Environmental Protection and Sustainable Development in Ecological Functional Zones

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Abstract. In order to explore the impact of ecological environmental protection measures on ecological functional zones and promote the sustainable development of ecology, the ecological functional zone of a hilly region in south China is taken as the research object in this study. Combined with the data of ecological environment and land use type in the past ten years, the ecological function index (water conservation index), ecological structure status (forest coverage, grassland coverage, and ratio of wetland in waters), and ecological stress situation (ratio of cultivated land to construction land) are analyzed to reflect the ecological status of ecological functional zones. The results show that in the past ten years, the water conservation index and forest coverage rate in the studied area have been improved significantly, and the ecological condition has become better, which indicates that ecological protection measures such as returning farmland to forest and closing mountains for forest cultivation can improve the ecological environment of ecological functional zones and contribute to the sustainable development of ecology.

Keywords: ecological functional zone; environmental protection; sustainable development; ecosystem pattern.

1. Introduction
Ecological environment is composed of ecological relationships among soil, water, air, animals, and other resources closely related to human survival [1,2]. Since the reform and opening up policy has been conducted, the extensive and excessive development mode has caused great damage to the natural resources along with the rapid development of the national economy and society, which leads to various environmental problems, such as water and land loss, abnormal climate, and ecological balance destruction [3,4]. In order to prevent and mitigate natural disasters, restore the sustainable development of ecosystems, coordinate the ecological protection of river basins and regions and the development of economic society, China has established ecological function reserves to protect important regional ecological functions and ensure national and local ecological security [5,6]. The national ecological functional zones are designed mainly to restore and protect natural resources and the ecological environment that have been over-exploited, and in-situ investigate and analyze of the local ecological environment, reasonably develop industries that don’t affect the local ecological environment, which also provide corresponding products, control the population, and protect the ecological status of the ecological functional zones [7,8]. The main national ecological functional zones are divided into the
following four types, which are water conservation type, water and soil conservation type, windbreak sand-fixing type, and biodiversity maintenance type [9]. At present, the researches on ecological functional zones mainly focus on ecological benefit compensation, routes and modes of development, and industrial development. Some scholars have discussed ecological security evaluation, typical ecological services and evaluation methods, and so on in main ecological functional zones [10-12]. Although a single type or a single region has been studied, the change of ecological status of main ecological functional zones in the southern hills has rarely been analyzed. In this study, six main ecological functional zones of water conservation type in the hilly region in south China are selected to be studied. Changes in the structure and function of the ecosystem in the ecological functional zone in this region are analyzed after the ecological restoration projects such as returning farmland to forest and closing mountains for forest cultivation in the past ten years, which can provide scientific basis for the sustainable development of environmental protection and ecological restoration in this region.

2. Methods

2.1. Studied area overview
The area analyzed in this study is mountainous and hilly basin landform in general. The terrain is high in the northwest and low in the southeast, presenting a slope form from northwest to southeast. It is divided into 6 categories in turn: mountains, hills, tablelands, plains, stone mountains, and wetlands. More mountains and less lands are the main characteristics of the land resources in this area, among which mountains and hills account for about 70% of the total area, plains and tablelands account for 27%, and wetlands account for 3%. Located in a low latitude, it belongs to the subtropical monsoon climate zone and the tropical monsoon climate, with an annual average temperature of 19°C, a warm climate, abundant rain, and sufficient sunshine.

2.2. Methods
In this study, six main ecological function areas of water conservation type in this region are taken as the research objects (represented by numbers 1-6 in this study), with a total area of 20,800 km². The ecological status of main ecological functional zones is taken as the indicator, the ecological function index (water conservation index), ecological structure status (forest coverage, grassland coverage, and ratio of wetland in waters), and ecological stress situation (ratio of cultivated land to construction land) are analyzed combined with the data of ecological environment and land use type in the past ten years, so as to estimate the natural ecological status of the main ecological functional zones and reflect the ecological status of ecological functional zones.

Among them, the ecological status index of water conservation function area = 0.25 × water conservation index + 0.15 × forest coverage rate + 0.10 × grassland coverage rate + 0.15 × wetland proportion of wetland area - 0.15 × ratio of cultivated land and construction land area.

Water conservation index = [0.45 × (0.1 × river area + 0.3 × lake area + 0.6 × (beach area + swamp area)) + (0.6 × woodland area + 0.25 × shrub land area + 0.15 × other woodland area) + (0.6 × high-coverage grassland area + 0.3 × medium-coverage sparse area + 0.1 × low-coverage grassland area)] / whole area.

In the equations, A is the normalization coefficient of water conservation index, and the reference value is 526.79.

2.3. Data source and processing
Taking 2009 as the base year, 2013 as the reference year, and 2019 as the current year, the land use and coverage data (2009, 2013, 2019) are from the national ecological environment quality monitoring and evaluation project. Among them, the data in 2009 is from LandsatTM5 and China’s environmental satellite, the data for 2013 and 2019 are from the national land resources survey. According to the characteristics of land use and existing ecosystem classification, the correspondence between ecosystem and land use type are established. The land use types of the studied area are divided into the following
six types: forest land, grassland, wetland, farmland, construction land and unused land, which are in the level I classification (table 1). The area and change trend of ecosystem types in main ecological function areas are analyzed statistically. The NDVI data is from MOD13 data product of MODIS.

**Table 1.** Land cover classification system of ecological functional areas in the studied area.

| Level I classification | Level II classification                      |
|------------------------|---------------------------------------------|
| Forest land            | Tree woodland, shrub woodland, sparse forest|
| Grassland              | Meadow, grassland, grass, herbage land      |
| Wetland                | Rivers, lakes, reservoirs/pits, canals/channels, marshes |
| Farmland               | Paddy field, dry land                       |
| Construction land      | Urban land, residential land, industrial land, transportation land |
| Unused land            | Moss/lichen, bare rock, bare soil           |

3. Results and discussion

3.1. Ecological function index
The water conservation index can evaluate the water conservation function of the ecological functional zones in the studied area. The areas of rivers, lakes, marshes, tidal flats, woodlands, and grasslands in the studied area can be used to evaluate their water conservation function [13,14]. The ecosystem with high water conservation function is used to evaluate the difference between water conservation index in the studied area, as shown in figure 1. From 2009 to 2019, the water conservation index of the ecological functional zone of the studied area increased year by year, and the increase trend from 2013 to 2019 is relatively large, which indicated that the water conservation function of the main ecological functional zones in the studied area has increased in the past ten years. In 2019, ecological function zone 2 had the highest water conservation index, while ecological function zone 5 had the lowest water conservation index and the worst situation. Compared with 2009, the rangeability of water conservation index of ecological function zone 1 is the largest, while the water conservation index of ecological function zone 4 remains basically unchanged. According to the analysis of land use type, the main reason for the increase of water conservation index is the conversion of grassland, dredging forest, and other forest lands into forest lands and shrub lands. This is closely related to the environmental protection measures that the studied area has vigorously promoted in the past 10 years.

![Figure 1. Water conservation index of main ecological functional zones in the studied area.](image-url)
3.2. Ecological structural status
The ecological structure of water conservation main ecological functional zones can be reflected by the three indicators of forest coverage, grassland coverage, and water wetland area proportion \[15\]. As can be seen from table 2 and figure 2, the proportion of forest land, grassland, and wetland of each main ecological function area has slightly decreased during the period from 2009 to 2019. In 2019, the total forest coverage of the studied area was 82.97%, which increased 13.59% compared with 2009. Among them, ecological functional zone 6 increased the most, with an increase of 25.66%. The grassland coverage rate was 4.73%, which decreased 12.48% compared with 2009. The proportion of water and wetland was 2.84%, which increased slightly. The types of land use were mainly the conversion between grassland and woodland.

Table 2. Forest and grassland coverage, water and wetland area proportion in the studied area.

| Ecological functional zones | Year 2009 | Year 2013 | Year 2019 | Year 2009 | Year 2013 | Year 2019 | Year 2009 | Year 2013 | Year 2019 |
|----------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
|                            | Forest coverage (%) | Forest coverage (%) | Grassland coverage (%) | Grassland coverage (%) | Water and wetland area proportion (%) | Water and wetland area proportion (%) | Water and wetland area proportion (%) |
| 1                          | 59.98     | 66.72     | 82.06     | 20.43     | 16.19     | 5.42      | 2.86      | 3.73      | 6.86      |
| 2                          | 71.64     | 88.08     | 90.44     | 5.12      | 3.65      | 2.42      | 2.97      | 2.43      |           |
| 3                          | 57.32     | 66.42     | 73.68     | 20.14     | 12.21     | 6.65      | 2.14      | 2.43      | 4.36      |
| 4                          | 76.41     | 78.92     | 86.16     | 10.56     | 9.76      | 2.44      | 3.97      | 3.66      | 2.45      |
| 5                          | 70.34     | 76.64     | 82.66     | 12.32     | 8.53      | 3.66      | 4.12      | 3.66      |           |
| 6                          | 60.36     | 64.14     | 86.02     | 27.05     | 23.17     | 2.43      | 3.41      | 3.65      | 1.75      |
| Total                      | 69.38     | 74.08     | 82.97     | 17.21     | 12.19     | 4.73      | 2.17      | 2.43      | 2.84      |

Figure 2. Changes in forest and grassland coverage, water and wetland area proportion in the main ecological functional zones of studied area.

3.3. Ecological stress situation
The degree of ecological stress in ecological functional zones can be characterized by the proportion of cultivated land and construction land \[16\]. As can be seen from figure 3, the proportion of cultivated land and construction land in the studied area increased from 2009 to 2019. The results show that the cultivated land area, the abundance of cultivated land resources, and the cultivated land also increase.
Only the ecological stress in ecological function zone 1 decreases, and the proportion of cultivated land and construction land decrease by 5.84%. Other ecological stresses all increase, among which the ecological function zone 3 increases the most, and the proportion of cultivated land and construction land increases by 7.25%.

![Figure 3. The proportion of cultivated land and construction land in the main ecological functional zones of the studied area.](image)

3.4. Ecological conditions and changes in the studied area

The land cover type of the main ecological function areas of water conservation in the studied area is mainly forest and grass land, accounting for 87.7%; followed by arable land, accounting for 12.3%. The comparison of the ecological status index between 2009 and 2019 shows that, the indicators of ecological status of the six main ecological functional zones show an overall trend of improvement. The rangability is from 0.53% to 60.21%, among which the rangability is the largest in ecological functional zone 1, and the minimum is in ecological functional zone 2.

4. Conclusion

Ecological function index, ecological structure index and ecological stress index are used in this study to reflect the function, structure, and pressure of main ecological functional zones. The state of the natural ecology is estimated from 2009 to 2019. From the perspective of change results and indicators affecting the ecological conditions, the water conservation ecological functional zone of the studied area has shown a better trend after the implementation of ecological environmental protection measures in the past 10 years. The main reason is the increase of woodland coverage, especially the conversion of grassland, dredging, and other kinds of woodland to woodlands and shrub woodlands, which enhances the water conservation function of woodlands. At the same time, as the studied area is in the period of industrial restructuring and accelerated urbanization, and the social economy continues to grow, the proportion of cultivated land and construction land has increased, but the overall stress condition is obviously lower than that of non-main ecological function areas. By analyzing the change trend of the ecological pattern and the ecological situation of the studied area, comprehending the ecological environment, resource status, and ecological environmental problems in this area, scientific basis is provided for ecological construction and protection with the focus on the protection of water resources,
the improvement of water conservation capacity, and the increase of forest vegetation coverage, so as to provide scientific support for effective ecological compensation.

In this study, only the water conservation index is selected to evaluate the ecological function index instead of analyzing the protected area ratio. In order to fully reflect the ecological function of the ecological functional zone, more studies should be done on this index in the subsequent studies.

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