Remote sensing monitoring of ecological environment based on Landsat data

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Abstract. An ecological environment is a complex system fundamental to the sustainable development of society and economy. Landsat series satellites are widely used for monitoring the changes in the earth's surface morphology. With long time series data, Landsat can provide new methods and technical support for eco-environmental monitoring. This study developed remote sensing monitoring methods based on Landsat data to observe the changes in the ecological environment in the Zhoushan region, China. The regional environmental changes in vegetation, water and other key ecological factors were analyzed using multi-temporal remote sensing data. This study shows the effectiveness of this method for the extraction of key eco-environmental factors such as vegetation and water body and the evaluation of regional eco-environmental quality. This study also reveals ecological patterns in Zhoushan region and provides data support for regional eco-environmental assessment.

1. Introduction
Ecological environment form an integrated whole composed of biological communities and abiotic natural factors [1]. The changes in key eco-environmental factors, such as vegetation and water, are a direct reflection of the ecological impact of human activities on the earth's surface [2-4]. Therefore, it is of great significance to study the spatio-temporal evolution of key ecological environmental factors, such as vegetation and water, in order to understand the changes in the regional environment and maintain ecological balance and sustainable development.

The traditional environmental monitoring techniques use methods such as field investigation and sampling surveys, which are time consuming, costly, and limited by difficult terrain conditions [5]. Remote sensing technology surpasses the above limitations and is widely used in vegetation and water body information extraction due to its advantages such as its wide imaging range, fast acquisition speed, large spectrum segment, large amount of information, high economic efficiency [5-7].

Zhoushan City is a prefectural city composed of an archipelago of 1390 islands [8]. The land area is small and scattered, and the land resources are scarce. This study analyzes the spatio-temporal evolution of vegetation, water and other key eco-environmental factors of the Zhoushan Islands, using Landsat long-time series of satellite remote sensing data. It monitors and evaluates the conditions and characteristics of environmental change in the island-type cities, in order to provide data support and decision-making reference for regional eco-environmental protection and water resources allocation.
2. Research methods
Using long-time series of satellite remote sensing data on vegetation, water as key eco-environmental factors, this study monitored and analyzed the regional eco-environment of Zhoushan Islands, China. This process is shown in Fig. 1.

Firstly, the satellite remote sensing data were pre-processed, using radiometric calibration, atmospheric correction. Secondly, the training samples were selected according to the features of remote sensing images (spectral, shape, and texture features) in order to extract vegetation and water information. Then, the spatial distribution and the area of vegetation and water body were obtained. Finally, the spatial-temporal evolution of ecological environment was analyzed by integrating the extraction results of key eco-environmental factors such as vegetation and water in different phases.

3. Study area and data
3.1 Study area
Zhoushan Islands, China is a prefectural city composed of an archipelago. It is located at the confluence of the southeast coast of China and the estuary of the Yangtze River, facing the Pacific Ocean (121°30′–123°25′E, 29°32′–31°04′N).
3.2 Data
The Landsat Program, a collaboration between National Aeronautics and Space Administration (NASA) and the United States Geological Survey (USGS), has been providing users with accurate data on the Earth's surface and land use since 1972. The spatial resolution, the spectral resolution, and the revisit time of satellites have unique advantages and is a suitable data source for monitoring the surface morphology of long time series. In this study, 20 Landsat satellite remote sensing images from 1984 to 2017 were collected.

4. Results and analysis
4.1 Classification results
In this study, information on vegetation, lake, and aquaculture water between 1984 and 2017 was extracted using the method of supervised classification, and the area of each water body was measured. The results are shown in Tables 1 and 3.

Fig. 3 Remote sensing image classification result map
Table 1 Table of area statistics by category

| Year  | 1984  | 1988  | 1990  | 1992  | 1993  | 1996  | 1997  | 1999  | 2000  | 2003  |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Vegetation area/km² | 972.51 | 950.54 | 966.72 | 872.89 | 1080.04 | 911.65 | 956.23 | 1020.90 | 1039.48 | 969.12 |
| Lakes and rivers area/km² | 7.58 | 9.12 | 8.11 | 7.14 | 7.89 | 5.1 | 7.95 | 8.53 | 9.23 | 6.24 |
| Aquaculture fields area/km² | 20.86 | 51.07 | 74.26 | 42.32 | 82.35 | 28.92 | 34.46 | 49.22 | 31.44 | 44.92 |
| Water area/km² | 28.44 | 60.18 | 82.36 | 44.63 | 90.23 | 34.02 | 42.40 | 57.74 | 40.67 | 51.16 |

| Year  | 2005  | 2007  | 2008  | 2009  | 2010  | 2011  | 2013  | 2015  | 2016  | 2017  |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Vegetation area/km² | 996.38 | 976.07 | 998.16 | 900.54 | 1007.73 | 908.48 | 939.04 | 925.66 | 949.38 | 967.42 |
| Lakes and rivers area/km² | 6.05 | 7.14 | 13.86 | 9.24 | 16.25 | 9.86 | 16.12 | 15.87 | 27.13 | 16.04 |
| Aquaculture fields area/km² | 56.18 | 62.42 | 32.74 | 51.57 | 38.55 | 50.5 | 38.9 | 57.21 | 62.76 | 52.93 |
| Water area/km² | 62.22 | 69.56 | 46.60 | 60.80 | 54.79 | 60.36 | 55.01 | 73.07 | 89.88 | 68.96 |

Fig. 3 and Table 1 show that the economic water bodies in the study area, such as lakes and rivers, have significantly increased in the aquaculture paddy field area. The coastal areas, such as the southeast of Zhoushan Island and the south of Daishan County, were developed into construction land, which reduced the vegetation cover. It can be seen from the classification results that there are obvious changes in vegetation and water body indexes with the development and construction in the area. Based on their spatio-temporal evolution, we can explore the changes in the ecological environment in this area in the past 30 years.

4.2 Analysis of spatial-temporal pattern of vegetation

Fig. 4 shows the vegetation area change over time. From Figure 4, a decrease in the vegetation area from 972.51 square kilometers in 1984 to 967.42 square kilometers in 2017 can be observed, showing an overall downward trend of about 0.51%.

From the spatial aspect, the following law of development can be seen. In the southern part of Zhoushan Island, the area of vegetation decreases in the north, east and west of the old city district of Dinghai (Fig. 5). There is a large amount of forestland in Lincheng New area in the southeast of Zhoushan Island. The cultivated land cover area has clearly reduced, among which the amount of cultivated land is reduced even more (Fig. 6), and the vegetation area in the northern part of Zhoushan Island is reduced (Fig. 7).
4.3 Analysis of spatio-temporal pattern of water body

As shown in Fig. 8, the area of water body varies over time. From Figure 8, the area of water body is 20.86 square kilometers in 1984 and 52.93 square kilometers in 2017, showing an upward trend (excluding seawater), with an increase of about 14.29%. Among them, the areas of rivers, lakes, and cultivated paddy fields increased by 111.61% and 153.74%, respectively. The process of urban development will cause a certain degree of disturbance and destruction to the original ecological environment and reduce the vegetation cover area. At the same time, the economic water body will increase gradually to promote urban construction and economic development. The ecological changes and regional development are complementary and inseparable in this region.

In terms of spatial variation, an increase in the area of cultivated paddy fields is mainly observed in the coastal areas of Daishan Island (Fig. 9) and Qushan Island in Daishan County, Putuo District (Fig. 10), and the coastal zone of Taimen Town in the north of Taohua Island, in the west of Maitao Island, and in Taimen Town. There is no obvious change in the distribution of lakes and rivers, and the area of some water bodies decreases slightly.
5. Conclusion and discussion
The main purpose of this paper is to develop an environmental monitoring method based on remote sensing data of Landsat long time series. The data of Zhoushan region from 1984 to 2017 were processed using radiometric calibration, atmospheric correction, supervised classification, and two types of ecological environmental factors, vegetation and water body, were extracted. Through the analysis of its temporal and spatial evolution, the ecological change in Zhoushan City was revealed.

Based on satellite remote sensing data, vegetation and water bodies in the study area were analyzed. However, the existence of mixed pixels will impact the accuracy of data. Therefore, it is one of the objectives of the next project to use higher spatial resolution data to obtain more accurate classification results. In addition, multi-source remote sensing data can be used in future research to extract ecological environmental factors such as vegetation coverage, surface humidity, temperature, dryness, air quality, water quality and other ecological environmental factors and to explore the spatial-temporal pattern changes. The development of a more objective ecological environmental assessment model will be an important direction for further research.

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