public facility | 0.77 | 42.18 |
| Road | 0.07 | 18.49 | Road | 0.00 | 21.68 |
| Green space | 2.34 | 125.74 | Green space | 1.44 | 120.30 |
| Agriculture land | 9.65 | 212.98 | Agriculture land | 7.36 | 179.53 |
| Water body | 0.03 | 9.76 | Water body | 0.02 | 11.06 |
| Others | 0.26 | 16.81 | Others | 0.47 | 20.70 |
| Sum | 103.95 | 538.11 | Sum | 111.47 | 538.11 |

There have been considerable changes of residential land density during the past 15 years (Table 4). In 1989, the percentage of HDR, MDR and LDR was 8.35%, 14.36% and 18.14%, respectively. Comparatively, the more dispersed or non-residential land (others) was greatest at approximately 59.15% of the total study area.

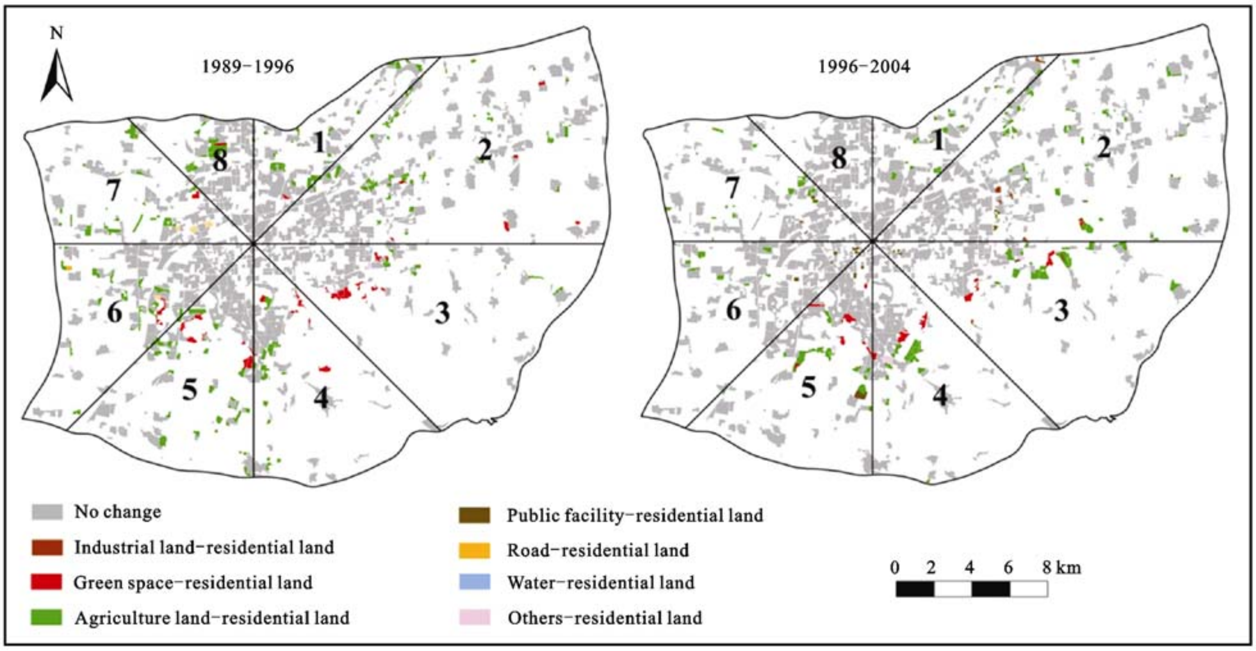



Fig. 3 Residential land changes in the period of 1989–1996 and 1996–2004 in 8 sectors

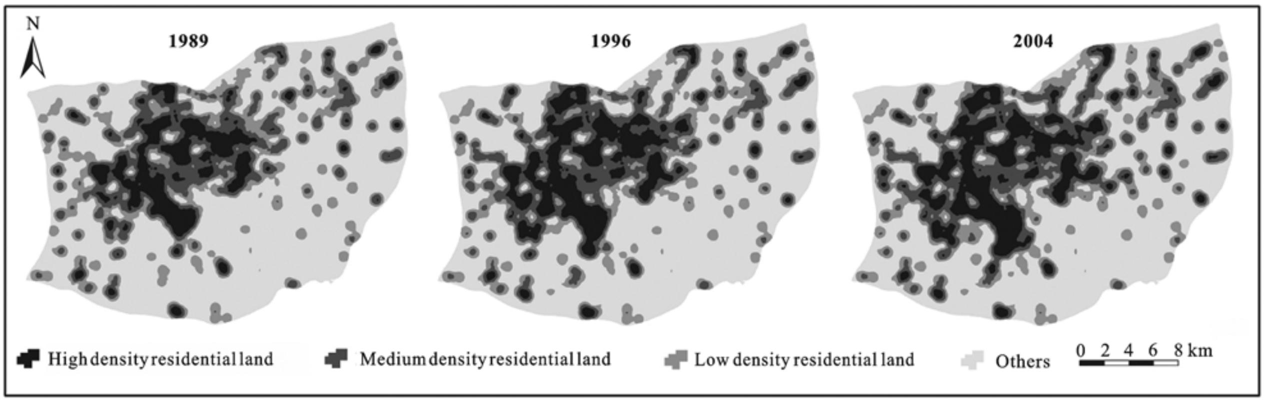



Fig. 4 Spatial patterns of residential land density in 1989, 1996 and 2004

Table 4 Descriptive statistics of classified residential land from 1989–2004

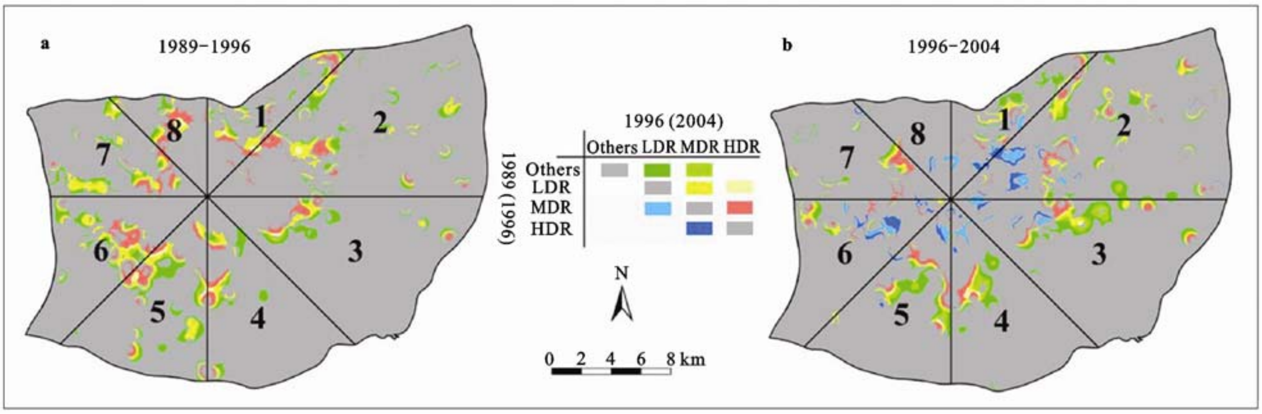
| Time | Descriptive index | High density | Medium density | Low density | Others |
|---|---|---|---|---|---|
| 1989 | Area (km$^2$) | 44.91 | 77.28 | 97.63 | 318.28 |
| | Percentage (%) | 8.35 | 14.36 | 18.14 | 59.15 |
| 1996 | Area (km$^2$) | 61.29 | 84.41 | 94.24 | 298.16 |
| | Percentage (%) | 11.39 | 15.69 | 17.51 | 55.41 |
| 2004 | Area (km$^2$) | 65.83 | 92.21 | 100.00 | 280.06 |
| | Percentage (%) | 12.23 | 17.14 | 18.58 | 52.05 |
| 1989–1996 | Increasing rate (%/yr) | 4.54 | 1.27 | –0.50 | –0.93 |
| 1996–2004 | Increasing rate (%/yr) | 0.90 | 1.11 | 0.74 | –0.78 |
| 1989–1996 | Increasing area (km$^2$/yr) | 2.34 | 1.02 | –0.48 | –2.87 |
| 1996–2004 | Increasing area (km$^2$/yr) | 0.57 | 0.98 | 0.72 | –2.26 |

During 1996 and 2004, with the exception of a 6.07% decrease in others, all three classified residential land density types increased in area (Table 4). From Period I to Period II, the increasing rate and area of HDR and MDR both raised but decreased significantly. The increasing rate of HDR declined from 4.54% to 0.90% from Period I to Period II. The rate of increase showed a change from –0.50% to 0.74% for LDR, indicating a sprawl of low density residential land. The residential land development pattern reflects not only a filling-in mode but also a sprawling process.

To identify the location of residential land density change, a further study was conducted to analyze the spatial changes among the classified residential land (Fig. 5). The results suggest that there have been significant changes of residential land area among the different densities in 8 sectors (Table 5). During Period I, there were no HDR transformed to LDR. The area of newly developed residential land was 20.01 $km^2$, including 18.00 $km^2$ of LDR and 2.01 $km^2$ of MDR both converted from others. Figure 5 indicates that residential sprawl lands are mainly located at the peripheral areas of urban centers or around dispersed villages. The filling-in densification area is approximately 34.97 $km^2$, including LDR being transformed to MDR and HDR, as well as of MDR being transformed to HDR. However, in Period II, except for the continuing residential sprawl from others to LDR and MDR, there was a significant de-densification process of residential land development. For example, there were 4.52 $km^2$ of HDR transformed to MDR and an additional 3.41 $km^2$ of MDR converted to LDR. Figure 5 shows that most of these areas are located in the inner city. Such changes were mainly due to the implementation of the Urban Master Plan 1996–2010 (Jinan Planning Bureau, 1996) and other polices related to the conservation of springs. To conserve the springs, the ′compaction′ development strategy is impossible in Jinan City, particularly in the urban center area where most of the springs are located (i.e., Baotu Spring and Zhenzhu Spring). Consequently, it was advanced to rebuild the old city area into a political, economic and cultural center which was mentioned in the Urban Master Planning 1996–2010 (Jinan Planning Bureau, 1996). According to the new city layout of central evacuation, Jinan City would reconstruct the urban center by transforming the residential area into high-grade commercial areas or cultural sections (Jinan Planning Bureau, 1996).

Transformations of different density residential land in 8 sectors indicate that the residential areas from the urban centers to the fringes have experienced considerable changes (Fig. 5). Attention was first paid to the newly developed residential areas, that is, LDR and MDR from others. During Period I, the greatest change occurred in the 5th sector, followed by the 2nd and 3rd sectors for others. However, during Period II, if only considering the transformation from others to LDR, the 2nd sector rather than the 5th sector shows the greatest change. If including the transformation from others to MDR, the 3rd sector demonstrates the greatest change, accounting for 25.94% of total changes for others in 8 sectors. For the filling-in densification process, during Period I, the transformation from LDR to MDR and HDR was most obvious in the 2nd sector and the 5th sector comparatively. During Period II, the transformation from LDR to MDR in the 2nd sector remains the highest with 3.48 $km^2$. On the other hand, the 4th sector has the highest transformation from LDR to HDR with 0.42 $km^2$. In general, the top 4 sectors with the highest residential area changes could be ranked as sectors 5, 2, 7 and 6 in Period I and sectors 2, 3, 5 and 4 in Period II at a descending order.

The residential land development pattern was the result of a series of factors. One important reason was the orientation of the urban development policy. Before 1996, the urban development policy of ′developing to the west′ had been proposed by the local government, which resulted in the significant development of the 5th, 6th and 7th sectors. However, after the publication of the Urban Master Plan 1996–2010 (Jinan Planning Bureau, 1996), development to the east became the main focus; hence, significant development occurred in sectors 2, 3 and 4. However, the development patterns, especially those in sectors 3, 4 and 5, are also associated with the increasing role of urban green spaces (Kong *et al.*, 2007). It was intended to integrate attractive recreational and aesthetic amenities in those areas where growth rates were highest, thus numerous policies and regulations were published to protect the scenic forest and green spaces in these areas. However, the illegally constructed houses built by developers encroached on these areas what is still widespread. From figs. 2 and 5, it can be seen that the newly developed residential area in the south resembles an ′antenna′ extending to the




HDR: high density residential land; MDR: medium density residential land; LDR: low density residential land; Others: the residential land scattered in the non-built–up area, and all other non-built-up areas; 1, 2, 3, 4, 5, 6, 7, 8 represent different directions

Fig. 5 Transformation of residential land in 8 sectors during 1989–1996 and 1996–2004

Table 5 Transformation between classified residential land types in 8 sectors during 1989–1996 and 1996–2004 ($km^2$)

| 1989–1996 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Sum |
|---|---|---|---|---|---|---|---|---|---|
| Others–LDR | 0.97 | 3.54 | 2.48 | 2.06 | 4.20 | 1.95 | 2.15 | 0.66 | 18.00 |
| | (5.37) | (19.65) | (13.76) | (11.43) | (23.32) | (10.84) | (11.97) | (3.69) | (100) |
| Others–MDR | 0.08 | 0.08 | 0.32 | 0.32 | 0.41 | 0.21 | 0.50 | 0.07 | 2.01 |
| | (4.17) | (3.97) | (15.90) | (15.93) | (20.52) | (10.69) | (24.92) | (3.69) | (99.78) |
| LDR–MDR | 2.06 | 3.85 | 1.36 | 1.27 | 3.28 | 2.72 | 3.26 | 0.76 | 18.57 |
| | (11.09) | (20.75) | (7.34) | (6.84) | (17.64) | (14.67) | (17.58) | (4.11) | (100) |
| LDR–HDR | 0.32 | 0.44 | 0.18 | 0.31 | 0.81 | 0.12 | 0.18 | 0.49 | 2.86 |
| | (11.21) | (15.46) | (6.23) | (11.01) | (28.42) | (4.29) | (6.30) | (16.96) | (99.88) |
| MDR–HDR | 1.33 | 2.30 | 1.21 | 1.11 | 2.15 | 2.09 | 1.46 | 1.89 | 13.54 |
| | (9.84) | (17.00) | (8.90) | (8.18) | (15.88) | (15.47) | (10.80) | (13.96) | (100) |
| Sum | 4.76 | 10.21 | 5.54 | 5.07 | 10.85 | 7.11 | 7.56 | 3.88 | 54.98 |
| | (8.66) | (18.58) | (10.08) | (9.22) | (19.73) | (12.93) | (13.75) | (7.05) | (100) |

| 1996–2004 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Sum |
|---|---|---|---|---|---|---|---|---|---|
| Others–LDR | 1.94 | 4.13 | 3.70 | 2.25 | 2.59 | 0.59 | 0.81 | 0.09 | 16.09 |
| | (12.06) | (25.69) | (22.97) | (13.98) | (16.07) | (3.67) | (5.01) | (0.56) | (100) |
| Others–MDR | 0.00 | 0.47 | 1.56 | 1.07 | 1.01 | 0.01 | 0.08 | 0.00 | 4.19 |
| | (0.00) | (11.11) | (37.18) | (25.44) | (24.16) | (0.29) | (1.80) | (0.00) | (100) |
| LDR–MDR | 1.31 | 3.48 | 1.85 | 0.68 | 1.24 | 1.08 | 0.90 | 0.03 | 10.57 |
| | (12.39) | (32.90) | (17.54) | (6.43) | (11.69) | (10.23) | (8.52) | (0.30) | (100) |
| LDR–HDR | 0.00 | 0.00 | 0.17 | 0.42 | 0.23 | 0.00 | 0.05 | 0.00 | 0.88 |
| | (0.00) | (0.00) | (19.70) | (48.26) | (26.57) | (0.00) | (5.50) | (0.00) | (100) |
| MDR–LDR | 0.47 | 1.19 | 0.51 | 0.31 | 0.28 | 0.46 | 0.05 | 0.15 | 3.41 |
| | (13.68) | (34.75) | (14.89) | (8.98) | (8.12) | (13.56) | (1.54) | (4.47) | (100) |
| MDR–HDR | 0.49 | 1.78 | 1.27 | 0.88 | 1.47 | 0.67 | 1.21 | 0.09 | 7.87 |
| | (6.19) | (22.62) | (16.19) | (11.17) | (18.70) | (8.51) | (15.39) | (1.19) | (100) |
| HDR–MDR | 0.53 | 1.50 | 0.39 | 0.16 | 0.42 | 1.34 | 0.08 | 0.10 | 4.52 |
| | (11.73) | (33.16) | (8.61) | (3.54) | (9.32) | (29.73) | (1.69) | (2.28) | (100) |
| Sum | 4.73 | 12.54 | 9.45 | 5.76 | 7.24 | 4.16 | 3.17 | 0.47 | 47.53 |
| | (9.96) | (26.39) | (19.89) | (12.13) | (15.22) | (8.75) | (6.67) | (0.99) | (100) |

Note: Figures in parentheses are percentages of area (%)

south and radiating outward along transportation routes. The amenities of green spaces have attracted migrants and triggered rapid development in these areas. Meanwhile, the development of transportation routes is also a great contribution to the development, which provides convenient access to the area. The expansion of residential areas in the south has been identified as a major issue for future urban green space management, especially as relating to the conservation of the springs in Jinan City.

## 5 Conclusions

In this paper, we employed the landscape metric of PLAND with the moving window method to capture the spatial pattern and changing characterizes of residential land from 1989 to 2004. The results indicate that the moving window method combing with the landscape metric of PLAND actually provides an effective way of visualizing and quantifying the expanding footprints of residential land. The analyses in 8 sectors with PLAND metric is useful for identifying and analyzing the changing pattern of residential land of different density in the local area, which can then expose the temporal and spatial variability of residential land development more clearly.

The residential land of Jinan City has undergone considerable development during the past 15 years. From 1989 to 2004, the residential land increased 1995.68 ha, accounting for 34.2% of the total increased built-up area, mainly from the agriculture land and green spaces. The urban pattern change is partly due to the residential land development. The increase of the aggregation degree of residential land indicates a filling-in process. The varied density of residential land is approximately arrayed in a ring. However, the urban center is covered by the MDR, and then surrounded with the HDR. The decline of annual increasing rate of HDR and the increase of increasing rate of others, as well as the transformation of different density types indicate the complicated residential land filling-in and sprawl process. The sprawl of residential land in the south sectors (the 3rd, 4th and 5th sectors) indicates that increased density is prominently due to the attractive recreational and aesthetic amenities of the south mountain region, while in the east, the urban policy as well as the infrastructure construction (e.g. road) has caused the development of residential land. Meanwhile, both the density and growth characteristics indicate the highest potential for future growth, which may result in a significant landscape change.

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