

Research on the Value Realization Mechanism And Path of Agroforestry Ecological Product Derived From Karst Soil And Water Conservation

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Received: November 16, 2025 Accepted: December 7, 2025 Online Published: December 12, 2025

Abstract

The karst area is a typical ecologically fragile and soil erosion area. The agroforestry derived from soil and water conservation plays an important role in its ecological restoration and sustainable development. However, research on the value realization mechanisms and paths for agroforestry ecological products in karst soil and water conservation remains limited. In this study, three typical karst demonstration areas of Bijie Salaxi, Guanling-Zhenfeng Huajiang and Qingzhen Hongfenghu were taken as examples to create an ecological product classification system. Employing methods such as ecological product value accounting and spatial analysis. It evaluates the GEP across these regions and conversion rate, revealing the realization mechanisms and paths under a multi-stakeholder approach. Results indicate: The Salaxi study area recorded total GEP of 679.1433 million yuan, with a total value conversion rate of 15.12%. Huajiang GEP was 403.7665 million yuan, with a total value conversion rate of 13.65%. Hongfenghu GEP: 495.8981 million yuan, total value conversion rate is 19.12%. All three study areas exhibited the highest value in regulating services and the lowest in cultural services. Moreover, the conversion rates of total ecological product value across the three study areas primarily showed the highest conversion for material products, while conversion rates for regulating and cultural services remained relatively low. Current value realization still relies predominantly on traditional agricultural products, with the market potential of regulating and cultural services yet to be fully tapped. This study not only enriches the theoretical framework for value realization mechanisms and pathways of ecological products in soil and water conservation but also provides scientific reference for implementing the “Two Mountains” theory in ecological protection and sustainable development within karst soil and water conservation areas.

Keywords: karst soil and water conservation, agroforestry, ecological product, value realization, mechanisms and paths

1. Introduction

China first introduced the concept of “ecological product” in the 2010 National Key Functional Zones Planning. Ecological product serve as the core elements for safeguarding ecological security and ensuring the stable functioning of ecosystems (Feng et al., 2022). They are not only vital resources for human survival and sustainable development but also play a significant role in enhancing overall human well-being (Du et al., 2024). Converting ecological product into economic value sources helps alleviate tensions between environmental protection and economic growth (Wang et al., 2023). The ecological product value realization refers to the process of transforming the inherent value of ecological product into economic, social, and ecological benefits (Sun et al., 2025). Academic circles currently categorize ecological product into three major types: material products, regulating services, and cultural services. In recent years, scholars have conducted in-depth explorations in this field. Temesgen et al. (2018) employed a combination of geospatial technology and natural capital economic valuation to calculate the value of agroforestry ecological product. Zhang and Xu (2024) designed a benefit evaluation framework to assess the ecological product costs, economic benefits, and ecological benefits of ecological restoration projects. Wang et al. (2022) calculated the value and conversion efficiency of forest ecological product, proposing optimization measures. While these findings provide important references for realizing the value of agroforestry ecological product, they have not deeply explored the mechanisms and paths for value realization. At the soil and water conservation level, the issuance of the “Opinions on Establishing and Improving the Value Realization Mechanism

for Ecological Product in Ecologically Clean Small Watersheds”(MWRPRC, 2024) explicitly integrates soil and water conservation functions with ecological product. This provides robust policy support for researching value realization mechanisms for agroforestry ecological product in soil and water conservation. Nevertheless, the paths for achieving this remain to be explored. Current obstacles persist in the transaction and monetization of ecological product value. Addressing these challenges requires breakthroughs in both institutional mechanisms and practical implementation paths.

Ecological product, serving as a bridge between natural capital and human well-being, hold particular strategic value in ecologically fragile areas like karst regions (Zhang et al., 2023). However, frameworks for ecological product value realization face practical challenges in karst areas (Zhang et al., 2022). Karst mountainous regions feature complex topography, fragmented landscapes, and diverse habitats. Their unique geological conditions and intricate ecosystems make them crucial for regional ecological conservation and development. Yet environmental degradation poses significant challenges. Irrational human activities have led to karst ecosystem degradation and accelerated soil erosion, rendering the ecological environment increasingly fragile (Xiong et al., 2002). Against this backdrop, soil and water conservation projects have become critical measures for protecting the ecological environment and promoting development in karst regions (Yuan et al., 2021). In mountainous areas, integrated management through soil and water conservation projects, biological measures, and agronomic practices has given rise to a unique integrated system: soil and water conservation agroforestry. This system organically combines multiple ecosystems, including forests, grasslands, and farmlands. Simultaneously, agroforestry systems leverage their ecological advantages and economic potential (Xiong et al., 2022) to become a vital pillar for advancing ecological restoration and economic growth in karst regions. These systems produce diverse ecological goods, occupying a significant position within the ecosystem, and their transactional conversion represents a key path for realizing the value of ecological products (Wu et al., 2024).

Agroforestry as a derivative system of karst soil and water conservation, play a crucial role in maintaining the local ecological environment. They enhance vegetation coverage (Martin et al., 2020), reduce soil erosion, improve soil quality (Panwar et al., 2018), and provide diverse agroforestry products to boost income and promote development (Yang et al., 2023). Simultaneously, it safeguards biodiversity and regulates environmental climate (Moreno et al., 2018). Its ecological product deliver combined ecological, economic, and social benefits. However, despite the significant ecological and economic advantages of agroforestry in karst regions, realizing the value of its ecological product faces numerous obstacles (Xiao and Xiong, 2022). On one hand, the fragile karst ecosystem complicates ecological value assessment (Chang et al., 2024), making accurate calculation of agroforestry ecological product value challenging. On the other hand, inadequate market mechanisms hinder ecological product market transactions (Li et al., 2024), impeding effective economic value conversion. Existing research predominantly focuses on the supply and structural optimization of agroforestry systems (Jiang et al., 2022), while value realization studies often concentrate on value calculation (Xu et al., 2023) or provincial-level macro-scale ecological product value realization (Zhu et al., 2024). There remains insufficient attention to more detailed value realization mechanisms and pathways for agroforestry ecological product in soil and water conservation. Therefore, this study aims to investigate the value accounting and value realization mechanisms and paths of agroforestry ecological product derived from karst soil and water conservation, thereby promoting the transformation of ecological advantages into economic advantages.

This study evaluates the ecological product value of karst soil and water conservation agroforestry systems using ecological product valuation methods. It systematically analyzes the value composition, realization mechanisms, and paths of ecological product from these agroforestry systems. Recommendations are proposed to improve the mechanisms and paths for realizing ecological product value. This research not only provides a basis for value realization of agroforestry ecological product derived from karst soil and water conservation, but also promotes the deep integration of soil and water conservation projects with ecological conservation. It aims to facilitate the continuous improvement of the ecological environment and sustainable economic development in karst soil and water conservation areas.

2. Study Area and Methods

2.1 Study Area

(1)The Salaxi Karst Plateau Mountain Research Area in Bijie (“Salaxi Research Area”) is located in Bijie City, Guizhou Province (105°01'00"-105°08'09"E, 27°11'30"-27°18'30"N). The study area covers 86.27 km², with karst landforms accounting for 73.94% of the total area. The average elevation is 1,878 m, the annual mean temperature is 12.8°C, and the annual average precipitation is 984.4 mm.

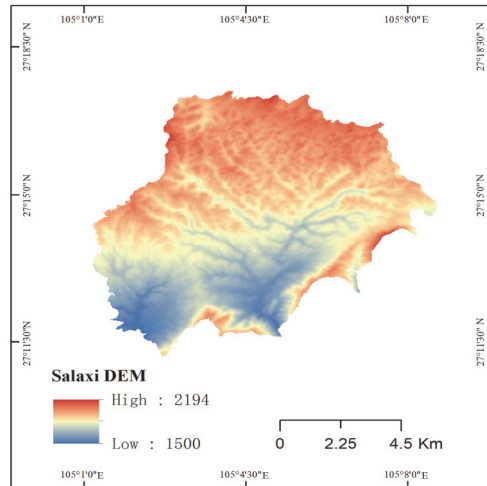


Figure 1. Salaxi Study Area Map

(2) Guanling-Zhenfeng Huajiang Karst Plateau Canyon Research Area (“Huajiang Research Area”): Located in southwestern Guizhou Province (105°36'00"-105°42'00"E, 25°36'00"-25°42'00"N). The area spans 51.62 km², with karst landforms covering 87.92% of the territory. The average elevation is 947 m, the annual mean temperature is 18.4°C, and the annual average precipitation is 1100 mm.

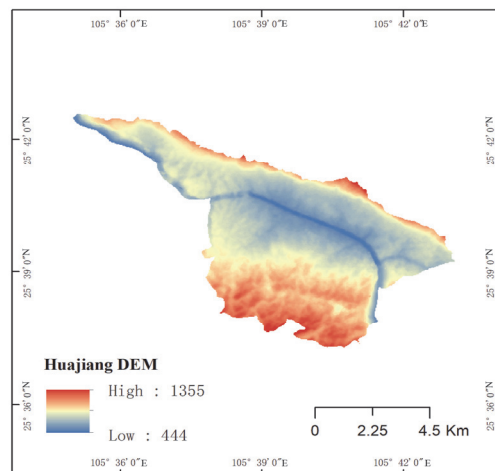


Figure 2. Huajiang Study Area Map

(3) Qingzhen Hongfenghu Karst Plateau Basin Study Area (“Qingzhen Study Area”): Located in the southwest of Qingzhen City (106°18'00"E–106°25'00"E, 26°29'30"N–26°33'00"N). The study area covers 60.44 km², with karst landforms accounting for 94.59% of the total area. The average elevation is 1300m, the annual mean temperature is 15.5°C, and the annual average precipitation is 1192.5mm.

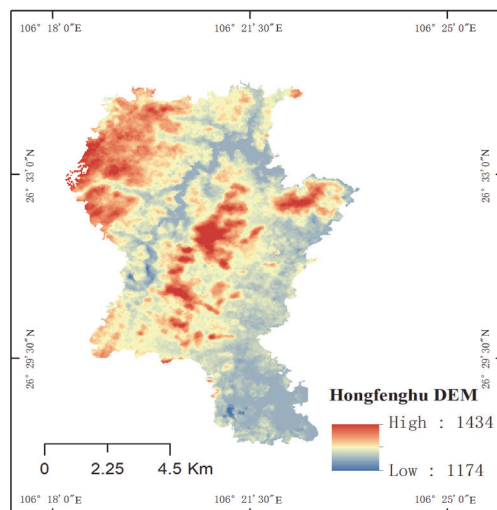


Figure 3. Hongfenghu Study Area Map

2.2 Data Sources

The foundational data for this study is derived from relevant statistical and experimental data. Statistical data related to ecological product accounting and conversion rate assessment are sourced from the ‘Technical specification for gross ecosystem product accounting’ (GEP), the ‘Theory and method of gross ecosystem product (GEP) accounting’ and the appendix ‘Methods for accounting for the value of ecological products for Soil and Water Conservation’ in the ‘Opinions on Establishing and Improving the Mechanism for Realizing the Value of Ecological Products from Soil and Water Conservation in Ecologically Clean Small Watersheds’(MWRPRC, 2024), The Environmental Protection Tax Law of the People's Republic of China, fiscal settlement reports, and data from the Guizhou Provincial Forestry Bureau and People's Government. Data sources include the Qixingguan District Statistical Yearbook, Qingzhen City Statistical Yearbook, Guanling Buyi and Miao Autonomous County Statistical Yearbook, China Rural Statistical Yearbook, and Guizhou Provincial Macroeconomic Database. Market information from Huinong.com (<https://www.cnhnb.com/hangqing/>) was integrated, and data was collected through field ecological surveys and socioeconomic questionnaires. Land use data were derived from remote sensing interpretation and field verification. DEM data were sourced from the General Bathymetric Chart of the Oceans(GEBCO)https://www.gebco.net/data_and_products/gridded_bathymetry_data.

For experimental data, three soil profiles were excavated at each study plot. After removing surface vegetation and litter, soil samples were collected in 0–10 cm and 10–20 cm layers, placed in self-sealing bags, and brought back to the laboratory for air drying. Some samples were used to determine soil carbon, nitrogen, phosphorus, and potassium content for soil conservation calculations. Others were collected using ring corers, dried in a 105°C oven to constant weight, and analyzed for bulk density and saturated water content.

2.3 Research Methods

2.3.1 Accounting of Ecological Product Value

The Methods for accounting for the value of ecological products for Soil and Water Conservation aims to quantify the economic benefits of soil and water conservation measures, primarily encompassing the valuation of three categories of products: material products, regulating services, and cultural services. Based on the ‘Methods for accounting for the value of ecological products for Soil and Water Conservation’ attached to the ‘Opinions on Establishing and Improving the Mechanism for Realizing the Value of Ecological Products from Soil and Water Conservation in Ecologically Clean Small Watersheds,’ and considering the actual conditions of karst terrain, this study combines the ‘Theory and method of gross ecosystem product (GEP) accounting’ to calculate the physical quantity of ecological products in the study area, thereby determining their value. Based on this, this study first constructs a classification system of agroforestry ecological product derived from karst soil and water conservation (Table 1) to serve the calculation. During calculation, following the principles and formulas for soil and water conservation ecological product valuation, the agroforestry ecological product value derived from soil and water conservation measures is determined as the increment between the measures scenario scenario and the baseline scenario. Considering the study area's actual conditions, the ecological product value under the measures scenario

encompasses all new added benefits resulting from soil and water conservation measures, while the baseline scenario value represents the ecological product value generated by the interaction between the study area's natural ecosystems and human activities in the absence of such measures. Subtracting the baseline value from the measure scenario value yields the value of soil and water conservation agroforestry ecological product derived from implementing these measures over the 12-year period. This calculation implements soil and water conservation management measures starting from 2011, accumulating 12 years of value-added growth by 2023 (the assessment year).

Table 1. Classification system of agroforestry ecological product derived from karst soil and water conservation

Primary Indicator	Secondary Indicator	Tertiary Indicator	Unit	
Material Product	Forest Ecological Products	Quantity of Wood (Bamboo) Forest Products	t	
		Quantity of Non-Wood Forest Products (Fruit Products, Chinese Herbal Medicines, etc.)	t	
	Grassland Ecological Products	Quantity of Livestock Products	t	
		Quantity of Poultry Products	t	
	Farmland Ecological Products	Quantity of Grain Products	t	
		Quantity of Vegetable Products	t	
		Quantity of Oilseed Products	t	
	Water Area Ecological Products	Freshwater Volume	t	
		Quantity of Fishery Products (Fish, Shrimp, etc.)	t	
	Water Conservation	Forest Water Conservation Volume	Forest Water Conservation Volume	m ³
			Grassland Water Conservation Volume	m ³
		Farmland (Terrace, Agroforestry Intercropping, Basic Farmland) Water Conservation Volume	Farmland (Terrace, Agroforestry Intercropping, Basic Farmland) Water Conservation Volume	m ³
			Forest Soil Erosion Reduction Volume	t
		Grassland Soil Erosion Reduction Volume	Grassland Soil Erosion Reduction Volume	t
Farmland (Terrace, Agroforestry Intercropping, Basic Farmland) Soil Erosion Reduction Volume			t	
Soil Conservation		Reduction Volume of Sediment Accumulation	t	
		Forest Soil Fertility Preservation Volume	t	
		Grassland Soil Fertility Preservation Volume	t	
Regulating Services		Farmland (Terrace, Agroforestry Intercropping, Basic Farmland) Soil Fertility Preservation Volume	Farmland (Terrace, Agroforestry Intercropping, Basic Farmland) Soil Fertility Preservation Volume	t
	Forest Soil Carbon Sequestration Volume		tC	
	Grassland Soil Carbon Sequestration Volume	Grassland Soil Carbon Sequestration Volume	tC	
		Farmland (Terrace, Agroforestry Intercropping, Basic Farmland) Soil Carbon Sequestration Volume	tC	
Carbon Sequestration	Karst Carbon Sequestration Volume	tC		
	Oxygen Release	Plant Oxygen Release Volume	t	
Climate Regulation	Energy Consumption from Vegetation Ecosystem Transpiration	kW.h/a		
	Species Conservation	Species Diversity (Shannon Index)	—	

	Flood Storage	Vegetation Flood Storage Volume	m ³
		Reservoir and Pond Flood Storage Volume	m ³
		Forest Reduction Volume of Non-Point Source Pollution	t
	Reduction of Soil Non-Point Source Pollution	Grassland Reduction Volume of Non-Point Source Pollution	t
		Farmland (Terrace, Agroforestry Intercropping, Basic Farmland) Reduction Volume of Non-Point Source Pollution	t
		Tourism Accommodation and Catering	CNY
		Admission Tickets	CNY
Cultural Services	Leisure and Recreation	Number of Outdoor Camping person times	person times
		Number of Leisure Picking person times	person times

2.3.2 Assessment of Ecological Product Value Conversion Rate

The value conversion of ecological product equals the sum of the value conversion of material products, the value conversion of regulatory services, and the value conversion of cultural services. The value conversion rate of ecological product is equal to the ratio of the value conversion volume of ecological product to the total value of ecological product (GEP)(Zhang et al., 2025). The formula is as follows:

$$VCEP = VCMP + VCRS + VCCS$$

$$VCREP = VCEP/GEP$$

In the formula, $VCEP$ is the value conversion volume of ecological product; $VCMP$ is the value conversion volume of material product; $VCRS$ is the value conversion volume of regulating services; $VCCS$ is the value conversion volume of cultural services; $VCREP$ is the value conversion rate of ecological product, and GEP is the total value of ecological product.

(1) Assessment of material product value conversion volume

The value conversion volume of material product is equal to the total amount of material products multiplied by the price of the year. The formula is as follows :

$$VCMP = \sum_{i=1}^n AM_i \times P_{AMi} - CP_{AMi}$$

In the formula, $VCMP$ is the value conversion volume of material product; AM_i is the total acquisition of material product; P_{AMi} is the actual selling price of the i th material product in the study are; CP_{AMi} is the cost price of the i th material product in the study area; i is the type of material product; n is the number of types of material product.

(2) Assessment of regulating services value conversion volume

The value conversion volume of regulating services is composed of two parts: market transactions and government funding support. The formula is as follows :

$$VCRS = V_t + V_{com}$$

In the formula, $VCRS$ is the value conversion volume of regulating services; V_t is the total market transaction value of regulation services (CNY), and V_{com} is the total ecological compensation related to regulating services (CNY).

(3) Assessment of cultural services value conversion volume

The value conversion volume of cultural services equals the sum of consumer travel expenditures (including transportation costs, accommodation and meal expenses, admission fees, etc.) within the value of cultural services and the product value realized through other models. The time costs and consumer surplus within the value of

cultural services are not realized in the market and are therefore excluded from the assessment. The formula is as follows :

$$VCCS = V_c + V_{com}$$

In the formula, $VCCS$ is the value conversion volume of cultural services, V_c is consumer expenditure (CNY), and V_{com} is the total ecological compensation related to cultural services (CNY).

3. Results

3.1 Assessment of Ecological Product Supply and Value Accounting

Table 2 Physical quantity of ecological product supply of agroforestry derived from karst soil and water conservation

Primary Indicator	Secondary Indicator	Unit	Salaxi	Huajiang	Hongfenghu
Material Product	Forest Ecological Products	(t)	2729.58	1170.74	850.39
	Grassland Ecological Products	(t)	429.62	31.49	18.13
	Farmland Ecological Products	(t)	13419.30	5527.99	17308.20
	Water Area Ecological Products	(m ³)	1920.37	10704.96	3313.93
	Water Conservation	(m ³)	20523932.36	13155209.37	29033624.45
	Soil Conservation	(t)	7320.01	3658.31	1508.58
	Carbon Sequestration	(t)	6263.20	369.60	488.36
Regulating Services	Oxygen Release	(t)	3303.28	485.23	548.19
	Climate Regulation	(kW·h/a)	4001634.81	1164506.94	43157.18
	Species Conservation	(H' Index)	2.59	2.06	3.02
	Flood Storage	(t)	7700.46	13747.44	15916.27
Cultural Services	Reduction of Soil Non-Point Source Pollution	(t)	1018.85	627.18	259.29
	Leisure and Recreation	(person times)	331	481	886

Based on physical quantity data (Table 2), the Salaxi study area demonstrates strong comprehensive capabilities in total ecological product supply. Regarding material product, forest ecological product output reached 2729.58 t, while farmland ecological products amounted to 13419.30 t, highlighting the region's agricultural production advantages. Regarding regulatory services, water conservation capacity reached 20523932.36 m³, carbon sequestration amounted to 6263.20 t, and climate regulation capacity reached 4001634.81 kW·h/a. These figures indicate that the Salaxi study area plays a significant role in maintaining regional ecological balance and mitigating climate change. Regarding cultural services, the relatively low number of recreational visits indicates untapped potential for developing ecotourism in the area.

The Huajiang study area exhibits distinct variations in ecological product supply. Among material product, aquatic ecological product output stands out at 10704.96 m³, significantly surpassing the other two regions—likely attributable to the area's abundant water resources. However, the Huajiang study area demonstrates relatively lower yields in forest, grassland, and farmland ecological products. Regarding regulatory services, while flood regulation capacity is strong at 13747.44 t, indicators for water conservation, soil retention, and carbon sequestration all fall below those of the Salaxi and Hongfenghu study areas. For cultural services, recreational visits reached 481

person-times, indicating the Huajiang study area possesses some appeal for ecotourism, though there remains room for improvement.

The Hongfenghu study area demonstrates unique advantages in supplying ecological product. Regarding material product, farmland ecological product yielded the highest output at 17308.2 t, reflecting the region's high efficiency in agricultural production. Regarding regulating services, the study area excels in water conservation, climate regulation, and species conservation. Notably, its species conservation H' index reached 3.02—the highest among the three study areas—indicating rich biodiversity. Additionally, its flood regulation capacity is strong, reaching 15916.27 t. Regarding cultural services, recreational visits reached 886 person-times, significantly higher than the other two areas, reflecting the Hongfenghu study area's strong appeal for ecotourism. Overall, the Hongfenghu study area possesses both quantitative advantages and qualitative characteristics in the supply of ecological product.

Table 3. The value of agroforestry ecological product derived from karst soil and water conservation

Primary Indicator	Secondary Indicator	Value (CNY 10 ⁴)		
		Salaxi	Huajiang	Hongfenghu
Material Product	Forest Ecological Products	2164.51	1508.34	2464.14
	Grassland Ecological Products	2784.80	1303.92	1076.44
	Farmland Ecological Products	4135.78	2195.40	5254.65
	Water Area Ecological Products	0.86	3.10	0.60
	Subtotal	9085.96	5010.75	8796.44
	Water Conservation	5815.46	4686.06	8065.72
	Soil Conservation	1363.07	263.78	169.23
	Carbon Sequestration	615.11	24.78	18.74
	Oxygen Release	1123.24	41.30	42.31
Regulating Services	Climate Regulation	4682.74	2853.04	1616.17
	Species Conservation	45171.83	27060.75	30830.44
	Flood Storage	18.98	32.52	27.20
	Reduction of Soil Non-Point Source Pollution	35.37	27.87	8.46
Cultural Services	Subtotal	58825.79	34991.13	40783.10
	Leisure and Recreation	2.59	3.61	6.04
	Subtotal	2.59	3.61	6.04
GEP	Total	67914.33	40376.65	49589.81

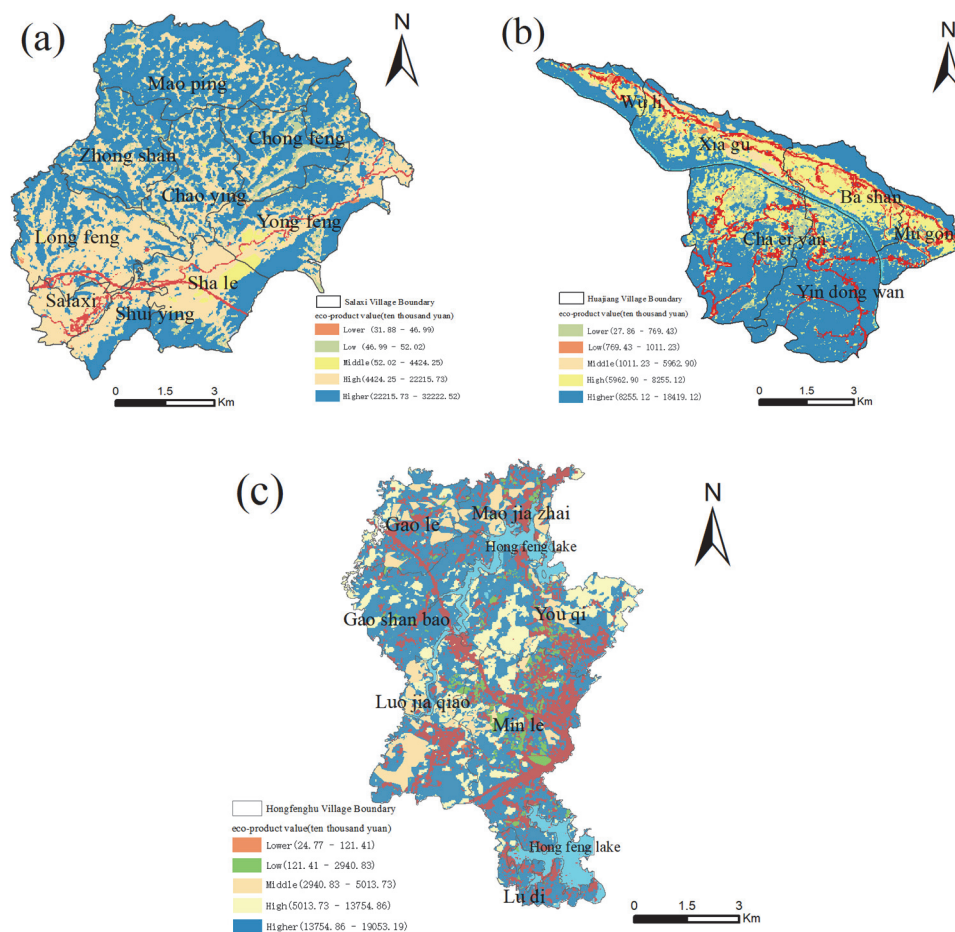


Figure 4. Spatial distribution pattern of value of agroforestry ecological product derived from karst soil and water conservation

The results of ecological product value accounting are shown in Table 3. The Salaxi study area demonstrated a significant overall advantage in ecological product value. Regarding material product, its total value reached CNY 9085.96×10^4 , with farmland ecological product contributing the most at CNY 4135.78×10^4 , reflecting the economic value of agricultural production in this region. The value of regulating services was even more prominent, totaling CNY 58825.79×10^4 . Notably, species conservation value reached CNY 45171.83×10^4 , highlighting the region's substantial contribution to biodiversity protection. Additionally, the values of regulating services such as climate regulation and water conservation were also at relatively high levels, collectively forming the high-value characteristic of ecological product in the Salaxi study area. Overall, Salaxi has achieved a favorable balance between ecological conservation and economic development.

The Huajiang study area exhibits relatively dispersed characteristics in terms of ecological product value. The total value of material product amounts to CNY 5010.75×10^4 , which is relatively low. The total value of regulating services reaches CNY 34991.13×10^4 . Although the aggregate value is substantial, the distribution of values across various regulating services is relatively uniform, without any standout items like those observed in Salaxi. Notably, Huajiang also achieved a species conservation value of CNY 27060.75×10^4 , highlighting its significance in biodiversity preservation. However, compared to Salaxi and Hongfenghu, Huajiang's overall competitiveness in ecological product value remains somewhat limited.

The Hongfenghu study area demonstrates unique advantages in ecological product value. The total material supply value amounts to CNY 8796.44×10^4 , with farmland ecological product contributing the highest value at CNY 5254.65×10^4 , reflecting the economic value of agricultural production in this region. The total value of regulating services reached CNY 40783.1×10^4 . Although slightly lower than that of the Salaxi study area, its values for climate regulation and species conservation were notably high. Particularly, the value of species conservation

reached CNY 30830.44×10^4 , second only to the Salaxi study area. Additionally, Hongfenghu exhibits relatively high cultural service value, with recreational value reaching CNY 6.04×10^4 , indicating its potential for ecotourism. Overall, Hongfenghu demonstrates both quantitative strength and qualitative distinctiveness in ecological product value, presenting the most balanced performance among the three study areas.

After accounting the value of baseline scenario and measure scenario, the value of agroforestry ecological product derived from soil and water conservation was obtained. The spatial distribution patterns of value across the three study areas were revealed (Figure 4). In the Salaxi study area, high-value zones accounted for a significant proportion, primarily distributed in the northwest, such as Maoping Village and Zhongshan Village. Low-value zones were mainly located in the southwest, including Longfeng Village, Salaxi Village, and Shale Village. In Huajiang, high-value areas were concentrated in the southern part of the study area, such as Yindongwan Village, while low-value areas were mainly distributed in the eastern part, including Muguang Village and Bashan Village. In Hongfenghu, high-value areas were primarily located in the northwest, such as Gaoshanbao Village and Gaole Village, while low-value areas were mainly distributed in the central part, including Luojiqiao Village and Minle Village.

3.2 Conversion of Ecological Product Value

The value conversion of agroforestry ecological product derived from karst soil and water conservation in the Salaxi study area reached CNY 10271.17×10^4 , with a conversion rate of 15.12%. Among these, material product, benefiting from relatively well-developed trading markets and mechanisms, achieved 100% ecological value conversion, where their ecological value was fully transformed into actual economic benefits through market mechanisms. However, regulatory services, being intangible in nature, possess high value yet are difficult to convert directly through market transactions. They primarily rely on indirect channels such as ecological compensation and tax policies, resulting in a conversion rate of only 1.74%. Regarding cultural services, low farmer participation and uneven income distribution mean most households rely solely on basic catering and lodging for meager earnings. This lack of incentive to enhance service quality or engage in product development limits cultural service quality and conversion efficiency, resulting in a conversion rate as low as 0.38%.

The value conversion of agroforestry ecological product derived from karst soil and water conservation in the Huajiang study area reached CNY 5516.84×10^4 , with a conversion rate of 13.65%. Similar to Salaxi, material product achieved 100% ecological value conversion through mature market systems. Regulatory services, due to their intangible nature, required indirect value conversion via ecological compensation and tax policies, achieving a conversion rate of 1.24%. In the cultural services sector, issues of farmer participation and revenue distribution remain prominent. Most farmers can only obtain limited income through basic catering and accommodation services, lacking initiative and innovation, which constrains the development of cultural services. The conversion rate stands at 0.89%, indicating that the potential for converting cultural service value remains to be further explored.

The value conversion of agroforestry ecological product derived from karst soil and water conservation in the Hongfenghu study area reached CNY 9479.68×10^4 , with a conversion rate of 19.12%, standing out among the three regions. Regarding material product, well-established trading markets and mechanisms ensured full conversion of their ecological value, achieving 100% conversion. Regulating services, being intangible, rely on indirect conversion methods such as ecological compensation and tax policies, achieving a conversion rate of 1.37%. For cultural services, issues of uneven farmer participation and income distribution mean most households can only obtain limited income through simple catering and lodging services. This lack of motivation to improve service quality and engage in product development limits the quality and conversion efficiency of cultural services, resulting in a conversion rate of 1.21%. Significant room for improvement remains.

4. Discussion

4.1 Ecological Product Value Realization Mechanisms of Agroforestry Derived from Karst Soil and Water Conservation

4.1.1 Business Development Mechanism

Through the systematic implementation of soil and water conservation projects, enhance land productivity and ecosystem stability to form composite ecological assets that consolidate soil, conserve water, increase carbon sequestration, and enhance landscape value. By developing distinctive economic orchards and agritourism integration through operational development, transform ecological assets into market-competitive products and services. Realizing the value of ecological product transforms restored ecological resources and product systems into economic benefits. This process involves establishing a scientific classification system for ecological

products, quantifying their service values in water conservation, soil retention, carbon sequestration, and carbon sink enhancement. This makes implicit ecological benefits explicit, forming a connected mechanism of “ecological restoration-resource accumulation-value realization.” This provides a sustainable material foundation and economic guarantee for realizing the value agroforestry ecological product derived from soil and water conservation.

4.1.2 Multi-faceted Collaborative Safeguard Mechanism

Regarding value conversion safeguards, different demonstration zones have introduced distinctive institutional innovations. This mechanism encompasses three dimensions: policy guidance, market development, and technical support. Salaxi mobilized farmers' enthusiasm for conservation through establishing an ecological compensation mechanism for soil and water conservation; Huajiang introduced a corporate cooperative development model, forming a “research institute + enterprise + farmer” benefit-sharing mechanism; Hongfenghu leveraged property rights reforms to explore mortgage financing using ecological resource management rights. Effective value conversion requires synergistic advancement through policy guidance, market operations, and community participation (Li et al., 2021). Only by constructing a comprehensive safeguarding system encompassing ecological certification, financial support, and technical services can the developmental bottlenecks of difficult measurement and transaction of karst ecological product be overcome.

4.2 Ecological Product Value Realization Paths of Agroforestry Derived From Karst Soil and Water Conservation

4.2.1 Government-Led Institutional Safeguards and Foundational Development Paths

The government should play a leading role in establishing a robust policy and institutional foundation for realizing the value of agroforestry ecological product in karst soil and water conservation. The primary task is to plan and implement soil and water conservation projects tailored to local conditions, improving site conditions through engineering measures. Developing composite industries such as under-forest farming enhances system output diversity and stimulates participation from farmers and enterprises (Bettles et al., 2021), laying the groundwork for specialty agroforestry production. Building upon this foundation, the government must focus on establishing robust mechanisms of the ecological product value realization. This involves clarifying property rights and transaction rules for ecological products, providing clear institutional safeguards for market transactions. Simultaneously, policy tools such as fiscal subsidies and tax incentives (Sun et al., 2025) should be employed to directly reduce development and operational costs for enterprises and cooperatives, thereby stimulating market participation. Furthermore, strengthening infrastructure like roads and water conservancy facilities will enhance the comprehensive production capacity of regional ecological product. Initial market cultivation and promotion can be achieved through hosting regional agricultural product exhibitions and establishing local public brands, creating favorable conditions for deeper market involvement.

Soil and water conservation projects have significantly enhanced the composite management benefits of agroforestry (Fu et al., 2025). Among these, Salaxi adopted the “economic orchard + soil and water conservation” model, achieving dual ecological and economic benefits through planting specialty fruit trees; Huajiang leveraged remediation projects to develop forest-medicinal compound cultivation, boosting comprehensive land productivity; while Hongfenghu integrated ecological tourism development to promote agritourism synergy and value enhancement. This demonstrates that the operation and development of karst ecological product must be grounded in regional resource endowments, exploring sustainable paths that integrate “management-production-benefits.”

4.2.2 Market-Driven Value Enhancement and Channel Expansion Paths

The market serves as the core driving force for realizing the value appreciation and efficient conversion of ecological product (Xie et al., 2025). Currently, karst soil and water conservation agroforestry ecological product face practical challenges such as insufficient market recognition, limited demand, and inadequate trading channels (Duan et al., 2024), which constrain their value conversion efficiency. Therefore, market channels should be expanded by diversifying distribution methods, such as organizing specialty agricultural product exhibitions and leveraging e-commerce marketing. At the market level, the key path lies in fully leveraging the outcomes established by the government in the early stages to develop diversified business models like under-forest economy and forest-medicine integration, thereby enhancing system output capacity and enriching value sources. Establishing a “company + cooperative + farmer” joint operation system will promote standardized production and scaled management, consolidating fragmented ecological resources into competitive, market-ready products. Furthermore, cultivating consumer recognition of the value in agroforestry-based ecological product is essential. This can be achieved through cultural empowerment and green finance (Alharbi et al., 2023), shaping a differentiated product image to activate market potential from the demand side.

Improving policy support is essential for enhancing value conversion efficiency (Wang et al., 2023). Governments should implement policy measures such as fiscal subsidies and tax incentives to support the development, production, and marketing of agroforestry ecological product in karst soil and water conservation. This approach reduces enterprises' production costs and operational risks. Concurrently, strengthening infrastructure development improves production conditions, thereby enhancing ecological product output capacity. Establish and improve the mechanism of ecological product value realization, clarify the property ownership and trading rules of ecological product, and create a good policy environment for the value transformation of ecological product.

5. Conclusion

A classification system for karst soil and water conservation ecological product was established, revealing that material product supply capacity follows the order: karst plateau basins > mountains > gorges. Regulation services primarily involve water conservation and climate regulation, while cultural services follow the sequence: basins > gorges > mountains. This resolved the critical scientific issue of insufficient physical quantity data in the valuation of agroforestry ecological product.

This study elucidates the spatial patterns and value quantities of agroforestry ecological product for soil and water conservation across different karst landform types. Findings indicate that material product value follows the sequence: karst plateau basins > mountains > gorges; regulatory services show mountains > basins > gorges; and cultural services exhibit basins > gorges > mountains. The overall spatial value pattern for mountainous areas shows high-value zones in the northwest and low-value zones in the southwest; for canyons, high-value zones are in the south and low-value zones in the east; for basins, high-value zones are in the northwest and low-value zones in the center. This addresses key scientific challenges in accurately quantifying the spatially heterogeneous value of ecological product and transforming them into tradable and distributable value realization mechanisms.

This study reveals the ecological product value conversion rates of agroforestry derived from soil and water conservation across different karst landform types. Overall value conversion rates follow the sequence: karst plateau basins > mountainous > gorges. Within the three study areas, the conversion rate of total ecological product value is dominated by material product, yet the market potential embodied in regulating services and cultural services remains untapped.

In the future, it will be necessary to deepen the integration of soil and water conservation projects with the ecological product value conversion by improving ecological compensation mechanisms, innovating market-based transaction models, and strengthening collaboration among diverse stakeholders. This approach will promote the coordinated development of ecology and economy in karst regions.

References

- Alharbi, S. S., Al Mamun, M., Boubaker, S., & Rizvi, S. K. A. (2023). Green finance and renewable energy: A worldwide evidence. *Energy Economics*, *118*, Article 106499. <https://doi.org/10.1016/j.eneco.2022.106499>
- Bettles, J., Battisti, D. S., Cook-Patton, S. C., Kroeger, T., Spector, J. T., Wolff, N. H., & Masuda, Y. J. (2021). Agroforestry and non-state actors: A review. *Forest Policy and Economics*, *130*, Article 102538. <https://doi.org/10.1016/j.forpol.2021.102538>
- Chang, J., Li, Q., Zhai, L., Liao, C., Qi, X., Zhang, Y., & Wang, K. (2024). Comprehensive assessment of rocky desertification treatment in Southwest China karst. *Land Degradation & Development*, *35*(5), 3461–3476. <https://doi.org/10.1002/ldr.5146>
- Du, Y., Wang, J., & Li, J. (2024). How can ecological product value realization sustainably enhance the well-being of farmers? A case study of Xingyuan Village in China. *Forests*, *15*(8), Article 1457. <https://doi.org/10.3390/f15081457>
- Duan, Y., Liang, L., Gao, P., Jiang, M., & Kang, D. (2024). Research on the realization path of ecological product value based on the perspective of supply and demand integration. *Journal of Natural Resources*, *39*(12), 2946–2961. <https://doi.org/10.31497/zrzyxb.20241213>
- Feng, J., Chen, F., Tang, F., Wang, F., Liang, K., He, L., & Huang, C. (2022). The trade-offs and synergies of ecosystem services in Jiulianshan National Nature Reserve in Jiangxi Province, China. *Forests*, *13*(3), Article 416. <https://doi.org/10.3390/f13030416>
- Fu, Y., Zhang, M., Li, Z., Xiong, K., Fang, Q., Hu, W., You, L., & Luo, Z. (2025). Agroforestry in the soil and water conservation of karst can improve rural eco-revitalization: Evidence from the core area of the South China karst. *Forests*, *16*(6), Article 955. <https://doi.org/10.3390/f16060955>
- Jiang, S., Xiong, K., & Xiao, J. (2022). Structure and stability of agroforestry ecosystems: Insights into the

- improvement of service supply capacity of agroforestry ecosystems under the karst rocky desertification control. *Forests*, 13(6), Article 878. <https://doi.org/10.3390/f13060878>
- Li, F., Yan, H., Lv, G., Li, Z., & Zhu, X. (2021). Research on the premise of ecological product value realization mechanism: A case study of Gaochun District, Nanjing. *Environmental Protection*, 49(12), 51–58. <https://doi.org/10.14026/j.cnki.0253-9705.2021.12.006>
- Li, W., Chen, J., & Nie, P. (2024). Pricing ecological products under duopoly. *Polish Journal of Environmental Studies*, 33(4), Article 4101. <https://doi.org/10.15244/pjoes/182904>
- Martin, D. A., Osen, K., Grass, I., Hoelscher, D., Tschardtke, T., Wurz, A., & Kreft, H. (2020). Land-use history determines ecosystem services and conservation value in tropical agroforestry. *Conservation Letters*, 13(5), Article e12740. <https://doi.org/10.1111/conl.12740>
- Ministry of Water Resources of the People's Republic of China. (2024). *Opinions on establishing and improving the mechanism for realizing the value of ecological products for soil and water conservation in ecologically clean small watersheds*.
- Moreno, G., Aviron, S., Berg, S., Crous-Duran, J., Franca, A., de Jalon, S. G., Hartel, T., Mirck, J., Pantera, A., Palma, J. H. N., Paulo, J. A., Re, G. A., Sanna, F., Thenail, C., Varga, A., Viaud, V., & Burgess, P. J. (2018). Agroforestry systems of high nature and cultural value in Europe: Provision of commercial goods and other ecosystem services. *Agroforestry Systems*, 92(3), 877–891. <https://doi.org/10.1007/s10457-017-0126-1>
- Panwar, P., Pal, S., Bhatt, V. K., Prasad, R., Tiwari, A. K., & Patra, S. (2018). Toposequential agroforestry based land use system for soil and water conservation in sloping lands. *Range Management and Agroforestry*, 39(1), 93–96.
- Sun, Y., Zhao, J., Qiao, Q., Lin, Z., & Zhang, W. (2025). Unlocking the value of nature: A deep dive into China's ecological product realization and its driving mechanisms. *Forests*, 16(1), Article 37. <https://doi.org/10.3390/f16010037>
- Temesgen, H., Wu, W., Shi, X., Yirsaw, E., Bekele, B., & Kindu, M. (2018). Variation in ecosystem service values in an agroforestry dominated landscape in Ethiopia: Implications for land use and conservation policy. *Sustainability*, 10(4), Article 1126. <https://doi.org/10.3390/su10041126>
- Wang, H., Luo, J., Tian, L., Liu, J., Gan, Y., & Han, T. (2023). “Realization-feedback” path of ecological product value in rural areas from the perspective of capital recycling theory: A case study of Zhengjiabang Village in Changyang County, China. *Sustainability*, 15(18), Article 13905. <https://doi.org/10.3390/su151813905>
- Wang, N., Xu, C., & Kong, F. (2022). Value realization and optimization path of forest ecological products—Case study from Zhejiang Province, China. *International Journal of Environmental Research and Public Health*, 19(12), Article 7538. <https://doi.org/10.3390/ijerph19127538>
- Wu, L., Wu, Z., & Liu, W. (2024). Exploring the realization level and the obstacles affecting different types of ecological product value—A typical case from Zhejiang, China. *Sustainability*, 16(22), Article 9856. <https://doi.org/10.3390/su16229856>
- Xiao, J., & Xiong, K. (2022). A review of agroforestry ecosystem services and its enlightenment on the ecosystem improvement of rocky desertification control. *Science of the Total Environment*, 852, Article 158538. <https://doi.org/10.1016/j.scitotenv.2022.158538>
- Xie, G., Zhang, Z., & Wang, B. (2025). Spatiotemporal heterogeneity in the efficiency of agricultural eco-product value conversion: An empirical study from China. *Sustainability*, 17(6), Article 2643. <https://doi.org/10.3390/su17062643>
- Xiong, K., Li, P., Zhou, Z., An, Y., Lv, T., & Lan, A. (2002). *A typical study on RS-GIS of karst desertification with a special reference to Guizhou Province*. Geology Press.
- Xiong, K., Xiao, J., & Zhu, D. (2022). Research progress of agroforestry ecosystem services and its implications for industrial revitalization in karst regions. *Acta Ecologica Sinica*, 42(11), 1–12. <https://doi.org/10.5846/stxb202101080090>
- Xu, D., Wang, Y., Wu, L., & Zhang, W. (2023). Evaluation of the degree of the value realization of ecological products of the forest ecological bank in Shunchang County. *Forests*, 14(11), Article 2269. <https://doi.org/10.3390/f14112269>
- Yang, Y., Xiong, K., Huang, H., Xiao, J., Yang, B., & Zhang, Y. (2023). A commented review of eco-product value realization and ecological industry and its enlightenment for agroforestry ecosystem services in the karst

- ecological restoration. *Forests*, 14(3), Article 448. <https://doi.org/10.3390/f14030448>
- Yuan, L., Yue, K., Gu, Z., Chen, H., & Chi, Y. (2021). Analysis of rainfall factors and soil erosion in different soil and water conservation measures in the karst plateau-mountain. *Polish Journal of Environmental Studies*, 30(6), 5343–5349. <https://doi.org/10.15244/pjoes/135824>
- Zhang, W., & Xu, D. (2024). Benefits evaluation of ecological restoration projects based on value realization of ecological products. *Journal of Environmental Management*, 352, Article 120139. <https://doi.org/10.1016/j.jenvman.2024.120139>
- Zhang, Y., Fu, Y., Xiong, K., Yan, J., Zhang, Z., Ning, Y., & Zheng, P. (2025). Mechanisms and pathways of realizing the value of karst ecological products in Hebei Province. *Carsologica Sinica*, 44(4), 572–586. <https://doi.org/10.11932/karst2025y010>
- Zhang, Z., Xiong, K., Chang, H., Zhang, W., & Huang, D. (2022). A review of eco-product value realization and ecological civilization and its enlightenment to karst protected areas. *International Journal of Environmental Research and Public Health*, 19(10), Article 5892. <https://doi.org/10.3390/ijerph19105892>
- Zhang, Z., Xiong, K., Huang, D., Zhang, W., & Chang, H. (2023). Spatial zoning of the value realization models for ecological products in Shibing Karst Natural World Heritage Site. *Forests*, 14(7), Article 1449. <https://doi.org/10.3390/f14071449>
- Zhu, Y., Zhao, C. X., & Huang, Y. J. (2024). Value realization ability of sustainable ecological products in the Yangtze River Economic Belt, China. *Applied Ecology and Environmental Research*, 22(1), 309–326. https://doi.org/10.15666/aecer/2201_309326

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