Vegetation Growth Monitoring in Jiaozhou Bay Coastal Wetland Based on Multi-Source Remote Sensing Data

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Abstract. Jiaozhou Bay coastal wetland, located in the mouth of the Dagu River, is an estuary wetland. In this wetland seawater blends with freshwater. It is a rare type of national wetland, a unique ecosystem on earth. It is of great research value, but there are few articles conducting multi-indicator studies about Jiaozhou Bay coastal wetland ecosystem. This paper helps to formulate wetland conservation measures comprehensively through multi-source remote sensing monitoring. Based on NDVI, FVC, LAI, NPP and the spatial distribution changes of land use, this paper is a synthetical exploration of the vegetation growth of Jiaozhou Bay coastal wetland. The results show that: 1) From 2013 to 2019, NDVI, LAI and NPP indices rose to varying degrees in the coastal wetlands of Jiaozhou Bay. FVC showed a broad downward trend, and its indicators are declining in the north-central region; 2) The major land types are impervious surface and grassland, where the decrease proportion of grassland is the largest, and the increase proportion of impervious surface is the largest in the study area; 3) Analytical results demonstrate that the overall vegetation situation of Jiaozhou Bay coastal wetland improved on the whole, but with local deterioration. So, ecological protection measures in the study area have begun to bear fruit.

Keywords: Jiaozhou Bay; coastal wetland; vegetation index; remote sensing; land use.

1. Introduction

Wetlands, together with forests and oceans, are the three major ecosystems of the earth. Wetlands play an irreplaceable role in degrading pollutants, regulating climate, conserving water sources, maintaining the global carbon cycle and protecting animal and plant resources [1]. More recently, due to the over-reclamation and pollution of wetlands, overutilization of biological resources, siltation and irrational planning of water resources, wetlands continue to degrade, biodiversity is sharply reduced, soil erosion is intensified, and even human survival is threatened [2]. Jiaozhou Bay coastal wetland, located in the mouth of the Dagu River, is an estuary wetland. This wetland blend ocean water with freshwater. It is a rare type of national wetland, a unique ecosystem on earth, and of great research value [3]. Therefore, long-term monitoring and research of coastal wetlands in Jiaozhou Bay is of great significance for accurately estimating the evolution of wetlands and formulating targeted protection plans.

A single indicator is often used for the monitoring and research of wetland vegetation at present. For example, Baqi et al. used the normalized vegetation index to study the vegetation changes of wetlands in the Yellow River Delta [4]. Yuan Yirong et al. studied plant photosynthesis in Ruoergai Steppe with vegetation index [5]. Zhu Jiangtao et al. explored the long-term temporal and spatial changes of wetland vegetation in Poyang Lake by making wetland vegetation mapping [6]. However, a single index cannot fully reflect the vegetation change of wetland, and there are few articles on multi-index monitoring.

Therefore, this paper uses remote sensing technology to reflect the long-term temporal changes of vegetation in coastal wetlands in Jiaozhou Bay, and comprehensively explores the land type and growth of wetland vegetation in the region in the past 10 years by using Normalized Difference

Vegetation Index (NDVI) and Fraction Vegetation Coverage (FVC). Provide a theoretical basis for the future conservation plan of wetlands, and make the protection more targeted and scientific.

2. Data and Methods

2.1. Overview of the Study Area

The coastal wetland of Jiaozhou Bay is mainly located in the north and northwest coast of Jiaozhou Bay, with an elevation of 0-5 meters, and the total area of the wetland is about 348 km^2. It belongs to the northern temperate zone and has a continental monsoon climate influenced by the ocean [7]. The main rivers are the Jiolai River, Dagu River, Baisha River, Yang River, Jili River and Moshui River, of which the Dagu River has the largest flow. The local average annual temperature is 12 °C, with the highest temperature occurring in August and the lowest in January, and the average annual precipitation is 900 mm, which is unevenly distributed within the year, with the highest in July and the lowest in January [8].

2.2. Origin and Processing of Data

In this study, four periods of Landsat 8 data were obtained from 2013 to 2019, and all data in that year were synthesized at the median, and then banded operations were performed to obtain Normalized Difference Vegetation Index (NDVI) data, Leaf Area Index (LAI) and Net Primary Productivity (NPP), Fraction Vegetation Coverage (FVC) MODIS data products, and land use and land cover change (LUCC) products. The specific sources of data are shown in Table 1.

According to the study area, the NDVI, FVC, LAI, NPP, and LUCC data were clipped and Mosaic. The changes of them were used to monitor vegetation growth status, and the changes of land use types were monitored by LUCC.

Table 1. Research data source

Data	Time	Resolution	Data sources
Landsat8	2013-2019	30 m	Geospatial data cloud platform (http://www.gscloud.cn)
FVC	2013-2019	500 m	MODIS FVC(https://modis.gsfc.nasa.gov)
LAI	2013-2019	500 m	MODIS Leaf Area Index (https://modis.gsfc.nasa.gov)
NPP	2013-2019	500 m	MODIS NPP (https://modis.gsfc.nasa.gov)
LUCC	2020	30 m	Data sharing service system（http://data.casearth.cn）

2.3. Research Methods

2.3.1 Normalized Difference Vegetation Index(NDVI)

NDVI has strong indicative properties on vegetation, can effectively observe the growth trend of vegetation to a certain extent, and can express the spatial distribution characteristics of vegetation in a specific range [9]. In this paper, NDVI was used to analyze vegetation change from 2013 to 2019.The formula is as follows [10]:

$$NDVI = \frac{Band_{NIR} - Band_R}{Band_{NIR} + Band_R} \tag{1}$$

Among them, $Band_{NIR}$ is the near-infrared band and $Band_R$ is the red band.

2.3.2 Leaf Area Index (LAI)

LAI is defined as the sum of plant single-leaf areas per unit level of ground [11]. LAI is a major structural parameter of ecosystems, which is the basis for the characterization of crop growth changes and predicted crop yields [12]. This paper researches the average annual change of LAI from 2013 to 2019.

2.3.3 Net Primary Productivity (NPP)

NPP is defined as the total amount of organic matter accumulated by vegetation through photosynthesis per unit time and per unit area. NPP cannot only measure the carbon sequestration capacity of ecosystems, but also has great significance in sustainable development research such as ecological environment suitability regulation [13]. This paper analyzes the changes of NPP in coastal wetlands of Jiaozhou Bay from 2013 to 2019.

2.3.4 Analytical Methods

The NDVI data was calculated using Lansat8 remote sensing images. ArcGIS software was used to analyze the change trend of each index from 2013 to 2019, draw the change trend map, and divide the vegetation index into four categories, from low to high: large decrease, small decrease, small increase and large increase, combined with temporal and spatial distribution to analyze the change characteristics of NDVI, FVC, LAI, and NPP.

3. Results and Analyses

3.1. Spatial and Temporal Distribution of Land Use in Coastal Wetlands of Jiaozhou Bay

The land use types in the study area from 2010 to 2020 were analyzed, and the transfer matrix was used to analyze the land use change, as shown in Table 2. Through table comparison, it was observed that grassland and water showed a decreasing trend, of which grassland types decreased by nearly 116 square kilometers, and the rest of the land types showed an increasing trend, of which impervious surface increased the most, accounting for about 83 square kilometers, followed by wetland area increased by about 43 square kilometers. As seen in Figure 1 and Figure 2, the area of grassland cover in the northern part of the study area decreases more substantially, the impervious surface in the northern and coastal areas increases more substantially, the range of woodland distribution in the northeast and southwest decreases, and the range of wetlands in the coastal bay area expands significantly.

Table 2. Land use transfer matrix from 2010 to 2020 (unit: km^2)

2010 \ 2020	Impervious surface	Grassland	Arable land	Forest	Wetland	Water body	Sum
impervious surface	409.35	2.97	2.02	0	1.77	0.21	416.32
Grassland	56.07	277.46	43.27	10.09	24.03	5.80	416.72
Arable land	4.10	6.05	14.60	0	3.22	0.67	28.65
Forest	0.02	5.44	0.13	9.79	0	0	15.39
Wetland	9.44	3.41	1.77	0	8.70	1.53	24.85
Water body	20.38	5.71	4.97	0	29.29	549.51	609.86
Sum	499.36	301.03	66.75	19.90	67.02	557.73	1511.79

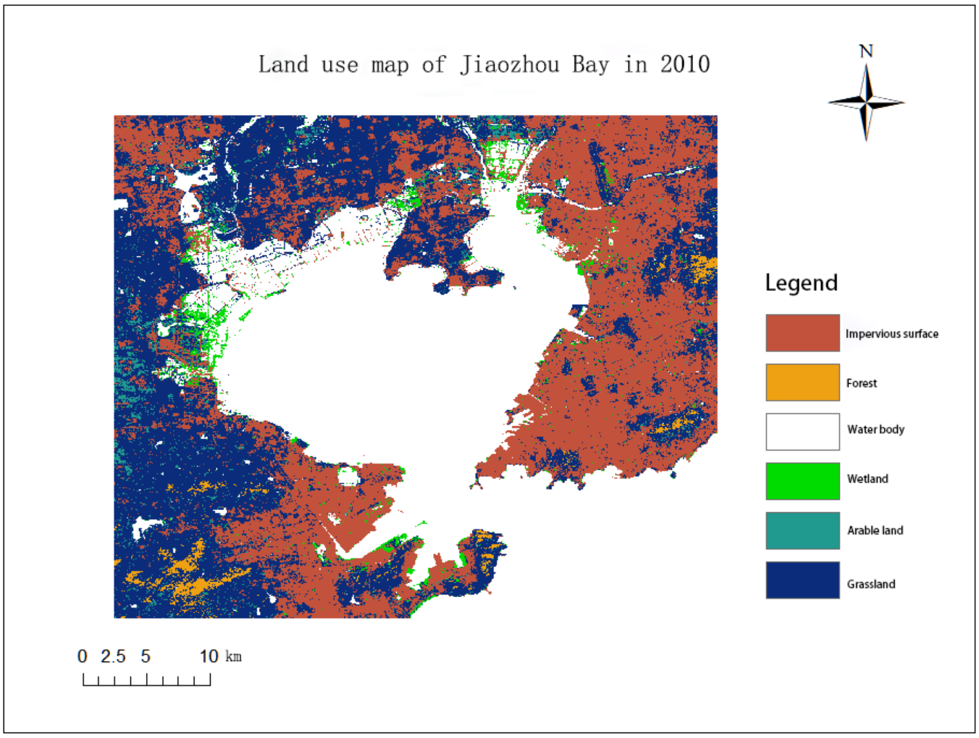

Fig. 1 Land use map of Jiaozhou Bay in 2010

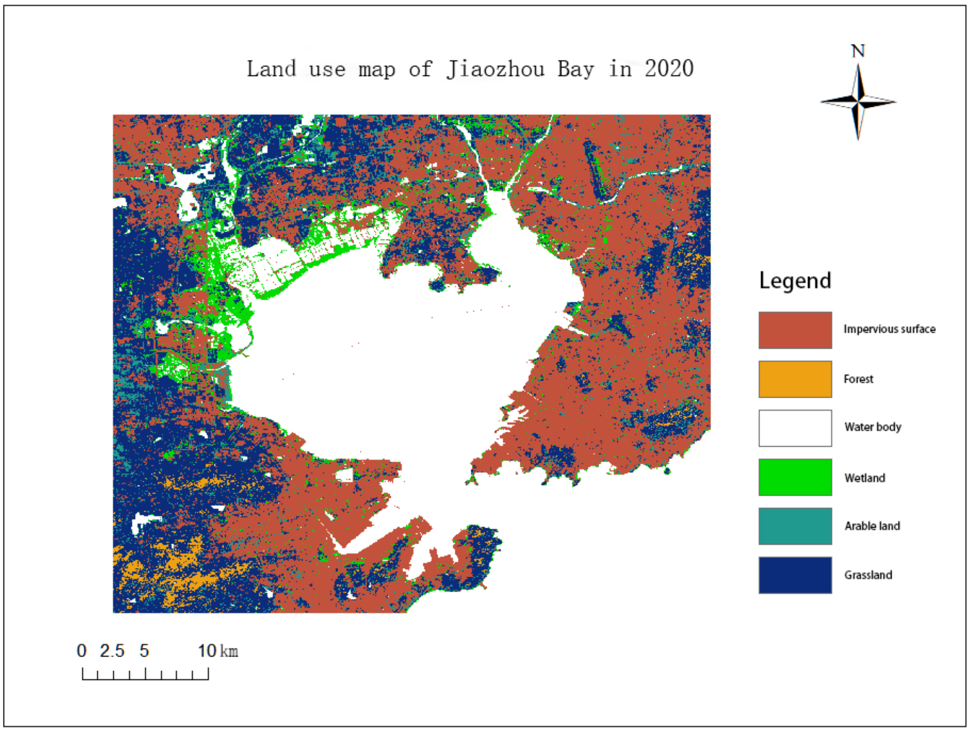

Fig. 2 Land use map of Jiaozhou Bay in 2020

3.2. Spatial and Temporal Characteristics of NDVI in Coastal Wetlands of Jiaozhou Bay

In the four images, the annual mean maximum NDVI decreased and then increased in 2013, 2015, 2017 and 2019, as shown in Table 3. From Figure 3 and Table 4, it can be seen that the vegetation in the coastal wetlands of Jiaozhou Bay showed a large increasing trend, and the increasing trend was more extensive in the southwestern and northeastern areas. The decreasing trend of NDVI was larger in the central and northern coastal areas. This shows that the overall vegetation growth in the wetlands is increasing year by year and the ecological environment is improving year by year.

Table 3. NDVI values of Jiaozhou Bay coastal wetland in four periods

Year	Annual average NDVI maximum value
2013	0.816645
2015	0.742785
2017	0.78617
2019	0.830195

Table 4. 2013-2019 Jiaozhou Bay coastal wetland indicators increase or decrease area ratio

	reduction	increase
NDVI	43.03%	56.97%
LAI	35.70%	64.30%
NPP	31.54%	68.46%
FVC	73.29%	26.71%

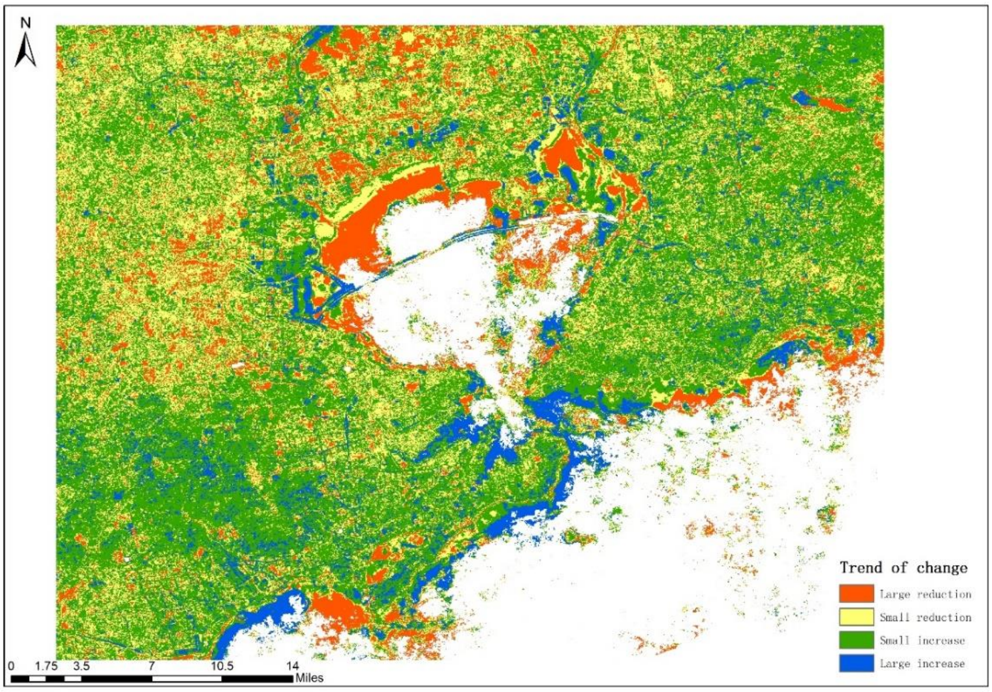

Fig. 3 Trend of NDVI from 2013-2019

3.3. Spatial and Temporal Characteristics of FVC in Coastal Wetlands of Jiaozhou Bay

From Figure 4, it can be seen that the FVC values show an overall decreasing trend, with a greater increasing trend in the northeast, a more concentrated decrease in the west, and a significant increase in the north-central region adjacent to a significant decrease. This indicates that with the increase of NDVI, the growth and denseness of vegetation are also increasing locally, especially in some areas along the water bodies. However, there are still areas with some degradation of vegetation growth as NDVI rises.

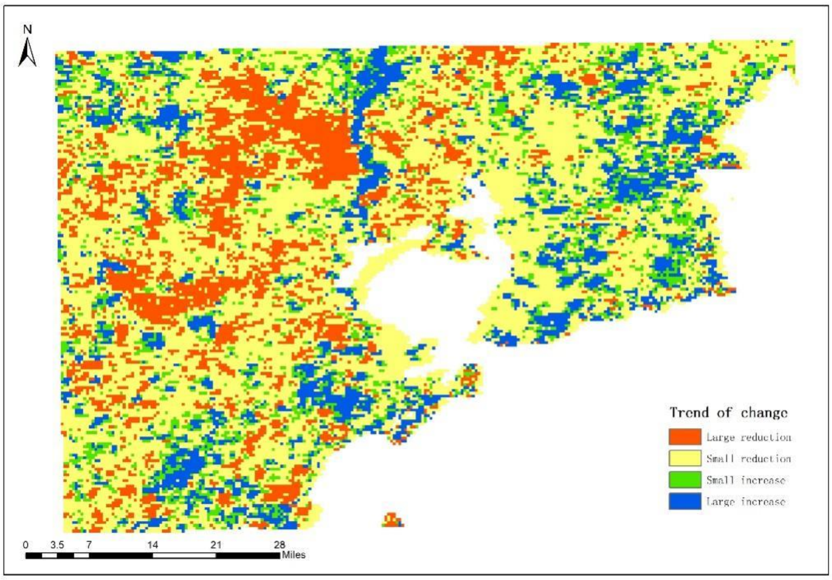

Fig. 4 Trend of FVC from 2013-2019

3.4. Spatial and Temporal Characteristics of LAI in Coastal Wetlands of Jiaozhou Bay

From Figure 5, it can be seen that the increasing range of LAI values in the study area is slightly larger than the decreasing range. In the northeastern coastal area, the increase is the largest and most concentrated, and in the south, the trend is increasing over a large area; in the north-central area, the reduction is the largest and most concentrated. The LAI index can reflect the information of photosynthesis, material exchange and energy balance of vegetation to a certain extent, which indicates that the vegetation health in the study area is increasing [14].

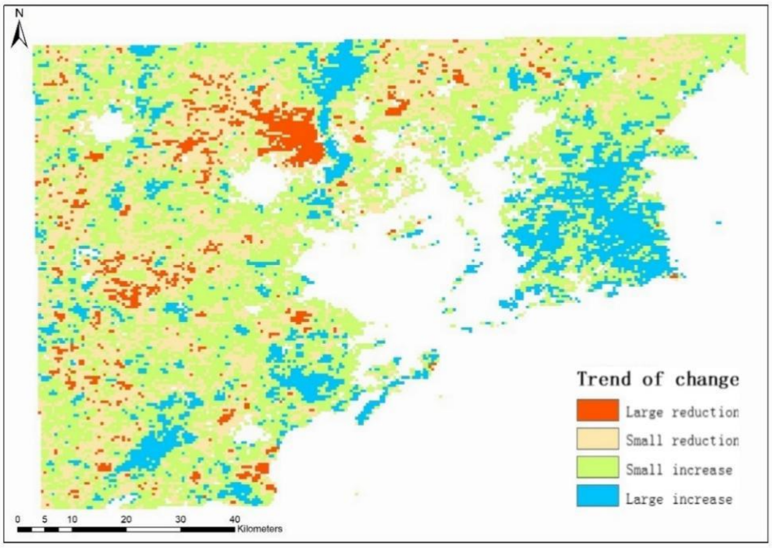

Fig. 5 Trend of LAI from 2013-2019

3.5. Spatial and Temporal Characteristics of NPP in Coastal Wetlands of Jiaozhou Bay

It can be seen from Figure 6 that the NPP value in the study area showed a large area of increasing trend, especially in the southwest and northeast coastal areas, and the central and northern areas showed a significant downward trend. The spatial and temporal distribution pattern of NPP can reflect the production capacity and carbon sequestration capacity of terrestrial vegetation to a certain extent, which indicates that the carbon sequestration capacity of wetlands continues to increase [15].

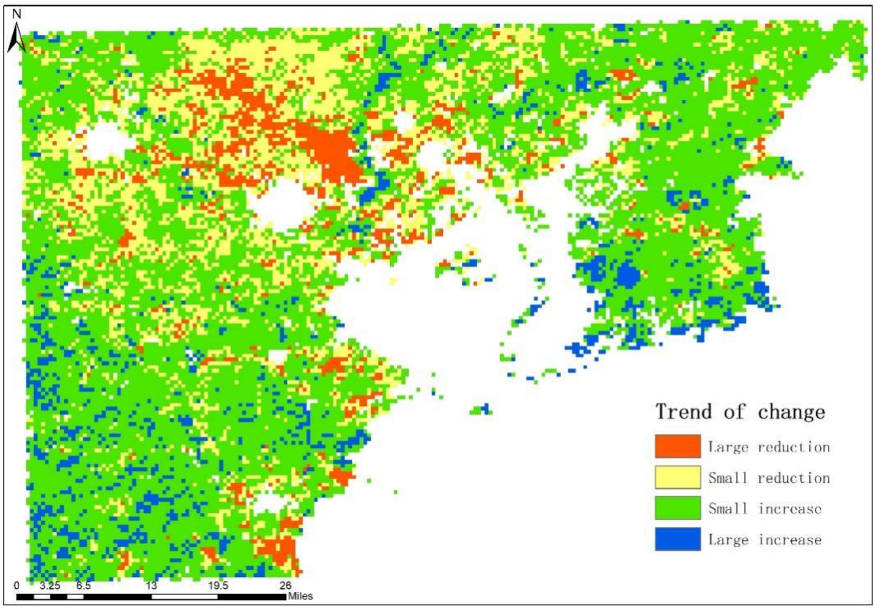

Fig. 6 Trend of NPP from 2013-2019

4. Discussion

In this paper, the land use distribution map as well as NDVI, LAI, NPP and FVC were integrated to reflect the vegetation growth of coastal wetlands in Jiaozhou Bay. NDVI, LAI, and NPP all showed an increasing trend in a wide range, except for FVC which had a large area of decline. The expansion of impervious surface area in the coastal part is associated with a sustained annual increase in the resident population of Qingdao of about 100,000 and a corresponding increase in both vegetation types; the increase in grassland area in the northeast and southwest has resulted in a large increase in the vegetation index of grassland sites [16]. Combined with the changes in land use distribution, it shows that although the area of cultivated land in the north is gradually expanding, the area of wetlands is also expanding at the same time. It indicates that Qingdao has strictly adhered to the resource red line area and balanced the relationship between development and conservation in the process of urban development [17]. In addition, the irrational exploitation of wetland resources in 2013-2015 and the continuous climatic droughts were among the reasons for the decrease in the annual maximum value of NDVI, and the subsequent initiative of co-existence of wetland parks and protected areas also contributed to the ecological recovery of wetlands [8]. In general, the vegetation coverage, vegetation density, vegetation status and ecological environment of the coastal wetlands in Jiaozhou Bay have been improving year by year.

Satellite remote sensing images cover a wide area and have high resolution, which can monitor vegetation changes on a large scale. However, this paper only analyzes the vegetation growth status through remote sensing monitoring data, without combining field research data, specific vegetation types, local policies, temperature and precipitation in a more detailed way, which needs to be improved.

5. Conclusion

This paper analyzes NDVI, LAI, NPP, FVC and land use changes from 2013-2019, and draws the following conclusions: from 2013 to 2019, NDVI, LAI and NPP have increased to different degrees in a wide range of coastal wetlands in Jiaozhou Bay, and the annual average NDVI maximum increased in a fluctuating manner. The area of FVC decreasing is larger, and all indicators are decreasing in the central and northern regions, and there is a significant expansion of cultivated land. The land types in the study area are mainly impervious surface and grassland, among which grassland coverage has the largest proportion of decrease and impervious surface has the largest proportion of rise.

Based on all the images, it can be seen that the vegetation condition of the coastal wetlands in Jiaozhou Bay has improved overall and deteriorated locally, and the ecological protection measures have shown initial results. However, there are still some problems worth noting: for example, the expansion of irrigated farmland in arable land and the expansion of impervious surfaces in urban development have affected ecology, and wetland protection measures need to be strengthened to better coordinate the relationship between development and ecology.

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