Spatiotemporal land use/cover change of Central Dongguan City in the past 30 years based on remote sensing data

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Abstract. The Pearl River Delta urban agglomeration is one of the fastest-growing urbanization area in China. In order to quantitatively study the spatiotemporal change characteristics of urbanization and reveal the evolution mechanism of it, this paper chooses central Dongguan city, a typical highly urbanized area as a case study. The DEM data of Dongguan city with a spatial resolution of 30m×30m was used to automatically extract the river system and drainage catchment in central Dongguan city, and 7 basins were extracted. Based on a total of 12 land use/cover change from 1987 to 2015 in Dongguan city, combined with single land use dynamic degree and integrated land use dynamic degree, the types and changes of land cover in each catchment unit were quantitatively analysed. The analysis results revealed the spatial and temporal characteristics of the land use in each catchment in downtown Dongguan city, showed the law of land cover evolution process in the past 30 years in central Dongguan city, which provided the ideas for the study of urbanization evolution mechanism in the Pearl River Delta urban agglomerations.

1. Introduction
Urbanization is the trend of the world over the past century. According to the data from the central government portal website, China’s urbanization rate has reached 57.35% by the end of 2016, and the Pearl River Delta region has the fastest urbanization pace. Urbanization has changed the Land Use/cover Change (LUC) of basin surface, LUC is the most direct manifestation of the effects of human activity on the natural ecosystem of the earth’s land surface, as well as a bond between human social and economic activities and natural ecological processes [1]. The study of land use change in urban areas is helpful to further explore the impact of land use change on ecological environment, and provide some decision basis for the regional ecological security protection and land use policy-making in the process of urbanization.

Dongguan city is one of the core cities in the Pearl River Delta urban agglomeration, its high-speed urbanization has caused rapid changes in land use. Dongguan city is located in central and southern Guangdong Province, on the east bank of the Pearl River Estuary and in the Pearl River Delta downstream of the Dongjiang River. It lies between latitudes 22°39′ and 23°09′N, and longitudes 113°31′ to 114°15′E. Located in the middle of the economic corridor between Guangzhou and Shenzhen, adjacent to Hong Kong and Macao. Dongguan city southeast high, low in the northwest. The landform is dominated by hilly platform and alluvial plain. Central Dongguan city consists of Wanjiang Street, Nancheng Street, Guancheng Street and Dongcheng Street. Figure 1 shows the location of central Dongguan city.

At present, the researches on land use change at home and abroad mainly focus on the space-time pattern, the change process, the driving mechanism and the environmental effect, and most are aimed
at only a few urbanized periods. The study of quantitative analysis on land use change in highly urbanized areas based on catchment units is relatively few. In order to quantitatively study the temporal and spatial variation of urbanization and reveal the evolutionary process of urbanization, this paper chooses central Dongguan city as a typical case of highly urbanized research. Based on the DEM data of Dongguan city, the main river system in central Dongguan city was automatically extracted and the watershed was divided. Based on the data of land use/cover change in Dongguan city from 1987 to 2015, the types and changes of land cover in each catchment unit were quantitatively analysed, and the law of land cover evolution process in the past 30 years in central Dongguan city.

Figure 1. Sketch map of central Dongguan city

2. Methodology and data

2.1. Rapid urbanization plain river basin watershed delineator

Based on the DEM data in Dongguan city, this paper used the hydrological analysis toolbox of ArcGIS10.2 software to realize the watershed delineator of the central Dongguan city. The main contents include the determination of the flow direction, the analysis of the confluence accumulation, the generation of watershed river network and the division of watersheds and boundaries. The flow direction is determined according to digital terrain elevation, and the principle is that water flows to the lowest grid in eight adjacent grids. Accumulation is also known as cumulative flow into grid number, that is, the total number of upstream grids flowing into a grid, based on the flow direction. The flow accumulation is the basis for calculating basin area [2]. Due to the error of DEM measurement and the existence of some real topography (such as castor geomorphology), DEM data tend to exist in some depressions. Therefore, in this paper, the DEM was firstly filled to avoid the false flow direction. Secondly, using D8 algorithm to analyse the confluence direction, the Steepest-descent method was adopted to determine the flow direction. The amount of water flowing through each grid was calculated to obtain the cumulative value, set a reasonable threshold to extract the digital water system, and the comparison with the real water system is carried out [3]. On this basis, the boundary of the catchment area and the sub-catchment area of each outlet is analysed in sequence according to the location of the water outlet.

Because the study area is located in the rapidly urbanized plain river network area, the terrain is too flat, and the runoff direction and hydrological elements extracted from the DEM directly using the D8 algorithm often make mistakes, resulting in a great difference between the extracted catchment boundary and the actual situation. In addition to the flat terrain, human activities (road construction,
high-density buildings, drainage ditches, etc.) also affect catchment paths and catchment boundaries [4]. Therefore, in this paper, digital water system and real water system are firstly compared by using Google Earth HD remote sensing image. Secondly, based on DEM extraction basin, combined with comprehensive planning data of drainage and waterlogging in Dongguan city, measured data of inner-river in Dongguan city and HD remote sensing imagery, comparative analysis of regional topography was carried out on the extracted basins, at the same time, unreasonable water system and watershed was corrected, to complete the watershed delineator.

2.2. Single land use dynamic degree
Single land use dynamic degree is often used to indicate the quantity change of a certain type of land use within a certain period of time in the study area. The expression is:

\[ K = \frac{U_2 - U_1}{U_1} \times \frac{1}{T} \times 100\% \] (1)

In the formula, \( U_1 \) and \( U_2 \) are the areas of the land use at the beginning and the end of the study period respectively, \( T \) is the length of time in the study area, and when \( T \) is set to year, the value of \( K \) is the annual rate of change of the land use in the study area.

2.3. Integrated land use dynamic degree
Integrated land use dynamic degree refers to the rate of change of the entire land use types within a certain period in the study area and is an index that depicts the regional differences in the rate of change of land use types and can reflect the comprehensive effect of the socio-economic activities within the area on the land use change. The expression is:

\[ LC = \frac{\sum_{i=1}^{n} \Delta A_{(i)}(t_2-t_1)}{\sum_{i=1}^{n} A_{(i)}(t_1)} \times \frac{1}{t_2-t_1} \times 100\% \] (2)

In the formula, \( LC \) denotes the integrated dynamic degree during \( t_2-t_1 \), \( \Delta A_{(i)} \) denotes the transition of land use \( i \) to land use non-\( i \) within \( t_2-t_1 \), \( A_{(i)}(t_1) \) is the area of the land \( i \) within the monitoring period \( t_1 \); \( t_2-t_1 \) is the length of the study period.

2.4. Data
The data used in this paper are DEM data throughout Dongguan city, vector data of Dongguan administrative divisions, statistical yearbook data of Dongguan city, comprehensive planning data of drainage and waterlogging prevention in Dongguan city, and vector data of land use status in central Dongguan city (Figure 2). Land use data used in the study area are from Dongguan Land Use Database of 1987 to 2015 provided by Yangbo Chen et al [5]. The data sources come from the web site of the USGS (http://glovis.usgs.gov/). After the preprocessing such as geometric correction, radiation correction and atmospheric correction, the SVM classification algorithm was used to classify the pre-processed remote sensing images of each period to obtain the land use types of the central Dongguan city. The land use data were classified into six categories according to the resource and environmental database technology standard of Chinese Academy of Sciences, namely forestry land, grass land, farm land, urban area, water body and bare land.

3. Watershed boundary delineator
The inner river drainage system in central Dongguan city is bounded by the canal, it's divided into canal tributary river and Wanjiang river water system. The inner river of canal tributary is divided by the highland hills of north and south, divided into two parts: the canal tributary and the tributary of the Huangsha River. Due to abundant water resources in Wanjiang Street and mostly man-made ditches and river networks, this paper only extracted river basins from tributaries of the canal.

According to the DEM data of Dongguan City, ArcGIS 10.2 software was used to automatically extract seven basins, namely Shigu River, Xinji River, Hongfu River, Xinkai River, Xiaqiao River, Kuaizi River and Hengzhu River (Huangsha River tributary). Considering that the landscape of Dongguan City is dominated by hilly terraces and alluvial plains, the terrain is too flat in the rapidly urbanizing plains. The runoff direction and hydrology factors extracted from the DEM using the D8
algorithm often have errors (such as parallel catchment). In addition, human activities such as road construction, high-density buildings and drainage ditches will also affect the catchment path and catchment boundary, so this paper is based on DEM extraction basins, combined with the comprehensive drainage and waterlogging planning data of Dongguan City, measured statistics of inner river in central Dongguan city and Google Earth HD remote sensing images, the regional geomorphologic contrast analysis was carried out on the extracted watershed, and the unreasonable water system and watershed were corrected, the result is shown in Figure 3. The basic information of each watershed is shown in Table 1.

Figure 2. Land use of 1987-2015 in central Dongguan city

Figure 3. The watersheds of central Dongguan city
4. Land use change analysis

4.1. Land use dynamic degree analysis in watersheds

According to the land use data from 1987 to 2015 of central Dongguan city, a total of 12 periods of land use data were extracted in Shigu River basin, Xinji River basin, Hongfu River basin, Xinkai River basin, Xiaqiao River basin, Kuaizi River basin and Hengzhu River basin respectively using the ArcGIS10.2 software, as is shown in Figure 4. In order to analyse the change trend of land use spatial pattern between different watersheds in central Dongguan city, the area and land use dynamic degree of each basin from 1987 to 2015 were calculated, as shown in Table 2 and Table 3 respectively.

As can be seen in Figure 4, the land use types in the early period in each watershed were mainly farm land, forestry land and grass land. During the study area, the common manifestation of the LUC change in the basins is the continued significant increase of the urban land area and the decrease of the grass land area (Table 2 and Table 3). According to the area of LUC change, the urban land area increased significantly while the grass land decreased greatly, and the other LUC types change was slightly different. The area of farm land in all watersheds decreased except for the Shigu River basin; in addition to the Kuaizi River basin, the bare land area of the other basins increased; and the area of forestry land and water body varied from basin to basin. From the perspective of land use dynamic degree, urban land area in the basins showed obvious growth. Among them, the dynamic degree of the Xiaqiao River basin, Xinji River basin and Hengzhu River basin was 215.79%, 198.09% and 97.92% respectively, while the lowest dynamic degree of Xinkai River basin was 24.37%. The decrease rate of grass land was not very different among the basins, with an average dynamic degree of -3.13%. The decrease rate of forestry land in Xiaqiao River basin was the fastest and the dynamic degree was -0.93%, while the forestry land increased fastest in Shigu River basin, which was 0.80%. The change rate of farm land area varied from basin to basin, and the dynamic degree varied from -3.20% to 0.56%. Furthermore, the rate of change of water body area and bare land area were different in different basins.

Table 1. The basic information of the watersheds in central Dongguan city

| Watershed     | Location                  | Area (km²) | Length (km) |
|---------------|---------------------------|------------|-------------|
| Shigu River   | Nancheng                  | 19.29      | 8.28        |
| Xinji River   | Nancheng and Dongcheng    | 22.53      | 9.78        |
| Hongfu River  | Nancheng and Dongcheng    | 14.82      | 6.67        |
| Xinkai River  | Guancheng and Dongcheng   | 15.19      | 5.27        |
| Xiaqiao River | Dongcheng                 | 4.78       | 2.49        |
| Kuaizi River  | Dongcheng                 | 7.56       | 3.41        |
| Hengzhu River | Dongcheng and Liaoabu     | 15.42      | 6.33        |

Table 2. Statistics of land use change of every watershed in central Dongguan city during 1987~2015 (km²)

| Watershed     | Forestry land | Grass land | Farm land | Urban land | Water body | Bare land |
|---------------|---------------|------------|-----------|------------|------------|-----------|
| Shigu River   | 1.523         | -5.220     | 0.617     | 3.702      | 0.055      | -0.678    |
| Xinji River   | -0.354        | -7.003     | -1.891    | 9.984      | -0.476     | -0.260    |
| Hongfu River  | 0.660         | -3.430     | -4.336    | 8.354      | -0.119     | -1.129    |
| Xinkai River  | 0.075         | -3.562     | -6.325    | 10.587     | 0.014      | -0.788    |
| Xiaqiao River | -0.104        | -1.568     | -1.904    | 3.751      | -0.046     | -0.130    |
| Kuaizi River  | -0.080        | -1.959     | -3.393    | 5.596      | -0.186     | 0.022     |
| Hengzhu River | -0.329        | -5.029     | -5.328    | 11.056     | -0.050     | -0.321    |
Table 3. Dynamic Index of different land use types of every watershed in central Dongguan city during 1987~2015 (%)

| Watershed     | Forestry land | Grass land | Farm land | Urban land | Water body | Bare land |
|---------------|---------------|------------|-----------|------------|------------|-----------|
| Shigu River   | 0.80          | -3.08      | 0.56      | 67.71      | 0.18       | -1.97     |
| Xinji River   | -0.20         | -2.97      | -1.16     | 198.09     | -1.71      | -1.31     |
| Hongfu River  | 1.25          | -2.78      | -2.42     | 42.02      | -2.44      | -3.27     |
| Xinkai River  | 0.15          | -3.28      | -3.20     | 24.37      | 0.46       | -3.29     |
| Xiaqiao River | -0.93         | -3.27      | -2.89     | 215.79     | -3.04      | -2.29     |
| Kuaizi River  | -0.74         | -3.40      | -2.76     | 49.02      | -2.64      | 1.46      |
| Hengzhu River | -0.69         | -3.11      | -2.82     | 97.92      | -0.83      | -1.98     |

(a) Shigu River basin  (b) Xinji River basin  (c) Hongfu River basin  (d) Xinkai River basin
Figure 4. LUC types from 1987 to 2015

4.2. Watershed integrated land use dynamic degree
From the analysis of the integrated land use dynamic degree in the watersheds of central Dongguan city (Figure 5), there were obvious differences from basin to basin, which generally showed a decreasing trend from north to south. Among them, the integrated land use dynamic degree of Xiaqiao River basin was the largest, reaching 3.34%; followed by the Hengzhu River basin and Kuaizi River basin, the integrated land use dynamic degree was 3.21% and 3.09% respectively. The integrated land use degree of Shigu River basin was the lowest, which was only 2.12%, which reflected the general trend of land use change and extent is most moderate.
4.3. The impact of urbanization on LUC change

From the above analysis we could draw a conclusion that in the past 30 years, the LUC change in downtown Dongguan city has been marked by a significant decrease in farm land and grass land, and the area of urban land has increased significantly. Urbanization is one of the most important factors for the expansion of land use. In China, whether it is with the economic development and population caused by urban sprawl, or expansion of small towns in rural areas, will lead to the expansion of residential land and traffic land, and urban land area has been expanded by encroachment on farmland. The sharp reduction of farm land and grass land and the significant increase of impervious surface in urban land have changed the regional hydrologic cycle characteristics, making frequent flood disasters of central Dongguan city in recent years, which seriously affected people’s daily life. Therefore, in city construction, how to plan the urban land area of impervious surface distribution pattern, ensure that a certain area of farm land, forestry land and grass land is very important. The protection of regional ecological security and the development of land use policy are badly needed. Dongguan city should coordinate the urban land area and vegetation, water resources allocation ratio in the future development, so as to avoid a series of negative ecological effect.

5. Conclusion

This paper choose central Dongguan city, a typical highly urbanized area, to study the spatiotemporal LUC change in the past 30 years. Using ArcGIS 10.2 software to extract 7 watersheds, they are Shigu River basin, Xinji River basin, Hongfu River basin, Xinkai River basin, Xiaqiao River basin, Kuaizi River basin and Hengzhu River basin respectively. Based on the land use data of central Dongguan city from 1987 to 2015, the spatial and temporal characteristics of land cover type in the past 30 years were analyzed based on the watershed unit. The results showed that:

(1) In the past 30 years, the land cover type of central Dongguan city has changed significantly, showing a significant increase in the area of urban land and a significant decrease of farmland and grassland.

(2) From 1987 to 2015, the common features of the change of major land use types in the basins were: the continued significant increase in the area of the urban land and the significant reduction of grassland area. The difference is reflected in the dynamic degree of different land use types in different basins, and the dynamic degree of the urban land in Xiaqiao River basin is 215.79% while the Xinkai River basin has the lowest dynamic degree, only 24.37%. The decrease rate of grassland was not very different between the basins, with an average attitude of -3.13%. The decrease rate of forestry land in Xiaqiao River basin was the fastest and the dynamic degree was -0.93%, while the forestry land increased fastest in Shigu River basin, which was 0.80%. The change rate of farmland area varied
among the basins, and the dynamic attitude varied from -3.20% to 0.56%. Furthermore, there are also differences in the rate of change of area between water body and bare land.

(3) There are obvious regional differences in the integrated land use dynamic degree of each watershed from 1987 to 2015, which generally showed a decreasing trend from north to south. The overall land use dynamic attitude of Xiaqiao River basin was the largest, reaching 3.34%, which reflected the general trend of land use change and extent was most dramatic. The integrated land use dynamic degree of Shigu River is the lowest, which is only 2.12%, which reflected the general trend of land use change and extent is most moderate.

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