Transfer analysis of land-use type gravity center based on Landsat data - A case study of Zhoushan, China

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Abstract: Based on the Landsat images of 7-time phases from 1984 to 2016, this paper analyzes the center of gravity transfer of land types in Zhoushan City, China. The research shows that the center of gravity migration distances of construction land, forest land, water, tidal flats, cultivated land/grassland and bare land are 1.80km, 0.37km, 4.27km, 3.84km, 0.55km and 1.60km respectively. The construction land expands along the coastal plain of each island, leading to the gradual encroachment of cultivated land/grassland and the spatial distribution of cultivated land/grassland tends to be discrete. This study will provide data support for the rational decision-making of land resource management in Zhoushan City and promote the sustainable use of land resources.

1. Introduction

Land resources are the material basis for human survival and a resource in short supply. The sustainable use of land resources is conducive to the sustainable development of the regional economy. In recent years, with the continuous development of urbanization, regional land-use types have undergone great changes. Therefore, the center of gravity transfer analysis of land-use types can understand regional development and provide a reference for resource management and land planning.

With the rapid development of science and technology, the development of remote sensing technology makes it possible to study land surface changes in a large range, high precision and long time series. For example, Akinyemi used Landsat and SPOT data to study land-use change in the northern region of Rwanda [1]. Alam A used Landsat satellite data to assess land use and land cover change in Kashgar Valley [2]. Mohamed M A and other scholars used multi-temporal Landsat images and GIS monitoring to analyze the land use/land cover changes in Syria from 2010 to 2018 [3]. Allam M et al. evaluated land use/land cover changes in arid regions based on Landsat images [4]. Deng Z et al. used time-series Landsat 8 images to conduct land use/land cover classification analysis in highly urbanized areas [5]. Hasan S et al. used Landsat and night light data to monitor land use/land cover and socio-economic changes in south China in the past 30 years [6]. Mehrabi A et al. used multi-temporal Landsat images to monitor land-use change in Rafsanjan (Iran) over the past 30 years [7].

Zhoushan is the first prefecture-level city established by archipelago in China. The land area is small and scattered, and land resources are very scarce. Since the establishment of Zhoushan Archipelago New Area in 2011, the economy of Zhoushan has been developing rapidly and the permanent resident population has been increasing continuously, which leads to the increasingly prominent contradiction between supply and demand of land resources. This study supervised and classified the Landsat images of 7-time phases from 1984 to 2016, analyzed the center of gravity transfer of land use types, provided data support and technical support for rational allocation of land resources and improvement of land use.
efficiency.

2. Method

2.1. Technical Route
In this study, transfer analysis of land-use type gravity center was carried out based on long time series Landsat satellite remote sensing data, the technical route was shown in Figure 1. Firstly, the remote sensing image is preprocessed, the digital quantization value of the image is converted into the radiant brightness value of the ground object through radiation calibration, the radiation error caused by atmospheric absorption and scattering is eliminated through atmospheric correction and the image within the study area is obtained through clipping. Secondly, a classification system is constructed according to the characteristics of the features and research needs of the research area, training samples are selected and image classification is carried out based on supervised classification. Finally, the center of gravity transfer is carried out based on the results of land use classification in different periods.

2.2. Gravity center migration
The center of gravity transfer of land-use types can reflect the spatial pattern characteristics of regional land-use change. The concept of land type center of gravity is derived from the concepts of the population center of gravity and the economic center of gravity in geography. Assuming that a certain type of land in the study area is composed of \(i\) patches, the center of gravity coordinate of this type of land in the year \(t\) is shown in Equation (1):

\[
\begin{align*}
X_t &= \frac{\sum_{i=1}^{n}(Cti \times Xi)}{\sum_{i=1}^{n}Cti} \\
Y_t &= \frac{\sum_{i=1}^{n}(Cti \times Yi)}{\sum_{i=1}^{n}Cti}
\end{align*}
\]

where, \(X_t\) and \(Y_t\) are the latitude and longitude coordinates of the center of gravity of this type of distribution in a year \(t\), \(X_i\) and \(Y_i\) are the longitude and latitude coordinates of the geometric center of the \(i\)th patch, and \(Cti\) represents the area of the \(i\)th patch.

3. Research area and data

3.1. Research area
Zhoushan Archipelago has a total of 1,390 islands of various sizes, with a land area of 1,440.12km\(^2\). Zhoushan Island is the largest island in Zhoushan Archipelago New District and the administrative and economic center of Zhoushan City. It is 44km long from east to west and 18km wide from north to south, with an area of 502.65km\(^2\). Selection in this paper, the research area of Zhoushan's core development area, including the Zhoushan Island, Changzhi Island, Aoshan Island, Xiaogan Island, Lujiazhi Island and Diaoshan Island (Lidiao, Zhongdiao and Waidiao), as shown in figure 2.
3.2. Data
Landsat is a series of Landsat satellites launched by the National Aeronautics and Space Administration (NASA). Eight Landsat satellites have been launched since 1972. Landsat has accumulated large range and long time series of remote sensing image data of the surface, which are widely used in earth observation research. According to the current data source status and research requirements of this paper, 7 Landsat satellite images with a cloud cover of less than 5% and good imaging effect are selected, with a time interval of about 5 years, a total period of 32 years and an image spatial resolution of 30m. See Table 1 for the specific information.

| Imaging time | Image number | Sensor | Strip number |
|--------------|--------------|--------|--------------|
| 1984–04–23   | LT51180391984114HAJ00 | TM     | 118 / 39     |
| 1990–06–11   | LT51180391990162HAJ00 | TM     | 118 / 39     |
| 1995–08–12   | LT51180391995224HAJ00 | TM     | 118 / 39     |
| 1999–04–01   | LT51180391999091HAJ00 | TM     | 118 / 39     |
| 2005–06–04   | LT51180392005155BJC00 | TM     | 118 / 39     |
| 2011–05–20   | LT5118039201140BJC00 | TM     | 118 / 39     |
| 2016–05–01   | LC81180392016122LGN00 | OLI    | 118 / 39     |

4. Results and analysis

4.1. Results
Considering the characteristics of the study area and the spatial resolution of remote sensing images, the land use types were set as construction land, forest land, water, tidal flats, cultivated land/grassland and bare land. Based on the selection of training samples, the supervised classification was carried out based on the maximum likelihood method, the classification results were shown in Figure 3.

The barycenter coordinates of the ground-like objects can be obtained by calculating the classification results according to the area weight, thus the barycenter transfer distance of each type of
ground-like object can be calculated (as shown in Table 2).

| Period             | construction land | forest land | water | tidal flats | cultivated land/grassland | bare land |
|--------------------|-------------------|-------------|-------|-------------|----------------------------|-----------|
| 1984—1990          | 0.72              | 0.25        | 1.00  | 0.79        | 0.04                       | 3.18      |
| 1990—1995          | 0.64              | 0.15        | 0.35  | 0.53        | 0.42                       | 1.90      |
| 1995—1999          | 0.43              | 0.53        | 1.09  | 1.89        | 0.61                       | 1.68      |
| 1999—2005          | 0.77              | 0.11        | 4.76  | 1.65        | 0.75                       | 1.78      |
| 2005—2011          | 0.67              | 0.04        | 3.29  | 5.52        | 0.20                       | 3.29      |
| 2011—2016          | 0.93              | 0.22        | 1.40  | 11.40       | 0.20                       | 1.37      |
| 1984—2016          | 1.80              | 0.37        | 4.27  | 3.84        | 0.55                       | 1.60      |

4.2. Transfer analysis of land-use types gravity center

The transfer trajectory of land-use types gravity center is shown in Figure 4.

Figure 4 Transfer route of land-use type gravity center
The center of gravity transfer trajectory of construction land is shown in Figure 4(a). According to Figure 4(a) and Table 2, the center of gravity of the construction land has moved 1.80km to the north, the construction land has gradually expanded from the two main centers of Dinghai and Shenjianman in the coastal area in the south of Zhourshan Island to the coastal plain of each island in the study area.

The center of gravity transfer trajectory of forest land is shown in Figure 4(b). It can be seen from Figure 4(b) and Table 2 that the center of gravity of the forestland moved to the southeast before 1995, then the overall migration trend showed a northwest direction. In general, the center of gravity of the forest moved 0.37 km to the northwest.

The center of gravity transfer trajectory of water is shown in Figure 4(c). According to Figure 4(c) and Table 2, the center of gravity of the water body migrates 4.27km to the northeast. At the end of the study, the water bodies were mainly scattered between the coastal areas and forest land in the northwest and northeast of Zhourshan Island.

The center of gravity transfer trajectory of tidal flat is shown in Figure 4(d). According to Figure 4(d) and Table 2, it can be seen that before 1999, the center of gravity of the tidal flat moved to the northwest. From 1999 to 2016, the center of gravity of the tidal flat migrated in multiple directions, with a migration distance of 3.84km. After 32 years of reclamation and development, the few existing tidal flats are mainly located in the northwest of Zhourshan Island and the west of Xiaogan Island.

The center of gravity transfer trajectory of cultivated land/grassland is shown in Figure 4(e). According to Figure 4(e) and Table 2, the center of gravity of cultivated land/grassland migrated 0.55km from south to north. With the encroachment of construction land, the contiguous cultivated land/grassland was mostly located in the basin between the coastal plain and hills in the northwest and southwest of Zhourshan Island.

The center of gravity transfer trajectory of bare soil is shown in Figure 4(f). It can be seen from Figure 4(f) and Table 2 that before 1990, the center of gravity of bare soil shifted to the southwest. After 1990, reclamation projects shifted to the southeast coast and the northwest coast of Zhourshan Island and the center of gravity of bare soil moved in the same direction. The existing bare soil was mainly located in the coastal reclamation and construction area.

5. Conclusion
Based on the Landsat satellite images from the 7 phases covering the research area from 1984 to 2016, this paper obtained land-use type information through supervised classification, calculated the gravity center of each land-use type, and carried out the gravity center transfer analysis of land use type. The results show that :(1) the center of construction land moves 1.80km to the north and the construction land gradually expands from the two main centers of Dinghai and Shenjianmen in the coastal area in the south of Zhourshan Island. At present, it has spread all over the coastal plain of each island in the study area. (2) The forest land center of gravity migrates 0.37 km to the northwest, mainly distributed on the mountains and hills in the center of the island, with strong continuity of spatial distribution and small change of spatial distribution. (3) The center of gravity of the water migrates 4.27km to the northeast, with strong continuity and dispersion of the spatial distribution. (4) During the study period, the center of gravity of the tidal flat migrated to multiple directions, with a migration distance of 3.84km. A small number of the existing tidal flat is mainly located in the northwest of Zhourshan Island and the west of Xiaogan Island and the continuity of spatial distribution was reduced. (5) The center of cultivated land/grassland shifted 0.55km from south to north, mostly located in the basin between the coastal plains and hills in the northwest and southwest of Zhourshan Island, with reduced spatial distribution continuity. (6) The center of gravity migration distance of bare soil is 1.60km. The existing bare soil is mainly located in the coastal reclamation and construction area, the spatial distribution continuity has been enhanced.

In this study, limited by the image resolution and the distribution characteristics of ground objects in the study area, grassland and farmland cannot be separated and the influence of tidal changes on boundary extraction cannot be overcome. Therefore, using higher spatial resolution remote sensing data to obtain more detailed land use information is the direction of continuous efforts.
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