J. Geogr. Sci. 2018, 28(4): 415-428
DOI: https://doi.org/10.1007/s11442-018-1481-1

Ecosystem assessment and protection effectiveness of a tropical rainforest region in Hainan Island, China

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Abstract: Ecosystem services have become one of the core elements of ecosystem management and evaluation. As a key area of ecosystem services and for maintaining national ecological security, ecosystem changes and implementation effect evaluation are important in national key ecological function zones, for promoting the main function zone strategy and for improving the construction of an ecological civilization. This article studies the ecological zone of a tropical rainforest region in the central mountain area of Hainan Island, China. Multi-source satellite data and ground observation statistics are analyzed with geo-statistics method and ecological assessment model. The core analysis of this paper includes ecosystem patterns, quality and services. By means of spatial and temporal scale expansion and multidimensional space-time correlation analysis, the trends and stability characteristics of ecosystem changes are analyzed, and implementation effect evaluation is discussed. The analysis shows a variety of results. The proportion of forest area inside the ecological zone was significantly higher than the average level in Hainan Island. During 1990–2013, settlement gradually increased inside the ecological zone. After implementation of the zone in 2010, human activity intensity increased, with the main land use being urban construction and land reclamation. Water conservation in the ecological function zone was higher than that outside the zone. In general, it increased slightly, but had obvious fluctuations. Soil conservation inside the zone was also better than that outside. However, it demonstrated dramatic fluctuations and relatively poor stability during 1990–2013. The human disturbance index inside the zone was significantly lower than that outside, and had a lower biodiversity threat level. Especially in 2010–2013, the increased range of the human disturbance index inside the zone was significantly less than that outside.

Keywords: ecological function zone; ecosystem; ecosystem service; protection effect

Received: 2017-10-13 **Accepted:** 2017-11-30
Foundation: National Key R&D Program of China, No.2017YFC0506506, No.2016YFC0500206; National Natural Science Foundation of China, No.41501484
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1 Introduction

The convening of the United Nations Conference on human environment and United Nations Conference on environment and development has prompted eco-environmental protection action all over the world. China has carried out ecological policies of classification and zoning to fulfil international responsibilities and promote regional ecological protection. Specific measures implemented include the establishment of nature reserves, national key ecological function zones, biodiversity protection priority areas and other types of ecologically important areas. The total area of these regions is 5365.9×10^3 km^2, accounting for 55.89% of China's land. These areas have played an important role in safeguarding national and regional ecological security (Hou *et al*., 2013). An increasing amount of research is focusing on assessment of the ecosystem status change and effectiveness analysis in ecologically important areas. Researchers have analyzed these issues from different perspectives to improve the level of regional ecosystem management and protection effectiveness. Related studies include single-type protected area effectiveness assessment using multiple monitoring indicators (Zheng *et al*., 2012; Yang *et al*., 2012; Zheng *et al*., 2012) and evaluation of the ecological security pattern of ecologically important regions by overlay analysis (Hou *et al*., 2013; Zheng *et al*., 2012; Yang *et al*., 2012; Zheng *et al*., 2012; Hou *et al*., 2017). Furthermore, some studies have focused on protected objects, by carrying out interference analysis on important areas for ecological protection by constructing sensitive ecological monitoring indexes (Zhao *et al*., 2014). By coupling spatial and temporal differences, research has also linked sensitive ecological parameters and protection effectiveness using a relative evaluation method (Zhao *et al*., 2015). The indicators used in monitoring and evaluation are mainly ecosystem type or ecological factor, which mostly describe the changes in the ecosystem pattern and specific ecological parameters.

The relationship between humans and nature has gained a new and deeper understanding with the present ecosystem services concept and in-depth research. With the implementation of the Millennium Ecosystem Assessment Project of the United Nations, ecosystem services based on supply, support, regulation and culture have clearly illustrated the complex relationship between ecosystems and human well-being. Based on this, management decision makers are beginning to pay attention to ecosystem services management. Ecosystem services have therefore become one of the core elements in the comprehensive assessment of ecosystems by the United Nations, international organizations and national governments (Hou *et al*., 2015; Zheng *et al*., 2013). In this context, the Chinese government and related departments are constantly exploring and practicing ecosystem services management at the regional scale. In 2010, the State Council promulgated *The Major Function-Oriented Zone Planning in China*, which identified 25 national key ecological function zones. As one of the key areas of ecosystem services and national ecological security, delineation and implementation of national key ecological function zones are of great significance for promoting regional sustainable development and improving human welfare. Previous studies on the national key ecological function zones have mainly been concentrated at the macro level, for example, ecological compensation (Kong, 2010), transfer payment (Li *et al*., 2013), development path choice (Wu *et al*, 2014), ecosystem services (Li *et al*., 2015) and ecosystem change (Huang *et al*., 2015). Due to the late delineation time of national key ecological function zones, there has been little research on the comprehensive assessment of the effectiveness of protection by ecosystem services in national key ecological function zones.

The concept of an ecological function protection area was first proposed in *The National Outline for Ecological Environment Protection*, which was released by the State Council in 2000. Meanwhile, ten national ecological protection areas, including North Yinshan Mountains and Horqin Sandy Land, had been established as pilot areas. The middle mountain area of Hainan Province was listed as a national ecological function protection pilot area in 2001. In 2005, Hainan Province approved the implementation of *The National Ecological Function Protection Area Plan of the Middle Mountainous Area in Hainan Province*. In 2007, the State Environmental Protection Administration of China issued *The Outline of National Key Ecological Function Protection Plan*, and, jointly with the Chinese Academy of Sciences, issued *National Ecological Function Regionalization*, which identified 50 national important ecological function zones. In the 2015 revised edition, the number of these zones increased to 63. After 17 years of continuous exploration and development, China has gradually proposed the important and key zones based on the ecological protection area concept. The tropical rainforest region of central Hainan Island was identified as a national key ecological function zone in the *Major Function-Oriented Zone Planning in China*, promulgated in 2010. As a rich biodiversity resource region in China, the ecosystem structure and services change of this zone are highly sensitive to local social and economic development.

In this article, multi-source satellite remote sensing data and ground observation statistics data are collected, and geostatistics and ecological assessment model methods are used to generate ecosystem patterns, vegetation growth and ecosystem functions. The main analysis methods are temporal and spatial expansion and multidimensional space-time contrast analysis. The temporal and spatial variation characteristics and conservation effectiveness of the ecological function zone are evaluated using the evaluation model of "comprehensive status and variation trend" (Hou *et al*., 2015). These could provide a scientific basis for improving the service capacity of the ecosystem in the national key ecological function zones of China.

2 Data and methods

2.1 Research area

The study area of this paper is the tropical rainforest region of central Hainan Island, including Wuzhishan City, Qiongzhong Li and Miao Autonomous County, Baisha Li Autonomous County, and Baoting Li and Miao Autonomous County. The area is located in central and southern Hainan Island and the geomorphic types of the area are mainly medium mountains, low mountains and hills. It covers about 9200 km^2, accounting for approximately 27.1% of the total area of Hainan Island. The main ecosystem services are biodiversity conservation and water conservation. The middle mountainous area of Hainan Island is important for biodiversity, river sources, water conservation and soil conservation. It plays an important role in balancing the ecology, mitigating natural disasters and safeguarding ecological security.

2.2 Data

Land use and land cover change data on the study area, from 1990 to 2013, were obtained from the Landsat, CBERS, HJ-1A/B and other satellites (Liu *et al*., 2014). Then, the ecosystem types of Hainan Island were obtained from the first category of land use and land cover change data.

Normalized Differential Vegetation Index (NDVI) data were obtained from MOD13Q1, one of the moderate-resolution imaging spectrometer (MODIS) series products (https://lpdaac.usgs.gov). The spatial resolution of the product was 250 m, and the temporal resolution was 16 days. A Savitzky-Golay filter was used to remove long time series data noise from clouds and the atmosphere (Chen *et al*., 2004; Savitzky *et al*., 1964). Average annual NDVI values were used for the analysis in this article. Meteorological data such as annual rainfall were obtained from the National Meteorological Science Data Sharing Platform (http://data.cma.cn/). The original site data included 19 national ground observation stations, with nine of them distributed in Hainan Island and the other ten in the provincial-level areas of Guangdong and Guangxi around Hainan Island. The Anusplin interpolation method was used to generate the raster data set with 250 m spatial resolution.

2.3 Methods

In this paper, the ecosystem was divided into cropland, forest, grassland, water and wetland, construction land and bare land, based on the land use and land cover change data set, in order to analyze the ecosystem pattern and spatial and temporal distribution characteristics. The proportion of ecosystem in the area was chosen as the statistical indicator. Average annual NDVI was selected for analysis of land vegetation growth characteristics.

Water conservation capacity, the main indicator for assessing water conservation, was evaluated using the precipitation storage method (Zhao *et al*., 2004). Annual precipitation was generated based on interpolation of data observed by meteorological stations. The observed threshold value of rainfall runoff was taken from some literature. Tropical Rainfall Measuring Mission (TRMM) satellite daily rainfall data of 3 hours were revised by observed daily rainfall data around national meteorological stations. Then, single rainfall values greater than the threshold of the rainfall runoff were cumulated to calculate the proportion of the single point runoff rainfall to annual precipitation. The spatial pattern of the proportion of the regional runoff rainfall to annual precipitation could be calculated from the linear relationship of the single point proportion and the streamflow coefficient. The benefit coefficient of forest runoff reduction was obtained from literature. The rainfall runoff rate of grassland was calculated from the grassland coverage.

Soil conservation capacity, the main indicator for assessing soil conservation, was evaluated using the Revised Universal Soil Loss Equation (RUSLE). The soil conservation capacity was the difference between the amount of soil loss under the extreme degradation condition and the actual amount of soil loss in the ecosystem (Savitzky *et al*., 1964). Rainfall erosivity was modeled by daily rainfall (Zhang *et al*., 2002). The Nomo diagram method and 1:100 million soil databases were used to evaluate the soil erodibility factor (Wischmeier *et al*., 1971). Slope and slope length factors were calculated using the McCool and Liu methods (McCool *et al*., 1987; Liu *et al*., 1994). Vegetation coverage and management factors were obtained using the Cai method (Cai *et al*., 2000).

The human disturbance index of biodiversity, the main indicator for assessing biodiversity maintenance, was calculated by evaluating different ecosystems and levels of disturbance (Zhao *et al*., 2014). The higher the disturbance index, the greater the threat of human activities to the biological diversity maintenance, and the lower the biodiversity maintenance. Based on the degree of disturbance of different ecosystem types, each ecosystem type was graded. Then, four disturbance classification indexes were obtained (Zhao *et al*., 2014). The disturbance index considered only the human disturbance of the ecosystem types with natural vegetation. The disturbance index of unused land considered only saline-alkali soil with halophytic vegetation and marshland with hygrophilous vegetation. Ice and snow, sandy land, Gobi, bare land, bare rocks, and other ecosystems with sparse vegetation or no vegetation were not included.

3 Results and analysis

3.1 Ecosystem status assessment

3.1.1 Ecosystem composition and spatial distribution

The distribution of ecosystems in Hainan Island in 2013 is shown in Figure 1. In the central part of Hainan Island, the main ecosystem was forest, at the edge of which were cropland and construction land. The distributions of cropland and construction land were more heavily concentrated in the north than in the south. From the area and proportion of the ecosystems, forest covered the largest area, accounting for 63.6% of the land area of the whole island. This was followed by cropland, with 25.7%. Comparison of ecosystem types inside and outside the function zones showed that the ecosystem in the zone was mainly forest and cropland. Inside the zone, the proportion of forest area was higher than that of the whole island, reaching 84.5%, whereas cropland area accounted for only 8.2%. Outside the zone, cropland accounted for 30.3%, 22.1 percentage points higher than that inside the zone (Figure 2). As a whole, the natural vegetation ecosystem area inside the zone was much higher than that outside of the zone. The ecological background was better inside the zone.

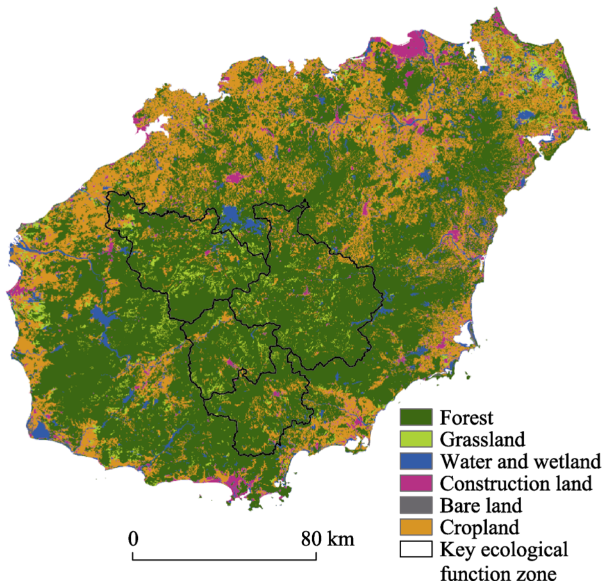

Figure 1 Spatial distribution of ecosystem types (2013)

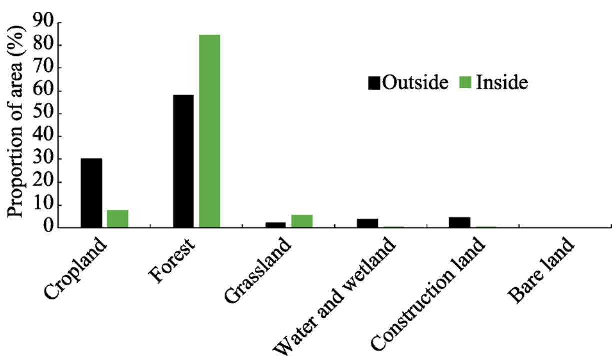

Figure 2 Statistical characteristics of ecosystem types (2013)

3.1.2 Vegetation growth

Long time series of MODIS NDVI data were used as the evaluation index of the land vegetation growth to identify the spatial and temporal distribution of vegetation growth during 2000–2013. The results showed that the growth of land vegetation inside the zone was obviously better than that outside the zone. NDVI values of 17 counties outside the zone were between 0.58 and 0.70, with a mean of 0.67 NDVI values of four counties inside the zone were greater than 0.74, with a mean of 0.77, 0.10 higher than that outside the zone. The maximum NDVI was 0.78, mainly in Baisha and Qiongzhong counties. The minimum two NDVI values were 0.58 and 0.61, for Meilan and Wenchang counties, respectively (Figure 3).

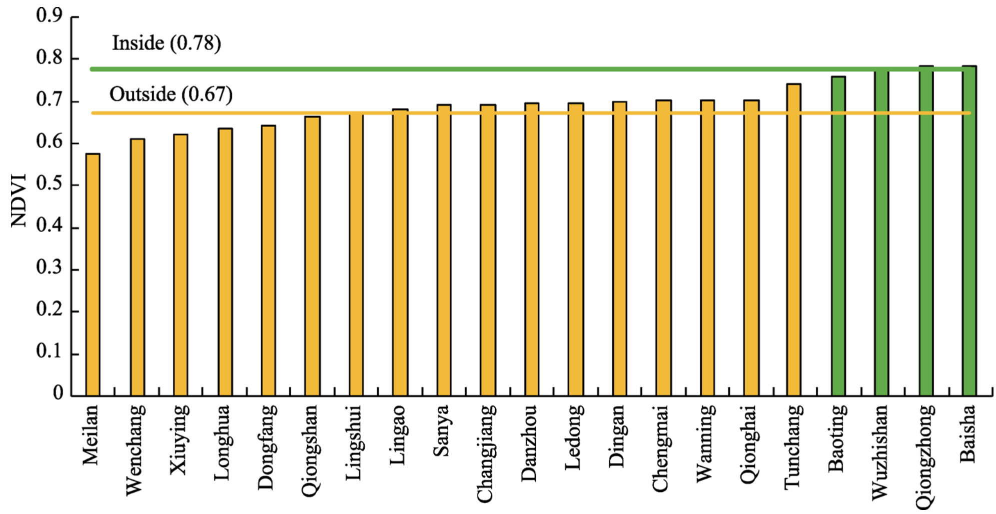

Figure 3 Statistical characteristics of NDVI in districts and counties (2013)

3.1.3 Ecosystem services

The water conservation capacity, simulated by the precipitation storage method, indicated that the mean water conservation capacities were 517.8×10^3 m^3/km^2 and 329.7×10^3 m^3/km^2 inside and outside the zone, respectively. The difference between the two values is 188.1×10^3 m^3/ km^2. In the 21 counties across the island, the three with the largest water conservation capacity (> 530×10^3 m^3/km^2) were located inside the zone: Baoting, Wuzhishan and Qiongzhong. Lingao and Dongfang had the minimum water conservation capacities of 210.9×10^3 m^3/km^2 and 226.6×10^3 m^3/km^2, respectively (Figure 4).

The soil conservation capacity, simulated using the RUSLE method, indicated that the mean soil conservation capacities were 19,540 t/km^2 and 6339 t/km^2 inside and outside the zone, respectively. The difference between the two values is 13,201 t/km^2. In the 21 counties across the island, the three with the largest soil conservation capacity (> 18,100 t/km^2) were located inside the zone: Qiongzhong, Baoting and Wuzhishan. Longhua and Xiuying Counties had the minimum soil conservation capacities of 577 t/km^2 and 931 t/km^2, respectively (Figure 5).

The mean human disturbance index in Hainan Island was 0.4597 (Figure 6). The centers of the counties and coastal areas had high human disturbance index values because of their large proportion of construction land. In the central island, the degree of disturbance was relatively low because of its large area of forest and grassland. Meilan had the maximum

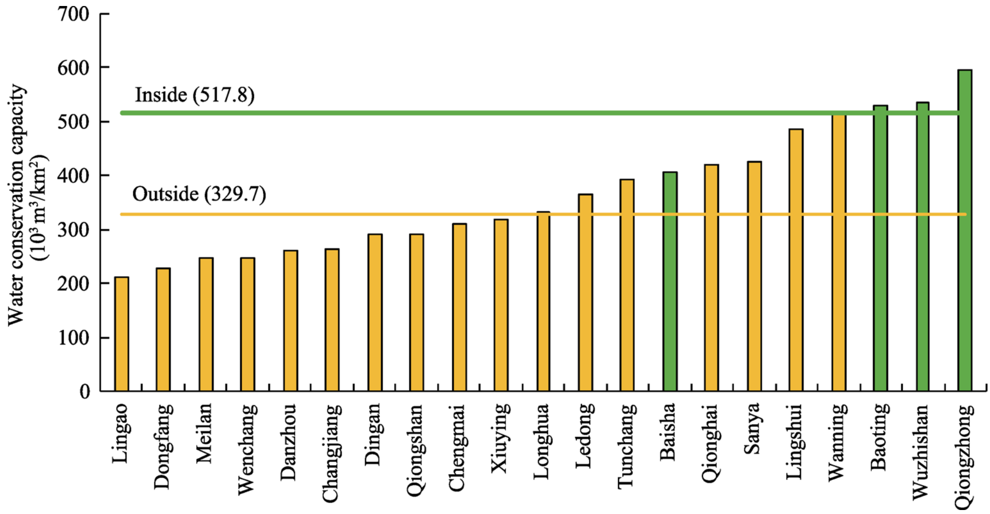

Figure 4 Statistical characteristics of water conservation in districts and counties (2013)

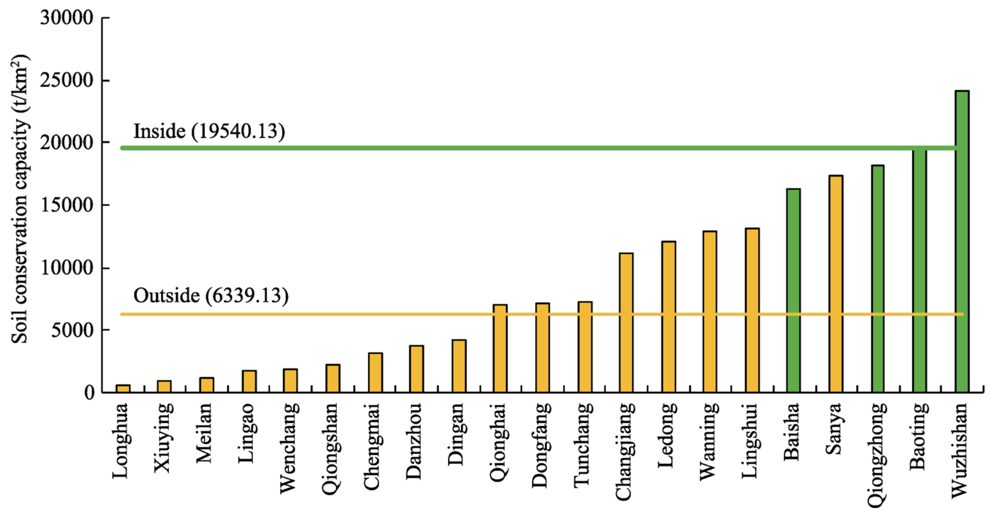

Figure 5 Statistical characteristics of soil conservation in districts and counties (2013)

disturbance index with 0.55, and Wuzhishan had the minimum value with 0.35. There were ten counties whose disturbance indexes were higher than the mean index of the island. In the 21 counties across the island, Wuzhishan, Qiongzhong, Baisha and Baoting, located inside the zone, had the minimum disturbance index values, averaging 0.3663. However, the mean value was 0.4816 outside the zone. Thus, the biodiversity maintenance function outside the zone was more obviously threatened than that inside the zone (Figure 7).

3.2 Ecosystem change and effectiveness analysis

3.2.1 Ecosystem temporal and spatial variation and effectiveness analysis

During 1990–2013, forest and cropland outside the zone showed a decreasing trend, and the area proportion decreased from 58.3% and 31.9% to 58.0% and 30.3%, respectively. Construction land increased, with the area proportion increasing from 2.3% to 4.6%, mainly distributed along the coastline and in cropland in the northern part of the island. The main reasons were urbanization and the gradual release of tourism resources (Figure 8). Inside the ecological zone, the area proportion of forest decreased from 85% to 84.5%, and the area proportion of cropland increased from 7.8% to 8.2%. That of construction land increased slightly, and the major change was during the period 2000–2013, with the area proportion increasing from 0.5% to 0.8%. The main increases were for urbanization and villages. This change was much lower than that outside of the zone, whose construction land area proportion increased from 3.1% to 4.6%. Although human disturbance was less inside the zone, its gradual increase should not be ignored.

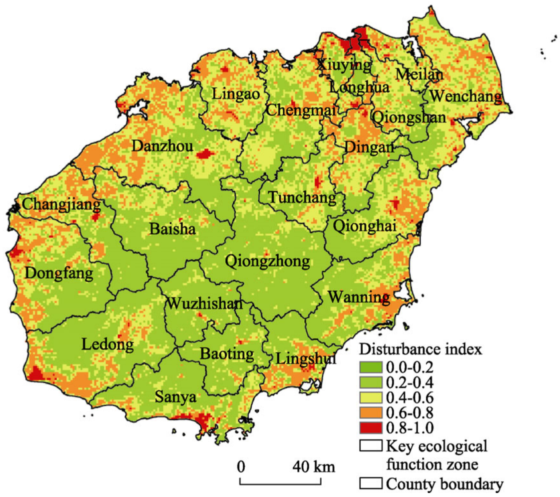

Figure 6 Spatial distribution of human disturbance index (2013)

3.2.2 Vegetation growth temporal and spatial variation and effectiveness analysis

During 2000–2013, the mean NDVI values inside and outside the zone gradually increased. The mean NDVI inside the zone was about 0.75, and higher than that outside the zone (about 0.6). The stability of the NDVI can be demonstrated using its standard deviation (SD). Figure 9 shows that the SD of the NDVI inside the zone was less than that outside the zone. Although the mean values of the two sample spaces were different, the SD of the NDVI inside the zone showed a gradual decrease and the NDVI was relatively stable from 2000 to 2013. This indicates that the vegetation growth inside the zone was less disturbed, and the stability was better than that outside the zone.

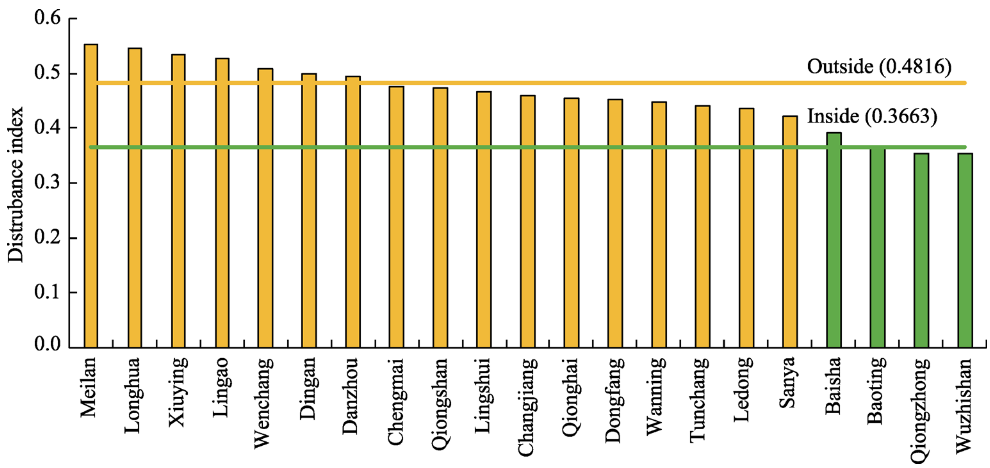

Figure 7 Statistical characteristics of human disturbance index in districts and counties (2013)

3.2.3 Ecosystem services temporal and spatial variation and effectiveness analysis

During 1990–2013, the mean water conservation capacity both inside and outside the zone increased slightly. During the two periods of 1990–2000 and 2000–2010, the water conservation

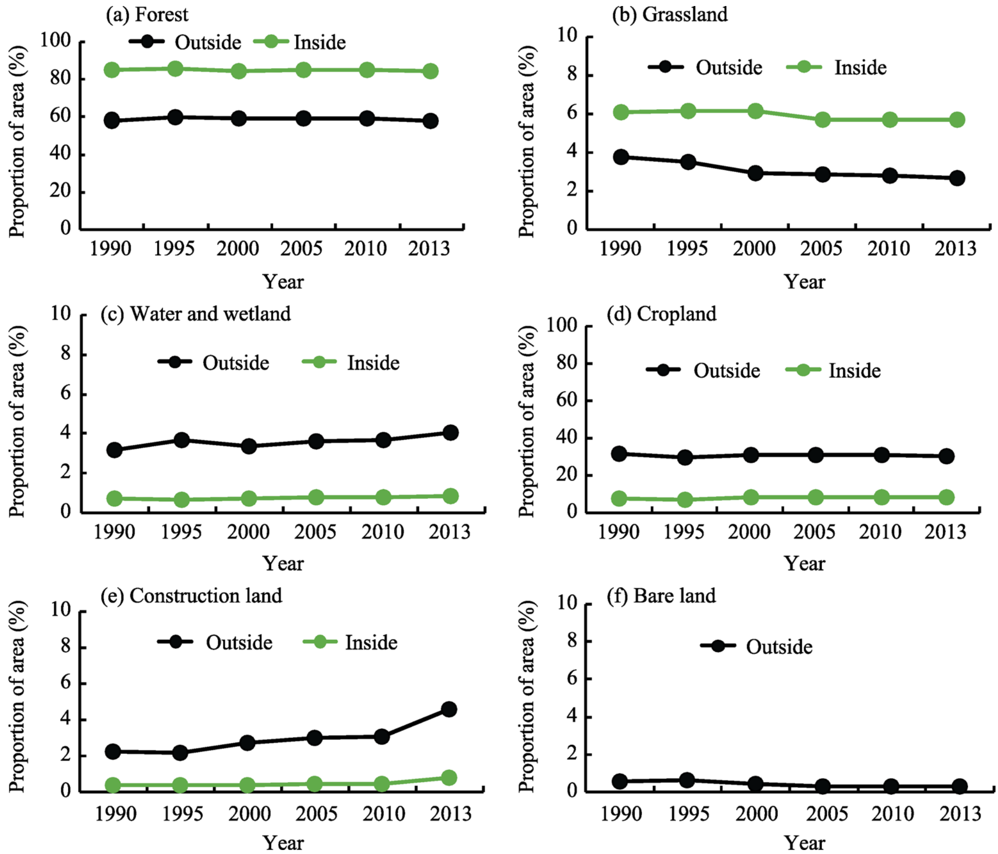

Figure 8 Statistical characteristics of ecosystem composition change in and out of key ecological function zone (1990–2013)

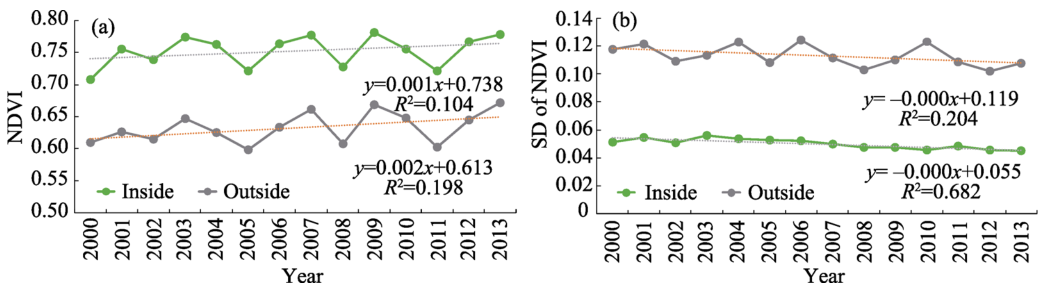

Figure 9 Statistical characteristics of mean and standard deviation change of NDVI in and out of key ecological function zone (1990–2013)

capacity first decreased and then increased. After 2010, it increased gradually (Figure 10). Figure 10 also indicates that the SD of the water conservation capacity inside the zone was less than that outside. This indicates that the water conservation inside the zone was less disturbed, and the stability was better than that outside.

Classification statistics of the water conservation capacity inside the zone were calculated for three periods: 1990–2000 (S1), 2000–2010 (S2) and 2010–2013 (S3). Figure 11 depicts the results of the analysis. During the three periods, the mean values of water conservation capacity inside the zone were higher than those outside. It was showed gradient variation from exterior to interior spatially. The amount of water conservation in Hainan Island had been increased in the three periods, this was consistent with the results shown in Figure 9. The mean values of water conservation capacity inside the zone were 424.8×10^3 m^3/km^2, 428.6×10^3 m^3/km^2 and 488.8×10^3 m^3/km^2, for the three periods, respectively, with ranges of variation of 3.8×10^3 m^3/km^2 and 60.22×10^3 m^3/km^2. The mean values of water conservation capacity outside the zone were 270.5×10^3 m^3/km^2, 279.1×10^3 m^3/km^2 and 318.2 × 10^3 m^3/km^2, respectively, with ranges of variation of 8.6×10^3 m^3/km^2 and 39.1×10^3 m^3/km^2 (Figure 11). Consequently, although the mean water conservation capacity increased both inside and outside the zone, the increase inside the zone was apparently higher than that outside the zone from period S2 to S3. This could reflect the impact of the key ecological function zone in promoting water conservation.

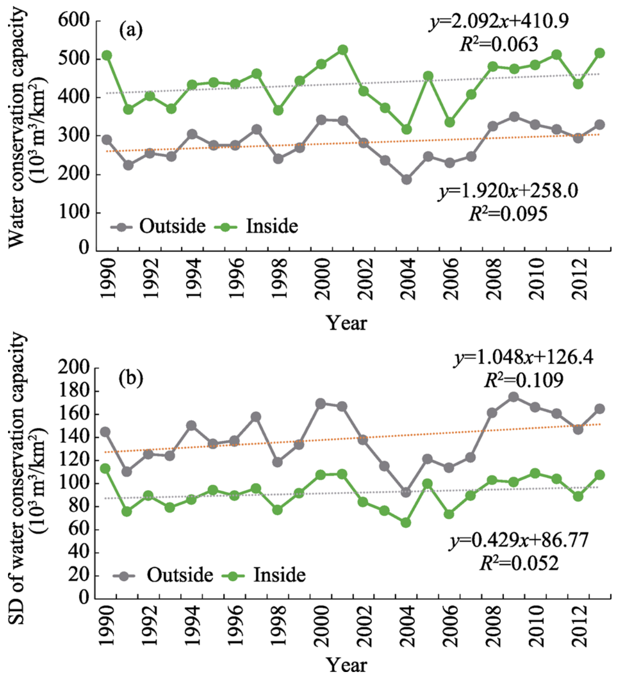

Figure 10 Statistical characteristics of mean and standard deviation change of water conservation in and out of key ecological function zone (1990–2013)

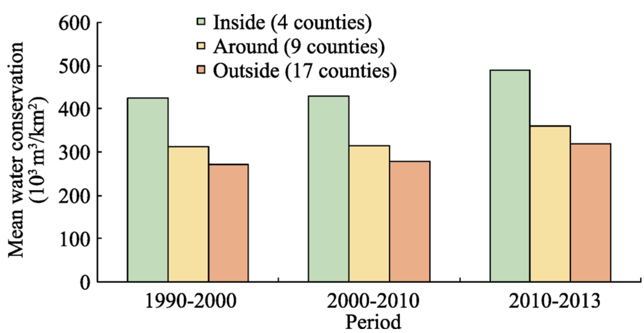

Figure 11 Statistical characteristics of mean water conservation during different time periods

During 1990–2013, the mean soil conservation capacity both inside and outside the zone increased slightly. During the two periods of 1990–2000 and 2000–2010, soil conservation capacity first decreased and then increased. After 2010, the change decreased outside the zone but increased inside (Figure 12). Note that the soil conservation capacity inside the zone was one order of magnitude higher than that outside. Thus, the SD of the soil conservation capacity inside the zone was higher than that outside.

Classification statistics of the soil conservation capacity inside the zone were again calculated for the three periods: 1990–2000 (S1), 2000–2010 (S2) and 2010–2013 (S3). Figure 13 depicts the results of the analysis. During the three periods, the mean values of soil conservation capacity inside the zone were higher than those outside the zone. The gradient variation from exterior to interior was shown spatially. The amount of soil conservation in Hainan Island had been increased in the three periods, this was consistent with the results shown in Figure 10. The mean values of soil conservation capacity inside the zone were 15,296 t/km^2, 16,972 t/km^2 and 19,390 t/km^2, for the three periods, respectively, with ranges of variation of 1576 t/km^2 and 2419 t/km^2. The mean values of soil conservation capacity outside the zone were 4560 t/km^2, 5328 t/km^2 and 6214 t/km^2, respectively, with ranges of variation of 769 t/km^2 and 886 t/km^2 (Figure 13). Consequently, although the mean soil conservation capacity increased both inside and outside the zone, the increase inside the zone was apparently higher than that outside the zone from period S1 to S2 and period S2 to S3. This could reflect the impact of the key ecological function zone in promoting soil conservation.

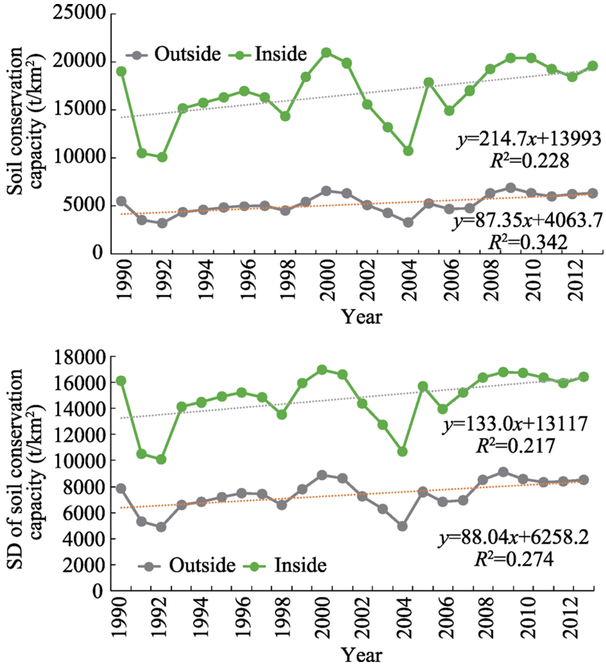

Figure 12 Statistical characteristics of mean and standard deviation change of soil conservation in and out of key ecological function zone (1990–2013)

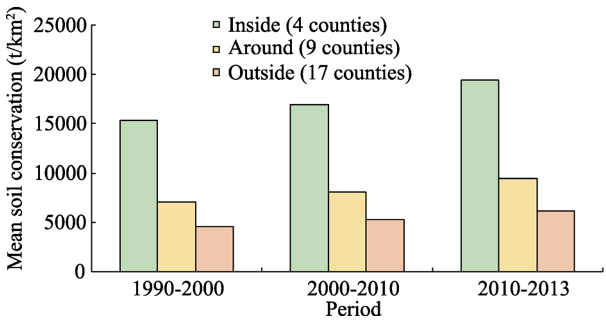

Figure 13 Statistical characteristics of mean of soil conservation during different time periods

During 1990–2013, the human disturbance index of Hainan Island had increased 0.0129. Because of urbanization, artificial construction land occupied a large area of other ecosystem types in the centers of counties and coastal areas, and human disturbance was obviously increasing. However, the extent of human disturbance decreased in parts of southern and northern Hainan Island. Ledong and Baisha had minimum variations of human distribution, which decreased slightly. However, the remaining 19 counties showed an increasing trend of the index. Longhua had the largest increase in the distribution index (about 0.0749). Four counties, Longhua, Xiuying, Meilan and Qiongshan, had a higher distribution index variation than that of the whole island. The human distribution index variations of Wenchang and Dezhou were similar to that of the whole island. Other counties had lower values (Figure 14).

During 1990–2013, the human disturbance index change inside the zone was 0.0029, but the value of the counties surrounding the zone was 0.0049, about 1.71 times the change inside the zone. The 17 counties outside the zone had a human disturbance index change of 0.0152, which was much higher, about 5.31 times the change inside the zone. This was mainly because urbanization exacerbated the human disturbance outside the zone. During the periods of 1990–2000, 2000–2010 and 2010–2013, the human disturbance index change was smaller inside the zone than that outside. Thus, the extent of the threat of biodiversity inside the zone was less than that outside. The gradient effect was also formed in space. This could reflect the impact of the key ecological function zone in promoting biodiversity maintenance (Figure 15).

4 Discussion and conclusions

Since the concept of ecological function protection was proposed in 2000, a number of national key ecological function zones and supporting policies have been formed after 17 years of continuous exploration and development in China. The zones are also an important basis for dividing ecological redlines and the main components of the strategy implementation of the *Major Function-Oriented Zone Planning*. This is of great significance to ensure regional ecological security and optimize the spatial pattern of the land. The middle mountain area in central Hainan Island was one of the key management areas. In this article, the tropical rainforest region of central Hainan Island was selected as the study area. Multi-source satellite remote sensing data and ground observation statistics data were collected, and geostatistics and ecological assessment model methods were used to were used to generate ecosystem patterns, vegetation growth and ecosystem functions. The main analysis methods were temporal and spatial scale expansion and multidimensional space-time contrast analysis. Temporal and spatial variation characteristics and conservation effectiveness of the ecological function zone were also evaluated. The main conclusions are as follows.

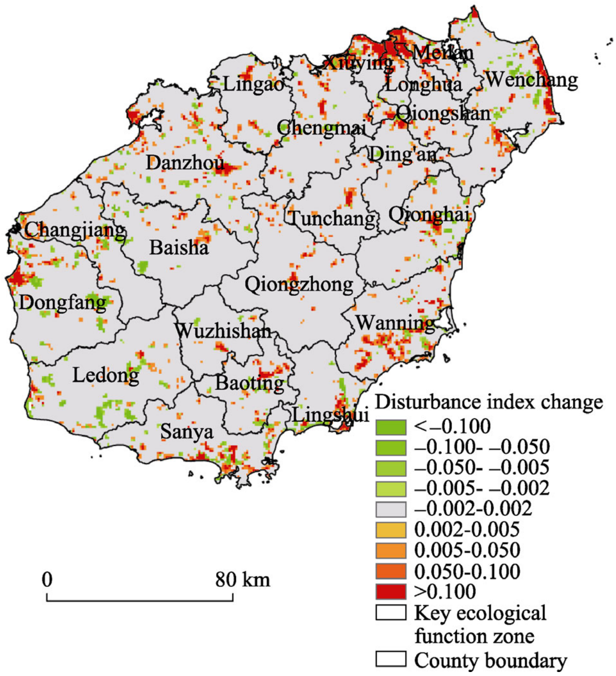

Figure 14 Variation characteristics of human disturbance index (1990–2013)

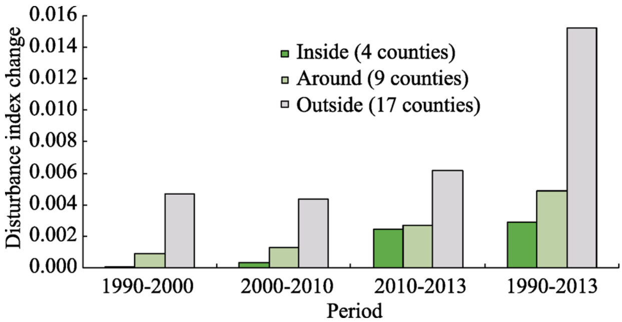

Figure 15 Variation statistical characteristics of human disturbance index during different time periods

(1) In 2013, the forest area proportion of Hainan Island was 25.7%, and the proportion inside the zone was 84.5%. The forest area inside the zone was thus significantly higher than the average level of the whole island. During 1990–2013, construction land increased gradually. After implementation of the ecological zone in 2010, the intensity of human activities continued to increase, mainly for urbanization and cropland land reclamation.

(2) Water conservation inside the zone was better than that outside the zone. In 2013, the water conservation capacity per unit area inside the zone was 517.8×10^3 m^3/km^2, which was

higher than the 329.7×10^3 m^3/km^2 outside the zone. The counties with the three largest amounts of water conservation were all located inside the zone: Baoting, Wuzhishan and Qiongzhong. Their water conservation capacity was higher than 530×10^3 m^3/km^2. During 1990–2013, water conservation in the island improved, but with obvious inter-annual fluctuations. There was a relatively stable change inside the zone. Comparing the three periods of 1990–2000 (S1), 2000–2010 (S2) and 2010–2013 (S3), water conservation capacity inside the zone had a larger increase than that outside after 2010. This reflected the impact of the key ecological function zone in promoting water conservation.

(3) Soil conservation inside the zone was better than that outside. In 2013, soil conservation capacity inside the zone was 19,540 t/km^2, which was higher than the 6339 t/km^2 outside. The counties with the three largest amounts of soil conservation were all located inside the zone: Qiongzhong, Baoting and Wuzhishan. Their soil conservation capacity per unit area was higher than 18,100 t/ km^2. During 1990–2013, soil conservation in the island improved, but with obvious inter-annual fluctuations. There was a relatively stable change inside the zone. Comparing the three periods of 1990–2000 (S1), 2000–2010 (S2) and 2010–2013 (S3), soil conservation capacity inside the zone had a larger increase than that outside after 2000. Moreover, it was more obvious after 2010. This reflected the impact of the key ecological function zone in promoting soil conservation.

(4) The ecological zone obviously had a smaller human disturbance index and a lower biodiversity threat than outside the zone. This will be beneficial to biodiversity conservation. The average of the human disturbance index inside the zone was 0.3664, which was 0.1152 lower than that outside. During 1990–2013, the human disturbance index change outside the zone was 0.0152, which was about 5.31 times the change inside the zone. During the three periods of 1990–2000, 2000–2010 and 2010–2013, the human disturbance index change inside the zone was smaller than that outside. Thus, the extent of the threat of biodiversity inside the zone was less than that outside. The difference in the threat level change was even greater after 2010. This could reflect the impact of the key ecological function zone in promoting biodiversity maintenance.

After 2010, the ecosystem status of the key ecological function zone gradually improved and was clearly better than that outside the zone. The ecological transfer payment fund and implementation of ecological engineering played positive roles in the improvement of the ecosystem status and services. During 2006–2010, the Hainan Provincial Government invested more than 2 million yuan in the central mountain area by transfer payment compensation. In 2008, Baisha, Qiongzhong and Baoting were brought into the government finance transfer payment. In 2009, Baisha, Qiongzhong, Changjiang, Ledong, Dongfang, Baoting, Sanya, Lingshui and Wuzhishan were brought into the government finance transfer payment. By the end of 2013, central finance had paid 2.68 billion yuan of funds for ecological transfer payments. In addition, since 2009, Hainan has started natural forest protection, afforestation, soil erosion prevention, ecological demonstration and other ecological engineering projects.

In this article, multi-source satellite remote sensing data and ground observation statistics data were used to assess the ecosystem patterns, vegetation growth and ecosystem functions. Geostatistics and ecological assessment model methods were also developed to identify ecosystem change and stability. An evaluation model of “comprehensive status and variation trend" was summarized to assess the spatial and temporal variation of the key ecological function zone. Optimization of the ecological assessment model, improvement of data resolution and clarification of the effects of different ecological engineering projects could be helpful in the implementation of ecological engineering projects according to local conditions.

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