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Original Paper

Study on the Identification Method of Ecological Source in Fujiang River Basin

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Abstract

Qualitative methods (direct identification of forest lands and nature reserves) and quantitative method (identification based on the evaluation of the importance of ecosystem services) were used to identify ecological sources.The results show: (1) The ecological source area identified based on the importance evaluation of ecosystem services is 7638.88 km^2, accounting for 19.34% of the total area of the Fujiang River Basin, which is mainly distributed in the eastern margin of the Qinghai-Tibet Plateau and the parallel mountains in eastern Sichuan. (2) Ecological sources were identified based on the importance evaluation of ecosystem services, the overlapping area of ecological sources and forest lands reached 87.76 % of the total area of ecological sources, and the overlapping area of ecological sources and nature reserves accounted for 51.61% of the total area of nature reserves. (3) Forest lands have multiple functions such as water conservation, soil and water conservation, and habitat quality maintenance. Therefore, most of the ecological sources extracted by ecosystem service indicators are forest lands. Due to the differences in classification criteria and consideration perspectives, approximately half of the areas in nature reserves are not within the ecological sources identified based on the evaluation of the importance of ecosystem services.

Keywords

ecological source, ecosystem service, forest land, nature reserve

1. Introduction

With the acceleration of urbanization and the increase of land development intensity, the dynamic balance of ecosystem has been destroyed, which has caused ecological problems such as soil erosion, biodiversity decreasing, biological habitat disappearance and fragmentation of ecological network. The contradiction between regional ecological security and economic development has become increasingly prominent (Yan et al., 2025). Therefore, it has become an urgent social demand to improve the level of ecological security through the construction of regional ecological security pattern (Deng et al., 2024). The ecological security pattern is supported by the theory of landscape ecology, in essence, it refers to a potential ecosystem spatial pattern in the landscape (Peng et al., 2018). At present, the construction method of ecological security pattern has become more and more mature. The research framework of "identifying the ecological source-constructing the resistance surface-extracting the corridor" has become the basic mode of ecological security pattern construction (Ma et al., 2021; Lin et al., 2022; Yao et al., 2023; Feng et al., 2024). Among them, the identification of ecological sources is the basis for the construction of ecological security pattern. Ecological sources are the core patches that maintain regional ecological integrity, serving as spatial carrier that drive ecological processes and ensure the supply of ecosystem services. It has an important radiation function to regional ecological security (Zhao et al., 2025). The identification of ecological sources is mainly based on the consideration of biodiversity and the importance of ecosystem services. At present, large areas of forest lands (Li et al., 2019; Wu et al., 2021) or ecological protection control areas such as nature reserves (Li et al., 2011; Yan et al., 2025) are usually directly identified as ecological sources. In addition, the method of identifying ecological sources based on the importance evaluation of ecosystem services is also widely used (Li et al., 2024; Wei et al., 2025; Zhou et al., 2025). Due to the inconsistent understanding of the connotation of ecological security and the specific differences in ecological security issues, the evaluation indicators selected by different research programs are different. In this study, water conservation, soil and water conservation and habitat quality were selected to comprehensively analyze the importance of ecosystem services in the Fujiang River Basin, and on this basis, ecological source identification was carried out. The ecological sources identified based on ecosystem service evaluation and the ecological sources identified by qualitative methods (forest lands and ecological protection areas are directly identified as ecological sources) are compared and analyzed, the differences in the results obtained by the three identification methods and their causes were compared, so as to lay a theoretical foundation for the construction of ecological security pattern and sustainable ecological restoration of land space in Fujiang River Basin.

2. Overview of the Study Area

Fujiang River originates from Xuebaoding, the main peak of Minshan Mountain. It is the largest tributary on the right bank of Jialing River. The main stream is 668 km long and the basin area is 39,500 km^2. The Fujiang River Basin is located in the transition zone between the eastern margin of the

Qinghai-Tibet Plateau and the Sichuan Basin, and the terrain tilts from northwest to southeast (Figure 1). The upper reaches of the main stream of the Fujiang River, from its source to Wudu Town in Jiangyou, are located in the high mountainous area in the northwest of Sichuan Province, the river valley is deep and the river water is flowing rapidly; The section from Wudu Town to Suining City is the middle reaches of the Fujiang River, the river flows through gentle hills and flat areas, with a wide river valley, gentle water flow and well-developed floodplains; The section from Suining City to Hejiang County is the lower reaches, the downstream basin is dominated by medium and low hilly landforms, and the I and II terraces formed by the alluvial layer of the river are distributed along the banks of the river, and the river course is tortuous. Due to the overall changes in the natural environment and the frequent impact of human activities in recent years, natural disasters such as landslides, collapses, and debris flows in the basin have occurred frequently (Zhang et al., 2021), resulting in a more fragmented landscape pattern in the region, and the landscape ecological risks faced by the Fujiang River Basin have become increasingly serious.

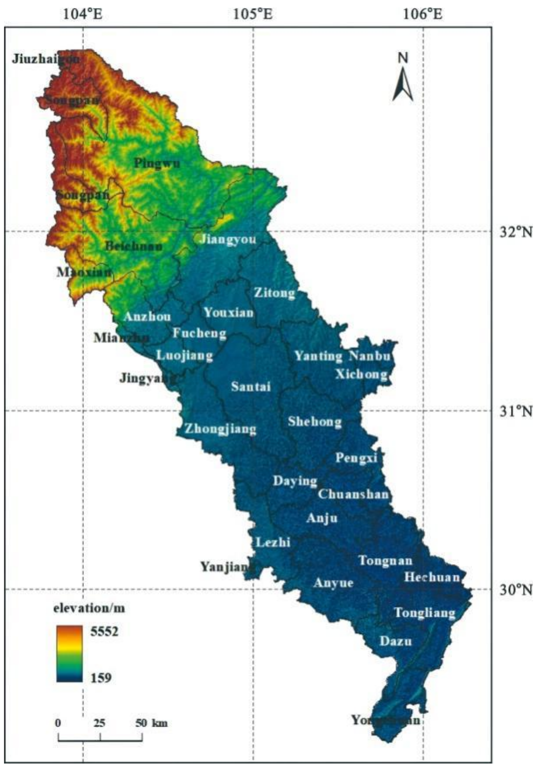


Figure 1. Digital Elevation of Fujiang River Basin

3. Data Sources and Research Methods

3.1 Data Sources

The basic data used in this study included digital elevation model, slope, soil erodibility, soil seepage flow, land use type, vegetation net primary productivity, annual average precipitation. Among these, the digital elevation model was derived from the geospatial data cloud platform, with a spatial resolution of 30 m, and the slope data was extracted from the digital elevation model. The data on soil seepage flow and soil erodibility were all derived from the Earth resources data cloud platform. Land use type was derived from the resource and environmental science data platform of the Chinese Academy of Sciences, with a spatial resolution of 30 m. The data of vegetation net primary productivity (2019-2023) was derived from the Google earth engine platform. The data of annual average precipitation (2019-2023) was derived from the national Qinghai-Tibet plateau scientific data center. The following data types, sources, and data source website were used (Table 1).

Table 1. Data Information List

Data types	Data sources	Data source website
Digital elevation model	Geospatial data cloud platform	https: //www.gscloud.cn/
Slope	Extracted from the digital elevation model	https: //www.gscloud.cn/
Soil erodibility	The earth resources data cloud platform	http: //www.gis5g.com/home
Soil seepage flow	The earth resources data cloud platform	http: //www.gis5g.com/home
Land use type	The resource and environmental science data platform of Chinese Academy of Sciences	https: //www.resdc.cn/
Vegetation net primary productivity (2019-2023)	The Google earth engine platform	https: //earthengine.google.com/
Annual average precipitation (2019-2023)	The national Qinghai-Tibet plateau scientific data center	https: //data.tpdc.ac.cn/home

3.2 Research Methods

3.2.1 Qualitative Identification

With reference to previous studies (Li et al., 2019; Wu et al., 2021) and the actual situation of the Fujiang River Basin, according to the structure, quantity and spatial distribution of forest lands in the study area, the scattered small-area forest lands were eliminated, and the large-area forest lands which are of great significance to the stable development of the ecological environment in the Fujiang River Basin was taken as the ecological sources of the study area. For nature reserves, in order to protect a species or a certain type of ecological environment for a long time, it is necessary to consider not only the target species or the target habitat itself, but also the ecosystem and related ecological processes in the region where it is located. Therefore, nature reserves are often the “stabilizer” of the ecological environment and belong to high ecosystem service value areas. In this study, wildlife nature reserves such as giant panda, waterfowl and alsophila spinulosa in the study area were selected as ecological sources.

3.2.2 Quantitative Identification

The importance of ecosystem services as the basis for the identification of ecological sources can reflect the degree of reflection of the ecological environment system on natural changes and human disturbance. Based on the "Technical Guidelines for Delineating Ecological Conservation Red Lines" issued by the Ministry of Environmental Protection, combined with previous studies (Deng et al., 2024; Li et al., 2024; Wei et al., 2025; Zhou et al., 2025) and the actual situation of the Fujiang River Basin, three indicators, namely water conservation, soil and water conservation, and habitat quality, were selected to comprehensively analyze the ecological quality of the Fujiang River Basin. The importance of ecosystem services was divided into five levels by natural breakpoint method. To reduce the fragmentation degree of ecological sources, patches with an area of less than 10km^2 are excluded, and regions with higher importance of ecosystem services and concentrated grid units were selected as ecological sources. The calculation formulas for each index are as follows (Yao et al., 2023):

Water conservation:

$$WR = \mathrm{NPP}_{mean} \times F_{sic} \times F_{pre} \times (1 - F_{slo}) \tag{1}$$

where WR is the importance index of water conservation, NPP_{mean} is the average value of the net primary productivity of vegetation for many years, F_{sic} is the soil percolation factor, F_{pre} is the multi-year average precipitation factor, and F_{slo} is the slope factor.

Soil and water conservation:

$$S_{pro} = \mathrm{NPP}_{mean} \times (1 - K) \times (1 - F_{slo}) \tag{2}$$

where S_{pro} is the importance index of soil and water conservation, NPP_{mean} is the average value of the net primary productivity of vegetation for many years, K is the soil erodibility factor, and F_{slo} is the slope factor.

Habitat quality:

The habitat quality module of the InVEST model was used to evaluate the habitat quality of the study area. The model established connections between different land use types and stress factors to evaluate the spatial characteristics of habitat quality. The calculation method is as follows (Du et al., 2024; Niu et al., 2025):

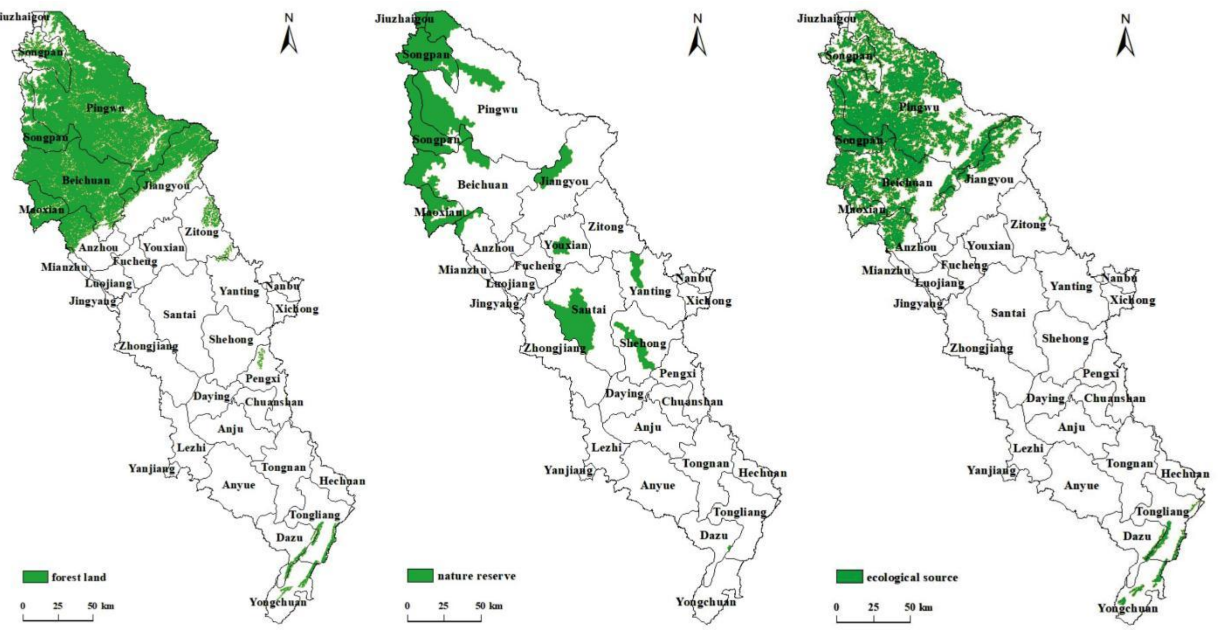
$$A_{xj} = H_j \left\{ 1 - \left(\frac{D_{xj}^{Z}}{D_{xj}^{Z} + K^{Z}} \right) \right\} \tag{3}$$

where A_{xj} is the habitat quality of patch x for land use type j, H_j is the habitat suitability of land use type j, D_{xj} is the threatened degree of patch x in land use type j, K is the semi-saturation coefficient, and Z is a constant.

4. Results of Ecological Source Identification

4.1 Distribution of Ecological Sources

The forest lands were extracted from the land use type data. As shown in Figure 2(a), the forest lands are mainly distributed in the eastern margin of the Qinghai-Tibet Plateau and the parallel mountains in eastern Sichuan, with an area of 11427.90 km^2, accounting for 28.93% of the total area of the Fujiang River Basin. The spatial location of the ecological sources identified based on the importance evaluation of ecosystem services is similar to the spatial location of forest lands. The ecological sources are mainly distributed in the counties of Pingwu, Beichuan, Jiangyou, Songpan and Maoxian in the north of the study area and in the districts of Tongliang, Dazu and Yongchuan in the south of the study area (Fig.2(c)), the area is generally smaller than the forest land area, which is 7638.88 km^2, accounting for 19.34% of the total area of the Fujiang River Basin. The nature reserves are mainly giant panda reserves distributed in Songpan County, Mao County, Pingwu County, Beichuan County and Anzhou District; Endangered plant (Urophysa rockii) reserves and Karst geomorphology reserves distributed in Jiangyou City; Waterfowl (Egrets, etc.) reserves distributed in Santai County, Yanting County, Youxian District; Wetland reserves distributed in Shehong City; Endangered plant (Alsophila spinulosa) reserves distributed in Dazu District (Fig.2(b)). The area of nature reserves is 5662.45km^2, accounting for 14.34% of the total area of Fujiang River Basin.



(a)Forest land identified as an ecological source (b)Nature reserve identified as an ecological source (c)Ecological source identified based on the evaluation of the importance of ecosystem services

Figure 2. Identification of Ecological Sources Based on Different Methods

4.2 Comparison of Identification Results

Comparing the "ecological sources identified based on the importance evaluation of ecosystem services" and "forest lands and nature reserves are directly defined as ecological sources", it can be seen that the overlapping area of ecological sources and forest lands reaches 6704.24km^2 (Table2), accounting for 87.76 % of the total area of ecological sources (Fig.3(a)). It shows that most of the ecological sources extracted by water conservation, soil and water conservation and habitat quality are forest lands. Forest lands have multiple functions such as carbon fixation and oxygen release, water conservation, prevention of soil erosion and protection of biodiversity, which is an important ecological guarantee for human survival and development. The overlapping area between the ecological sources identified based on the importance evaluation of ecosystem services and the nature reserves is 2,922.50km^2 (Table2), accounting for 51.61% of the total area of the nature reserves (Fig.3(b)), indicating that approximately half of the nature reserves are not located within the ecological sources. The main reason is that the nature reserves in the Fujiang River Basin mainly protect a rare animal or plant (giant panda, waterfowl, alsophila spinulosa, etc.) or a unique landform type (Karst geomorphology), without comprehensively considering the ecosystem service level of the nature reserves from the perspectives of water conservation, soil and water conservation, and habitat quality. The overlapping area of forest lands and nature reserves is 3,384.10 km^2 (Table2), accounting for 59.76% of the total area of nature reserves (Fig.3(c)), indicating that in addition to being located in forest areas, approximately 40% of nature reserves are situated in other land types such as water areas (Wetlands, etc.).

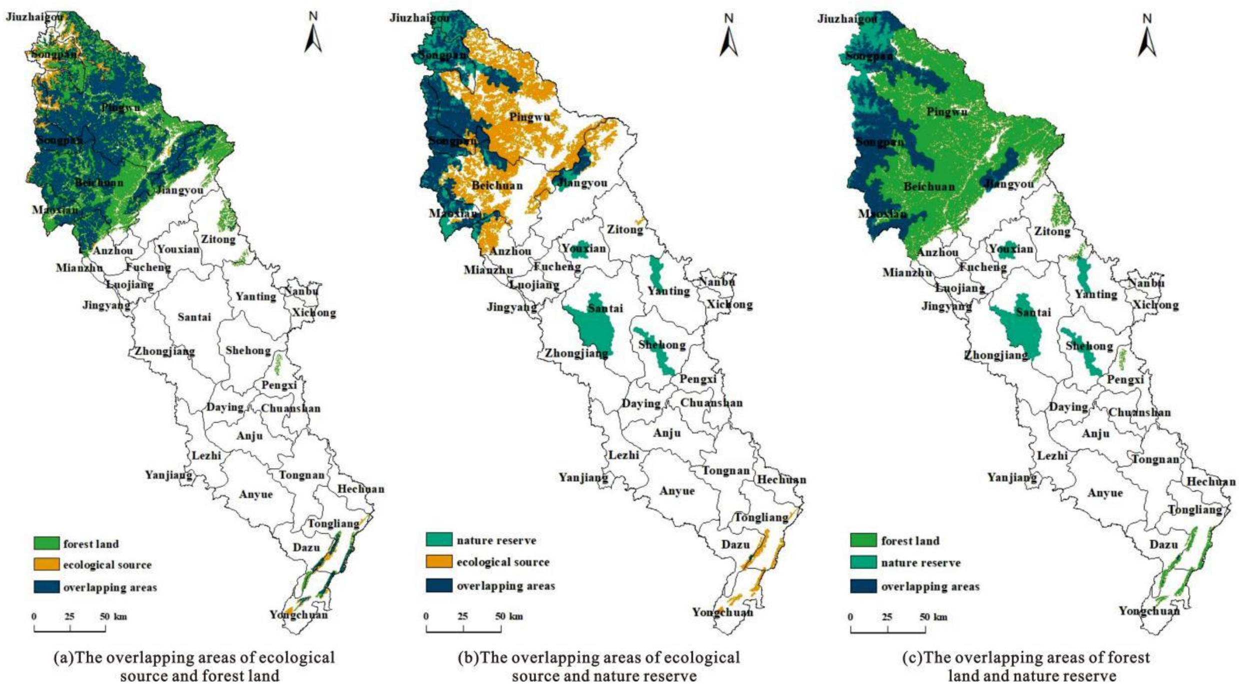


Figure 3. The Overlapping Areas of Ecological Sources Identified by Different Methods

Table 2. Comparison of Identification Result of Ecological Sources

Category of ecological sources	Area/km^2	The overlapping area of two types of ecological sources/km^2		
		Forest lands	Nature reserves	Ecological sources identified based on the importance evaluation of ecosystem services
Forest lands	11427.90	—	3384.10	6704.24
Nature reserves	5662.45	—	—	2922.50
Ecological sources identified	7638.88	—	—	—

5. Discussion

This study identified the ecological sources of the Fujiang River Basin respectively by using the ecosystem service importance evaluation method and the direct determination method (forest lands, nature reserves). Studies have shown that the locations of ecological sources identified by the three methods are quite different. Forest lands are an area covered by trees, shrubs and other vegetation, which plays a role in protecting water resources, controlling soil erosion and providing habitats for animals and plants (Li et al., 2019; Wu et al., 2021). However, directly treating forest lands as the ecological sources ignores the internal differences of the same land type. Nature reserves are areas that protect typical natural ecosystems, rare animals and plants, and natural relics of special significance (Li et al., 2011; Yan et al., 2025). It is very convenient to identify the nature reserves as the ecological sources. However, the establishment of the nature reserves itself has administrative control factors, and the internal spatial differences of nature reserves gradually increase over time. Especially with the rapid development of tourism in nature reserves, obvious ecological degradation, landscape fragmentation and decline in ecosystem service functions have emerged in some local areas (Peng et al., 2017). The ecological source areas identified based on the importance evaluation of ecosystem services are mainly areas that undertake important ecological functions such as water conservation, soil and water conservation, and biodiversity maintenance. They are areas where humans obtain various benefits from the ecosystem, emphasizing human needs and the services that the ecosystem can provide to humans (Xu et al., 2021; Deng et al., 2024; Niu et al., 2025). The difference in connotation leads to significant differences in the location of ecological sources extracted by the three identification methods. In future research, it is necessary to explore the integration of the ecological sources identified based on the importance evaluation of ecosystem services with the ecological protection and control areas (nature reserves, etc.), and to construct a scientific and complete ecological security pattern and ecological restoration network for the Fujiang River Basin, so as to provide theoretical references for the overall protection and systematic governance of the national ecological space. In general, the construction of ecological security pattern aims to improve the level of ecosystem services and enhance human well-being. Therefore, the identification of ecological sources should take meeting human needs as the primary goal, and focus on the ability of alternative ecological sources to provide effective services for human beings.

6. Conclusion

In this study, the ecological sources of Fujiang River Basin were identified by direct discrimination and evaluation based on the importance of ecosystem services. On the basis of the above work, the differences in the location of ecological sources obtained by qualitative identification and quantitative identification and the reasons for the differences were compared. The main conclusions are as follows:

(1) The ecological source area identified based on the importance evaluation of ecosystem services is 7638.88 km^2, accounting for 19.34% of the total area of the Fujiang River Basin. It is mainly distributed in the eastern margin of the Qinghai-Tibet Plateau on the north side of the study area and the parallel mountains on the south side of the study area. The distribution area of ecological sources is similar to the distribution area of forest lands, but the range of forest lands is wider. The ecological sources identified based on nature reserves are mainly concentrated in the forest areas on the northwest edge of the Fujiang River Basin, all of which are protected areas with giant pandas as the main protection objects. In addition, the nature reserves are also distributed in the hilly areas of central Sichuan, such as Jiangyou City, Shehong City, Youxian District, Yanting County and Santai County. They are mainly the endangered plant, waterfowl and wetland reserves, which do not overlap with the location of forest lands and ecological sources identified based on the importance evaluation of ecosystem services.

(2) Comparing the ecological sources extracted by the comprehensive evaluation method and the direct identification method, the overlap area between the ecological sources identified based on the evaluation of the importance of ecosystem services and the forest lands reached 87.76% of the total area of the ecological sources, indicating that the ecological sources extracted by the ecosystem service index are mostly forest lands. The concentrated distribution area of forest lands has multiple functions such as water conservation, soil and water conservation, and habitat quality maintenance. The overlap area between the ecological sources identified based on the importance evaluation of ecosystem services and the nature reserves accounts for 51.61 % of the total area of the nature reserves. Due to the differences in classification criteria and consideration perspectives, approximately half of the area in nature reserves is not located within the ecological sources identified based on the importance evaluation of ecosystem services.

(3) Future research needs to consider how to integrate ecological sources that focus on meeting human needs with nature reserves that focus on species and natural relics protection. Based on the consideration of improving the level of ecosystem services and promoting human well-being, ecological sources should be quantitatively identified by ecosystem service indicators, supplemented by qualitative identification methods, and ecological sources should be comprehensively delineated to

achieve coordinated development of natural environment and social economy.

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