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Study on Forest Eco-Products Value Changes for Karst Desertification Control in South and North China

Youze Ning[1]

[2] Guizhou Qianfengyuan Engineering Management Consulting Company, Guiyang, China

Correspondence: Youze Ning, Guizhou Qianfengyuan Engineering Management Consulting Company, Guiyang 550001, China. E-mail: ningyz1108@163.com

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Abstract

The forests in the dolomite karst region provide people with a variety of ecological products, and the realization of its value is related to the protection of forests and the well-being of local residents. In this paper, the spatial and temporal pattern and change rule of the value of forest ecological products from 2000 to 2020 are investigated through three forest study areas in China's southern and northern rocky desertification control. The equivalent factor method is used to calculate the value of forest ecological products, and Arc GIS and other tools are used for visualization and analysis. It was found that the forest land area in the three study areas was mainly forest-dominated, and the value of ecological products showed a fast and then slow decline rate in the southern region. The two study areas in the north, on the other hand, showed a gradual increase over the years in the study area of Yixian, while Zunhua showed an increasing and then decreasing trend of change. Meanwhile, different ecological product value realization path models are proposed according to the value changes in the study areas. The results of the study provide theoretical and practical support for the sustainable development of forests in karst desertification control areas, and have important academic and application values.

Keywords: south and north, karst desertification control, forests, ecological product value, equivalent factor method

1. Introduction

The global karst area is about $2.2 \times 10^7 km^2$, accounting for 15% of the total land area [1-3], with characteristics such as fragility. And China is one of the three regions in the world with the largest area of karst outcrop and the strongest development [4, 5]. Meanwhile, rock desertification, desertification and soil erosion are the three most serious ecological problems in China [6], which seriously constrain the sustainable development of regional economy[7]. In the early days, people paid more attention to its focus on the amount of function and value of forests in soil and water conservation, wind and sand prevention, and water conservation. For this reason, the state has successively implemented the rocky desertification control project and the "Three North" protection forest project. After years of management, people are now pursuing high-quality development of forest ecological environment and economy, and taking a development path that emphasizes both ecological and economic benefits. The 19th CPC National Congress also explicitly called for "providing more high-quality ecological products to meet the people's growing need for a beautiful ecological environment" to promote the protection of the ecological environment.

Eco-products are similar to ecosystem services in that they refer to a variety of tangible and intangible products and services that can be provided to human beings. Therefore, to a certain extent, eco-products include ecosystem services, and this paper will describe them from this perspective.

Forests are the main contributor to EPV (ecological product value), and their contribution is gradually increasing [8]. Therefore, for forest research, it is important to establish a repeatable, comparable and applicable ecological product value accounting system [9]. Costanza et al. [10] were the first to estimate the functional volume of global ecosystem services and accounted for the value volume with the engineered alternative value approach. On this basis, the Natural Capital project initiated by Daily [11] also specially developed the free-to-use valuation software In VEST. Xie [12] combined this method with China's national conditions and used Chinese indigenous values for some parameters in the original model to obtain a table of coefficients of the value volume per unit area on various ecosystem types in China. Many scholars have completed the assessment of ecosystem services as well as the valuation of ecosystem services in China using this method and software[13-16]. Some scholars have also

constructed the virtual monetary unit of "eco-dollar" on the basis of energy value equivalent, which is used to characterize the monetary value of ecosystem services. On this basis, Kenter [17] proposed a cultural value assessment method based on shared diversification. Both the demand and supply of ecological goods are quantified in consistent energy-value units to obtain a comprehensive TES indicator [18]. Therefore, studying the value of ecological products in forested areas of karst rocky desertification control has become an issue that needs to be continuously explored and considered in the current development process.

Similar studies have been conducted in karst desertification control areas. In this process, Crouzeilles et al. [19]found that the success rate of natural forest sealing and restoration is higher than that of artificial forestation. It is able to provide ecological products for human beings in a stable manner. Meanwhile the continuous increase in vegetation cover significantly improves the capacity of ecosystem regulation services[20]. For example, this can be used to control soil erosion[21]. At the small watershed scale, Li Yue [22] used the In VEST model to analyze the land use status of the Nanming River Basin from 2000 to 2020, and found that the water nutrient and carbon storage of forest land in the basin accounted for more than half of the total, which shows the importance of the ecological products of forest land in the whole ecosystem. On a larger scale, Chen et al. [23]estimated ecosystem services in karst mountainous areas of Guizhou Province from 2000-2015 using a geographical detectors and found that the net primary productivity, soil retention, and water production of vegetation all showed an increasing trend. Karst rocky desertification areas are characterized by fragile ecosystems and complex human-land systems, and contradictions between economic development and ecological environment[24]. Therefore, the exploration of the value of forest ecological products in rocky desertification control areas is carried out. It can not only better promote the process of rocky desertification control, but also promote the sustainable development of local economy.

Due to geographic and climatic differences, the value of forest ecological products in the southern and northern regions of China's dolomite karsts varies greatly. However, the current research in this area is relatively small and cannot give researchers a clearer understanding. The purpose of this paper is to illustrate the changes in forest provisioning after desertification control in China's southern and northern karsts by selecting three more typical regions, to promote forest protection and restoration through eco-products value accounting, and to quantify the contribution of forest ecosystems to human well-being. It provides a little reference for researchers to follow up the study and provides suggestions for the future development of forest ecosystems. Meanwhile, this study can have a positive contribution to the sustainable management of global karst forests.

2. Materials and Methods

2.1 Study Area

In this paper, three dolomite karst regions in the north and south of China are selected as research objects, aiming to understand the trend of value changes of forest ecological products due to geographic and climatic differences. Geographically, due to the barrier of the Qinling Mountains, there is a large difference in precipitation between the two areas, which results in a large difference in vegetation types, leading to different development patterns. At the same time and due to the research object are in the more fragile ecological areas, making the two studies comparable. Therefore, in this paper, Shibing County in Guizhou Province was selected in the southern region, while Yi County in the Taihang Mountainous Region and Zunhua City in the Yanshan Mountainous Region were selected as the study area in the north.

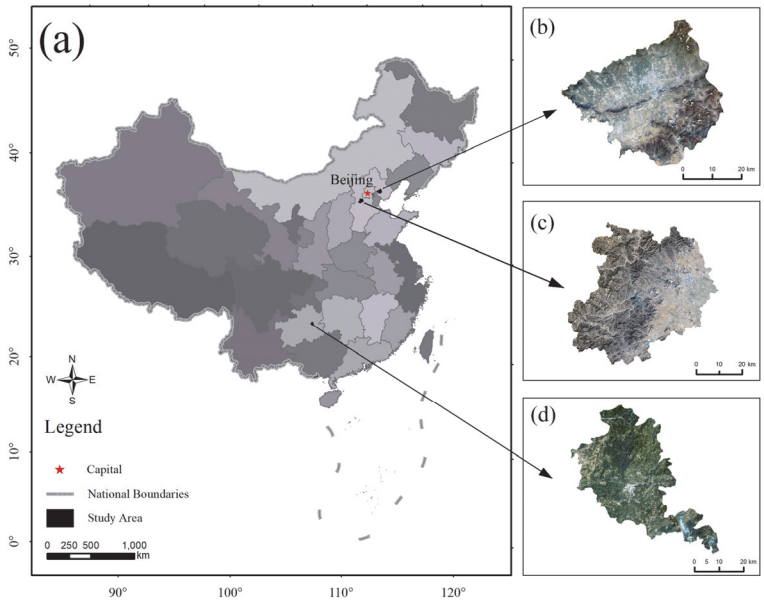

Figure 1. Study area

2.2 Method

2.2.1 Value of a Standardized Unit of Ecological Product Value Equivalent Factor

In order to better control the variables for analysis, the average value of rice, wheat and maize in the country in 2010 was used to calculate the unit equivalent price for the three study areas. In this paper, we refer to the treatment of Xie Gaodi [25] et al., and take the net profit of food production per unit area of farmland ecosystem as the amount of ecological product value of 1 standard equivalent factor. The specific formula is as follows:

$$Va = Ar \times Pr + Aw \times Pw + Ac \times Pc \quad (1)$$

Va denotes the amount of ecosystem service value of 1 standard equivalent factor (dollar/hm^2); Ar, Aw, and Ac denote the percentage (%) of the sown area of rice, wheat, and maize, respectively, to the total sown area of the three crops in 2010; Pr, Pw, and Pc denote the average net profit per unit area of rice, wheat, and maize, respectively, across the country in 2010 (dollar / hm^2), respectively. Based on the China Statistical Yearbook 2011, the National Compendium of Cost and Benefit Information on Agricultural Products 2011, and equation (1), the unit value is 479. 11dollar/hm^2.

2.2.2 Coefficient of Value of Ecological Products

The value coefficients of forest ecological products were revised with reference to the "Equivalent value of ecological services per unit area of terrestrial ecosystems in China" proposed by Xie Gao Di et al., and the formulas for calculating the value coefficients are as follows:

$$VE_{ij} = C_{ij}V_a \quad i = 1,2,\dots n \quad (2)$$

Where VEij represents the ecological product value coefficient (dollar/hm^2) of the jth ecological service function contained in i ecosystem; Cij represents the economic value of the jth service function contained in i ecosystem compared to the economic value of 1 unit of farmland in the whole country; i represents the ecosystem types existing in the study area; j represents the service function corresponding to each ecosystem; and Va represents the economic value of the crops planted in the 1 unit of farmland in the study area (dollar/hm^2), and the results of the modification are shown in Table 1.

Table 1. Coefficients of value of ecological products for different land use types (dollar)

Classify	Supply Services			Regulation Services				Supporting Services			Cultural Services
	Food Production	Raw Material Production	Water Supply	Gas Regulation	Climate Regulation	Purifying Environment	Hydrological Regulation	Soil Conservation	Maintain Nutrient Cycling	Biodiversity	Aesthetic Landscape
Forest	130.9567	301.8389	156.5093	993.3548	2970.482	863.995	1850.961	1208.954	92.62793	1100.356	482.3041
Shrub	91.03089	206.0178	105.4042	675.5451	2026.636	613.2608	1605.019	824.0692	62.2843	752.2027	330.5859

2.2.3 Accounting for the Value of Ecological Products Per Unit Area

Combined with the value equivalent table mentioned above, the value of forest ecological products in Shibing, Yixian and Zunhua was calculated separately with the following calculation model:

$$\mathrm{EPV} = \sum A_k E_k \quad (3)$$

Where EPV denotes the total ecological product value of the study area (dollar/a); Ak denotes the area (hm^2) of the k land classes in the study area; and Ek denotes the ecological product value corresponding to 1 unit area of the land classes (dollar/(hm^2*a))

The current use of this method focuses more on national forest parks, forest natural scenic spots and other areas with better habitat quality. It shows that the accounting of the value of forest ecological products can reflect the supporting role of ecosystems for economic and social development, and provide a basis for establishing a mechanism for assessing the benefits and effectiveness of ecosystem protection, and then constructing and perfecting the existing accounting system for the value of forest ecological products.

2.3 Data Source

The land cover data of the three localities used in this study came from the year-by-year surface cover dataset of China's sub-provinces deciphered by Mr. Yang Jie's team from Wuhan University, and the land use data of 2000, 2010 and 2020 were selected with an accuracy of 30*30 m. The second-level classification was carried out in accordance with China's Land Use/Land Cover Data Classification System, and two types of land use, namely, forests and shrubs, were obtained. And it was transformed into 100m*100m and 1km*km scales, which is convenient for calculating and analyzing the value amount of ecological products.

3. Results

3.1 Land Use Change in the Study Area

As can be seen from Table 2 and Figure 2, the forest land area in all three study areas decreased to a certain extent between 2000 and 2020. The woodland area in Shibing study area was 1. $61*10^5 hm^2$ in 2000, and it has been decreasing at a rate of 2.33% per year up to 2010, and the rate of decreasing woodland was controlled in 2020. Mainly, the area of forest and shrub is decreasing. The reason may be the success of the World Natural Heritage nomination of Shi Bing in 2014, which promotes the further development of forestry conservation. Both study areas of Yixian and Zunhua in the northern region showed a trend of increasing and then decreasing forest land area. Specifically, the forests and shrublands in Yixian show a steady upward trend. In Zunhua, the forested area shows an increasing and then decreasing trend.

Table 2. Area of land use distribution in the study area

Study area	Year	Cropland	Forest	Shrub	Grassland	Water	Sonw/Ice	Barren	Impervious	Wetland
Shibing	2000	38537.91	153563.94	7534.53	276.21	526.95	0	0	295.02	0
	2010	34844.31	118596.69	4919.58	200.34	446.22	0	0	383.94	0
	2020	41500.98	111582.18	3320.1	302.67	445.86	0	0	601.92	0

	2000	138963.3	169675.65	4257	87389.82	1512.36	0	1.44	21025.17	0
Yixian	2010	128594.3	185226.12	4300.47	77322.15	1458.27	0	16.47	25906.95	0
	2020	128074.9	189197.73	6419.7	65513.79	2235.6	0	23.58	31359.51	0
	2000	154383.8	61321.41	0.18	13981.14	1044.72	0	18.36	26122.77	0
Zunhua	2010	139311.4	62801.1	0.27	14152.41	1669.14	0	111.69	26122.77	0
	2020	146314.5	48795.84	0.18	12095.73	1878.3	0	119.25	47668.59	0

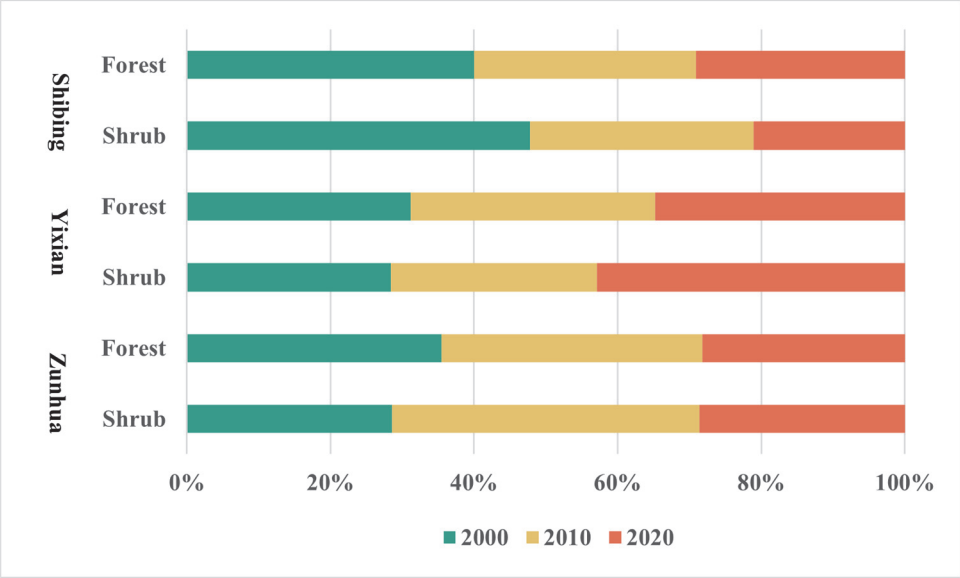

Figure 2. Spatial and temporal variations of different woodlands in the study area

3.2 Spatial And Temporal Changes in the Value of Ecological Products

3.2.1 Changes in The Value of Forest Land

The total value of ecological products in the three study areas was obtained after accounting for forest ecological products (Figure 3). The value of ecological products of forest land in Shibing study area is 1.613 billion USD in 2000, 1.240 billion USD in 2010 and 1.157 billion USD in 2020. The rate of decline of its value volume showed a trend of first fast and then slow. The values of ecological products of forest land in Yixian study area were: US$1.754 billion in 2000, US$1.911 billion in 2010, and US$1.968 billion in 2020, respectively. The value of ecological products of forest land in Zunhua study area was: US$623 million in 2000, US$638 million in 2010, and US$495 million in 2020, respectively. In the three study areas, the proportion of the value of regulating service products is the largest, reaching 65%. Based on this, Ouyang et al. [26] estimated the amount of regulating service value of ecosystems and found that the value of all indicators of forest ecological products was higher than other land use types. It can be seen that it occupies an important position among the components of forest ecological products.

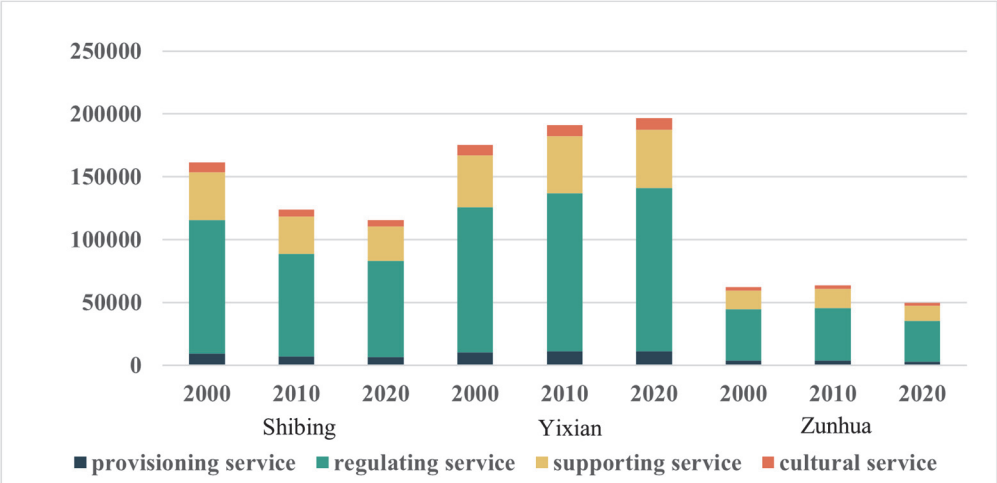

Figure 3. Value of ecological products of forest land in the study area

3.2.2 Spatial Analysis of the Value of Ecological Products From Forest Land

The 1km×1km standard grid of ArcGIS was used as the analysis unit, and the accounting results were averaged and adjusted on the basis of the grading of the natural discontinuity point method. The ecological product value (EPV) was divided into five grades according to the amount of ecological product value (EPV), which were low-value zone (0-211,200 USD), lower-value zone (211,300 USD-422,500 USD), medium-value zone (422,600 USD-63,700 USD), higher-value zone (633,800 USD-8450,000 USD), and high-value zone (845,100 USD-10,562,000 USD) (Figure 4). The results show that there are differences in the spatial distribution of EPV grades in different years. Although the total amount of forest EPV in Shibing is decreasing from 2000 to 2020, the value is increasing from the north and the center. The main reason is that the vegetation in this region has not been damaged and has been better protected after the inclusion of the World Heritage Site in 2014. The trend of forest EPV changes in Zunhua's regions is similar to that of the total value volume, and its high value volume is mainly concentrated in the north and a small part of the south. The EPV in Yixian is mainly due to the fact that the northern and southern areas are mostly state-owned forest farms, which are properly managed and have contributed to the conversion of some low-value forest land to high value.

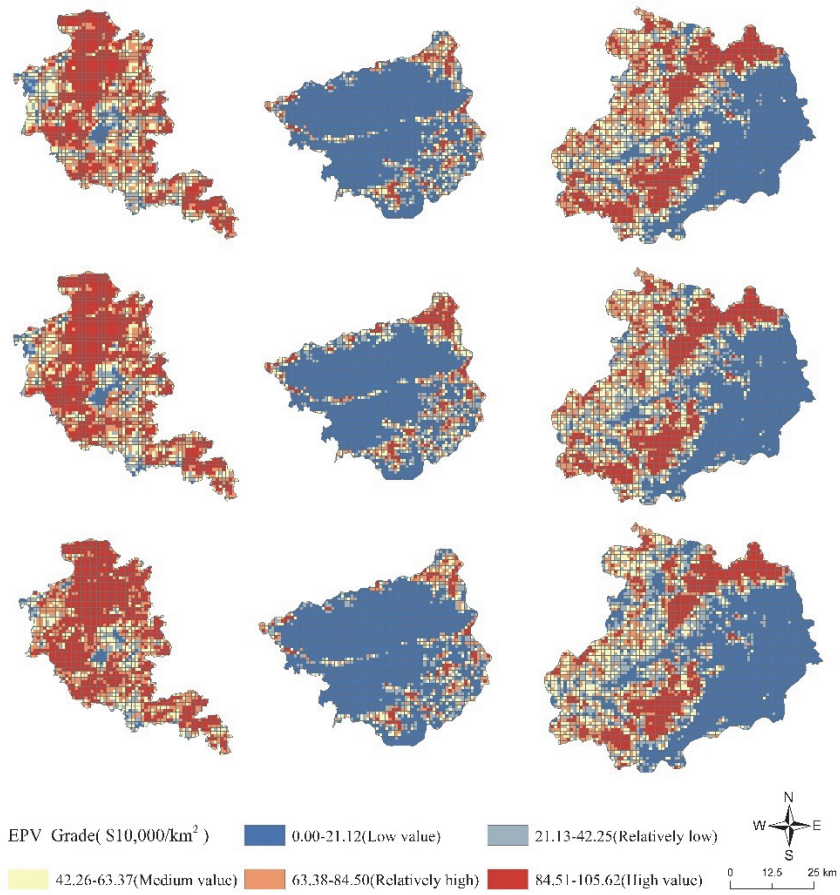

Figure 4. Spatial and temporal changes in forest EPV in the study area, 2000-2020

3.2.3 Comparison of Output Per Unit Area

As shown in Figure 5, the amount of forest ecological products unit area value in the study area has been increasing at a slight rate from 2000-2020. Among them, the value of forest ecological products per unit area in Yixian County has increased the fastest. It has been increasing upward at a rate of 0.2% per year during the past 20 years. The reason is that Yixian County has seven state-owned forest farms, as well as distinctive national forest parks with good habitats, such as Wolf Tooth Mountain.

In terms of the value of forest ecological products per unit area, the value of forest production in the Shi Bing study area is much higher than that of Yi Xian and Zunhua. Due to the influence of geographic differences, Shibing is located in the subtropical monsoon zone, where annual precipitation reaches about 1200 mm. The two northern study areas are located in the temperate monsoon zone, and the annual precipitation is only about 600-700mm, which is about half of that in the southern region. This is also the fundamental reason for such a big difference in the value of forest ecological products between the north and south of China.

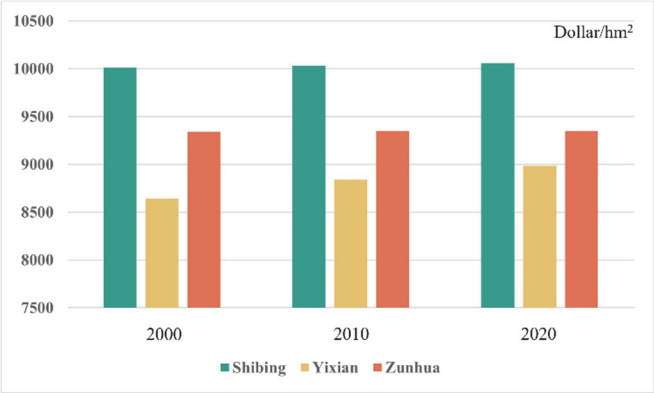

Figure 5. Value of ecological products per unit area in the study area

4. Discussion

4.1 Factors Affecting Changes in Forest Land Use

From the forest land utilization status from 2000 to 2020, Shiebing in the southern region shows a decreasing trend of first fast and then slow. Mainly, the area of forests and shrubs is decreasing. The main reason may be that after Shibing's successful heritage application, it has attracted the attention of the government and the public. Taking the buffer zone of the heritage site as an example, the forest area showed a continuous growth trend after 2014 [27], which in turn led to the restoration of forests in other areas.

Both study areas of Yixian and Zunhua in the northern region showed a trend of increasing and then decreasing forest area. Specifically, the forest and shrubland in Yixian showed a steady increase. In Zunhua, the forest area showed an increasing and then decreasing trend, and the shrubland area was small and negligible. The main reason for this may be that the construction of the Three North Protective Forests in the early period has contributed to the increase of forested land area, and then due to the lack of care and the increase of construction land, the forested land area has decreased. Secondly, Yixian and Zunhua have different development focuses due to historical and geographic conditions, resulting in a great difference in their forested areas.

4.2 Spatial And Temporal Changes Affecting The Value of Ecological Products

The forest value of the Shibing study area has been declining, and the rate of decline in the value of its ecological products has been effectively mitigated after the inscription of the World Heritage site, in which the amount of value of the heritage site has been increasing. The two northern study areas, on the other hand, show a trend of growth followed by decline. This may be due to the fact that the northern study area has carried out a lot of construction work of the Three North Protective Forests from 2000 to 2010. At the same time, the concept of ecological products was proposed for the first time in the National Main Functional Areas Plan issued by the State Council in 2010, which promoted the development of forest protection, and this is one of the main reasons why the decline of the total value of forest ecological products has been controlled during the period of 2010-2020. It can be seen that the change trend of the value of forest ecological products is consistent with the change trend of the area, and this process of change is similar to the conclusions of the research on other rocky desertification areas.

4.3 Ecological Product Value Realization Path

Forests contain huge ecosystem service value, but the current ecological product value realization mechanism is still in the stage of preliminary exploration and research. The small amount of value transformation leads to forest ecological products are still government-led, market-supported business situation, the current value of forest ecological products is only realized by the government to forest farmers or enterprises of ecological compensation, compensation standards are low and a single way, is not enough to drive everyone to participate in the enthusiasm. Secondly, the implementation of green finance in the forest is weak, low rate of return and other value realization path is a single dilemma. In this paper, the three research areas of forest ecological products value realization path can be developed from the following aspects.

4.3.1 Shi Bing Study Area

The Shibing study area contains a World Heritage site with a more stable forest vegetation structure and good ecological environment quality. Strengthen the publicity and education work on the forest financial transfer policy,

raise the awareness and attention of the public and relevant industries, form a consensus, and promote the in-depth development of forest protection and ecological construction. At the same time, under the premise of not affecting the protection of the world heritage site, the buffer zone can appropriately develop a certain scale of eco-industry, such as agro-industry to improve the income and life of local people. For the destruction of ecological environment behavior to develop relevant laws and regulations, increase penalties, so as to better protect.

4.3.2 Yixian Study Area

Yixian study area has a number of national forest farms and is also part of a national forest park. A portion of the local ecotourism income can be used as ecological transfer funds for local forest protection to compensate local people for the protection of the ecological environment. At the same time, it is necessary to set up corresponding supervisory departments to ensure that the whole process of using this fund is reasonable and transparent, so as to avoid the phenomenon of misappropriation or waste of special funds. For the active participation in the construction of forest protection of individuals and enterprises and other subjects, can give certain policy support and incentives. This will increase the motivation of the participants, and thus encourage more people and social organizations to join in the protection work.

4.3.3 Zunhua Study Area

The Zunhua study area belongs to the scope of the Three North Protective Forests, and most of the forests in the study area were sown by airplanes in the early days. Although it has been closed for many years, due to the lack of management, its tree woodlands are mostly concentrated in the leeward slopes of some mountain slopes, and the cypresses and oil pines are in a state of sub-health. Therefore, in order to better guarantee the rapid development of the local forest industry, the central government, in conjunction with the local financial and other relevant departments, to set up a special forest transfer funds, and continue to increase investment in the ecological restoration of forests. In the distribution process should also take into account the current status of the study area, to ensure that the funds can be fairly and accurately allocated to the local forest farmers or the corresponding business subjects. At the same time, governments at all levels should also formulate relevant policies and regulations to clarify the objectives, scope, standards and other specific content of the forest financial transfer payments, to ensure that the ecological transfer payments for forests can be effectively implemented in the long term.

4.4 Implications for the Development of Forest Ecological Products in Other Rocky Desertification Control Regions

The current management system of forest ecological products is still not perfect. In order to realize the value of ecological products and the development of ecological industry in mountain forestation in rocky desertification control areas, it is still necessary to analyze from the following aspects.

4.4.1 Improving the Mechanism of Compensation for the Benefits of Forest Ecological Products

Ecological compensation is the most widely used path to realize the value of forest ecological products at home and abroad. Currently, forest ecological compensation exists problems such as small scope of compensation, low standard, single source of funds and serious lack of market-oriented mechanism, etc., and the subsidy standard of public welfare forests in government finance is far lower than the ecological benefits played by public welfare forests. Therefore, in order to improve the compensation standard, enterprises, society and the market should be encouraged to participate. First of all, the central and local governments should increase the transfer payment of financial funds, and the compensation standard of the compensation area can be developed according to local conditions, focusing on compensating the areas with good development of ecological benefits. The second is to carry out inter-regional horizontal ecological compensation mechanism, for cross-regional forest ecological product benefits, in accordance with the "protectors benefit, beneficiaries compensation" guidelines, enterprises or third-party organizations included in the main beneficiaries. Thirdly, the mode of compensation for forest ecological products should be diversified, so that farmers' land in nature reserves and key ecological zones can be adjusted through government redemption, replacement and storage, thereby realizing a win-win situation in which society and farmers can benefit from each other.

4.4.2 Improvement of Ecological Product Tenure Trading

In the closed forest areas of karst desertification management, with "protection and restoration" as the core objective of ensuring the stability of forest ecosystems, the trading mechanism of forest ecological product ownership should be improved to further revitalize ecological assets and promote the high-quality development of ecological industries. Currently, there is a low willingness to operate collective forests, and the property rights reform of forest ecological products should be gradually promoted in accordance with local development needs.

Deal with the relationship between the ownership, contracting and management rights of forest land, and improve its tenure trading system. For forest ecological products with different tenure, social capital can be introduced into the forest ecological field of rocky desertification management by means of differentiated transaction forms, and the property rights such as the right to use the forest land for a certain period of time can be given to it for a short period of time. At the same time, in order to further promote the orderly flow of forest rights in karst areas, it is necessary to accelerate the construction of the risk prevention mechanism for the flow of forest land, to promote the high-quality development of new forest management ecological industries, and to vigorously explore and popularize the "forest ticket", "forest bank" and other modes implemented in other regions. We should vigorously explore and popularize the "forest ticket", "forest bank" and other models implemented in other regions.

4.4.3 Sound Support for the Development of Eco-Industries

In the karst region, China's ecological industry has been developing rapidly, but in general, the level of development of forest ecological industry is still lagging behind, and there are a series of problems such as low value-added products and incomplete industrial chain. From the government level, it is necessary to improve the relevant policy support for the ecological industry, build product brands with regional characteristics of origin, and accelerate the entry of forest ecological products into the international market. Compared with developed countries, China started late in this regard, and localities should first introduce corresponding industrial support policies according to the local actual situation, which can favorably guarantee the smooth development of ecological industry. At the same time, with the help of good local forest ecological resources, to establish and standardize the evaluation standards of forest ecological products with karst region characteristics.

The market side should guide the adjustment of industrial structure from the direction of demand, optimize the development mode of forest industry, and ensure the diversified development of forest ecological industry. First of all, it is necessary to change people's traditional demand concept of forests only for food and timber, and increase the publicity of new concepts such as forest recreation and forestry carbon sinks. For the traditional advantageous industries, they can be consolidated by means of upgrading the processing quality and improving the secondary use of fertilizers. Emerging industries can combine eco-tourism with forest eco-culture, leisure and recreation to create a number of new forest eco-industries with karst characteristics.

5. Conclusions

In this paper, three places with more typical rocky desertification control are selected as the study area by selecting them in the dolomite karst areas in the north and south of China. Equivalent factor method is used to study the spatio-temporal pattern and change rule of their forest ecological product value from 2000 to 2020. Through visualization and analysis with the help of Arc GIS and other tools, the following conclusions were obtained. (1) The forest land area of the three study areas is mainly dominated by forests, among which the forest land area of Shibing in the southern region shows a decreasing trend firstly and then slowly, the forest land area of Yixian County is increasing gradually, and the forest land area of Zunhua is increasing firstly and then decreasing. (2) The value of forest ecological products in the three study areas in 2000, 2010 and 2020 are Shi Bing (US$1.613 billion, US$1.240 billion, US$1.157 billion), Yi County (US$1.754 billion, US$1.911 billion, US$1.968 billion), and Zunhua (US$623 million, US$638 million, US$495 million). It can be seen that the value of ecological products shows a fast and then slow rate of decline in the southern region, while the two study areas in the north are: Yixian gradually increasing in successive years, and Zunhua is increasing and then decreasing in the trend of change. (3) Based on the value changes in the three study areas, the value realization paths of Shi Bing, Yi Xian and Zunhua models are proposed respectively. The conclusions of this paper are intended to provide certain theoretical support for the value realization and development of forest ecological products in other areas of the dolomite karst.

In the forest area of dolomite karst desertification control, the system of accounting methods for the value of ecological products is also only in the beginning stage. The accounting method in this paper also has some limitations due to the use of homogenized values. Therefore, it is necessary to establish a suitable accounting system for forest ecological product value according to the special characteristics of the environment and the principles of data accessibility and practicality of indicators.

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