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Quantifying the Preference of Stakeholders in the Utilization of Forest Resources

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Abstract: The economic contribution of forest resources to the communities surrounding nature reserves cannot be ignored. The method for which to find a forest resource utilization path to balance the contradiction between local farmers' economic development and ecological protection in the development of nature reserves is important. However, little attention has been given to the effect of forest resource users' behavioral preferences on forest resource utilization. This study selected Wolong Nature Reserve as a case study and randomly interviewed different stakeholders with semi-structured questionnaires to investigate the differences in forest resource utilization patterns among stakeholders with different behavioral preferences. According to the results of multi-attribute decision analysis with behavioral preference, stakeholders form different behavioral preferences by judging their own resource endowment. With a change of in the behavioral preference value λ, when the behavioral preference of stakeholders is more pessimistic (λ = 0.1), cautious (λ = 0.3), or neutral (λ = 0.5), they are more inclined to choose the economically dominant forest resource utilization mode; when the behavioral preference of stakeholders is optimistic (λ = 0.7) or even radical (λ = 0.9), they choose the eco-economic or eco-dominant forest resource utilization mode, respectively. This study confirms that stakeholders' behavioral preferences have an important impact on forest resource utilization patterns. Therefore, policy making should focus on improving the economic benefits of forest resources and providing alternative livelihoods, which will change the resource endowment of the stakeholders of nature reserve, guide them to turn to relatively optimistic behavioral preferences, enhance their awareness and motivation of ecological protection, and thereby improve forest conservation outcomes.

Keywords: nature reserve; forest resources utilization; behavioral preference; multi-attribute decision analysis

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1. Introduction

China is a country rich in biodiversity, and is one of the countries facing the greatest threat. The contradiction between protection and development is the protection and utilization of natural resources, and at the core is the coordination of the relationship between them [1]. As of September 2019, China has established 2750 nature reserves, including 474 national nature reserves, with a total area of 1.47 million square kilometers, accounting for approximately 14.86% of the land area. At present, the number of natural protected areas (including national parks, nature reserves, and nature parks) in China is 11,029 [2]. As a public policy, the establishment of nature reserves has played an important role in the protection of China's ecological environment. As nature reserves are areas with the richest biodiversity, while simultaneously being sensitive ecological environments and with underdeveloped economies, the indigenous people in or around nature reserves still extract traditional forest resources, such as logging, picking medicines, and collecting wild vegetables and firewood [3]. With the establishment of nature reserves, restrictions on resource utilization have forced local community residents to reduce their income from relying on natural resources. In order to survive, community residents have increasingly damaged the resources in protected areas. To a certain extent, this has exacerbated the conflict between the development of farmers in reserves and the needs of ecological protection [4–6].

Previous studies on the utilization of forest resources in nature reserves has explored how to coordinate the ecological protection of nature reserves and the development of surrounding areas through questionnaire surveys and quantitative analysis in terms of ecological service value, resource dependence, sustainable livelihoods, and ecological protection [7,8], but there is a lack of forest resource utilization methods from the perspective of farmers themselves in existing studies. However, in the process of national policy formulation, the traditional knowledge and customary practices and demands of local farmers cannot be ignored. Therefore, exploring the choice of future forest resource utilization methods through participatory scenario methods is also a way to provide a reference for policy making.

The “participatory scenario” approach is a way for stakeholders to achieve self-organization and self-actualization [9], which can also be applied through collaboration among stakeholders to better understand the cause of changes in driving factors and to improve future predictions [10]. It also allows participants to exert creativity, develop the various possibilities of the future development situation, and include the views of different stakeholders with different local knowledge backgrounds [11]. Therefore, referring to previous studies on participatory situations, this paper first reviews the historical process of local forest resource utilization [12], and then draws a local resource distribution map to help participants jointly recall past changes and make summarize the driving factors of forest resource utilization. Based on the drivers, the participators simulated four forest resource utilization scenarios. Finally, the multi-attribute decision-making method was adopted to make the selected situation more accurate and to analyze the reasons for its selection.

2. Conceptual Framework: Forest Resources Utilization through a Political Ecology Lens

Political ecology attempts to understand the governance issues associated with environmental change caused by human intervention and the uneven distribution of costs and benefits by analyzing the possible impacts on access to natural resources [13]. Political ecology has been widely deployed in understanding agricultural production [14], ecological development [15,16], water resource allocation [17,18], rural ecotourism [19,20], etc. In the field of forestry, some studies have focused on using political ecology methods to research the forest environmental governance mechanism in order to mitigate the conflict between the destructive use behavior driven by local economic interests and the sustainable development of forest resources [21–23]. However, other studies have focused on forest utilization and forest ecological transformation determined by changeable social environments and fragmented economic and political forces in southern countries [24–26]. The existing literature discusses the role of formal and informal institutions in the utilization and protection of forest resources from the perspective of policy design and implementation and community governance. The behavioral preferences of stakeholders in the utilization of forest resources have not been taken into account in such studies. Therefore, the manner in which stakeholders maximize their own interests on the basis of policies is specifically discussed in this paper.

Political ecology proposes that political structure directly affects environmental results [27]. According to Harding's “Tragedy of the Commons” theory [28], biodiversity in protected areas requires a political system to preserve it [29]. At present, in China's protected areas, the government authorities control the allocation and utilization of resources within the area through a top-down environmental governance system [30]. According to the distribution characteristics of important resources, different regions in China's protected areas are divided into core, buffer, and experimental zones [31]. In contrast to the experimental zone, the resources in the core and buffer zones are completely and strictly regulated, and the right to use the resources in these zones belongs to the authorities. Meanwhile, resources in the experimental zone are managed by the authorities and are partly open to other stakeholders. Such governance structures often ignore the development needs and rights of local people and the role of their traditional knowledge [32–36].

However, the results of environmental governance in protected areas may vary from region to region, reflecting differences in the regulatory capacity or levels of economic development [37,38]. Unequal power relationships can also lead to more intense environmental conflicts [39–41]. In protected areas, the top-down governance system affects the resource utilization patterns of surrounding communities. In regions with strong dependence on forest resources as the source of their livelihood, such an unbalanced governance structure often leads to the intensification of conflict between authorities and local residents [42]. In addition, due to the high cost and difficulty of supervision in some areas, the utilization of unregulated resources in these areas intensifies, bringing greater pressure to the local ecological environment [43].

Therefore, we posit that the situation of forestry resource utilization in reality is affected by political, economic, and ecological factors. Changes in these factors constitute different forestry resource utilization scenarios, which is in accordance with the view of interrelation between politics, economy, and ecology advocated by political ecology. In addition, these scenarios are also the result of the game between stakeholders in the prescribed institutional environment. Political ecology emphasizes that in the process of coordinating ecology and economy, the relationship between different stakeholders should be balanced [44]. Under the bottom-up governance structure, different stakeholders influence actual forestry resource utilization scenarios by changing the status of the influencing factors according to their own endowments and demands. Therefore, it is particularly important to place different stakeholders on an equal footing and quantify and analyze their preferences for forest resource utilization. By quantifying the preferences of different stakeholders for forest resource use, we can provide a more stable and successful path for balancing economic development and ecological conservation. Finally, based on the theory of political ecology, we constructed an analytical framework that can quantify stakeholders' preference for forest resource utilization (see Figure 1). Considering the overall impact factors and equal rights, different stakeholders choose the forest resource utilization scenarios that truly reflect their preferences according to their endowments and demands.

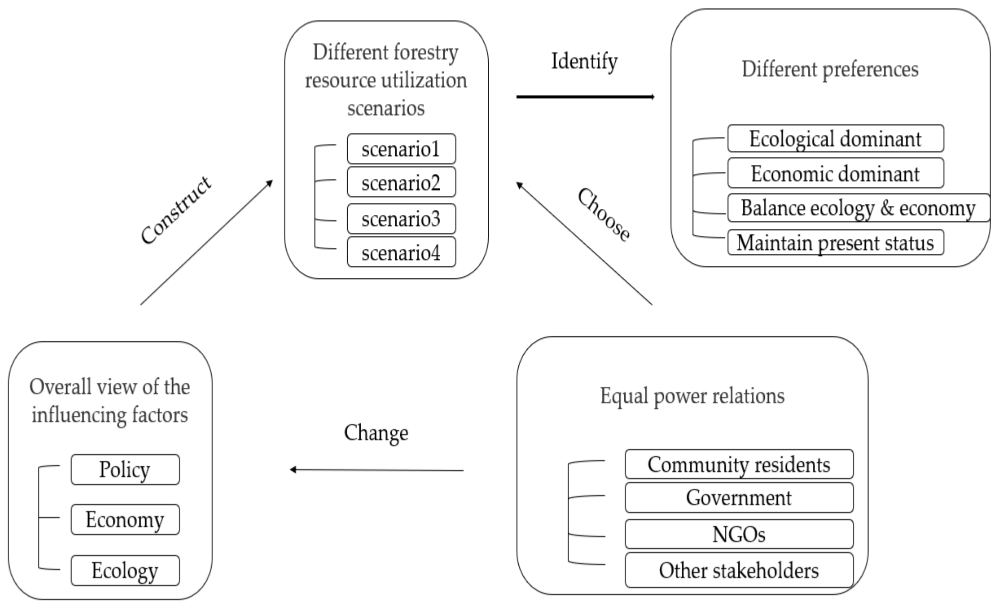


Figure 1. A conceptual framework for the utilization of forest resource.

3. Materials and Methods

3.1. Study Area

According to the Fourth National Survey on Giant Panda released by the National Forestry and Grassland Administration of China, the China Giant Panda Nature Reserve involves 196 townships of 49 counties (county-level cities and districts) of 17 cities in Sichuan, Shaanxi, and Gansu provinces, covering an area of giant panda habitat of nearly 1.39 million hectares. Thus far, 67 giant panda nature reserves have been set up across the country, and 53.8% of giant panda habitats and 66.8% of wild giant panda populations have been effectively protected in these nature reserves, which are mainly distributed in Qinling, Minshan, Qionglai, Daxiangling, XiaoXiangling, and Liangshan Mountains.

Among these reserves, this paper chose Wolong Reserve as an example, because it has advanced concepts in terms of ecological protection and people's livelihood development. Sichuan Wolong National Nature Reserve was established in 1963 with an area of 2000 km^2, located in Wenchuan County, Aba Tibetan and Qiang Autonomous Prefecture, Sichuan Province. It is a comprehensive national-level reserve focusing on protecting rare wild animals and plants such as giant pandas and their alpine forest ecosystems. In 1983, with the approval of the State Council, the Wolong Special Administrative Region of Wenchuan, Sichuan Province, was established within the jurisdiction of the protected area. The special administrative region governs 26 villager groups across six villages in two towns of Wolong and Gengda. There are 148 wild giant pandas in the reserve, making it the nature reserve with the most wild giant pandas in the country. There are also 96 species of rare animals and plants under national key protection, such as *Davidia involucrata* Baill. The location of the reserve is shown in Figure 2.

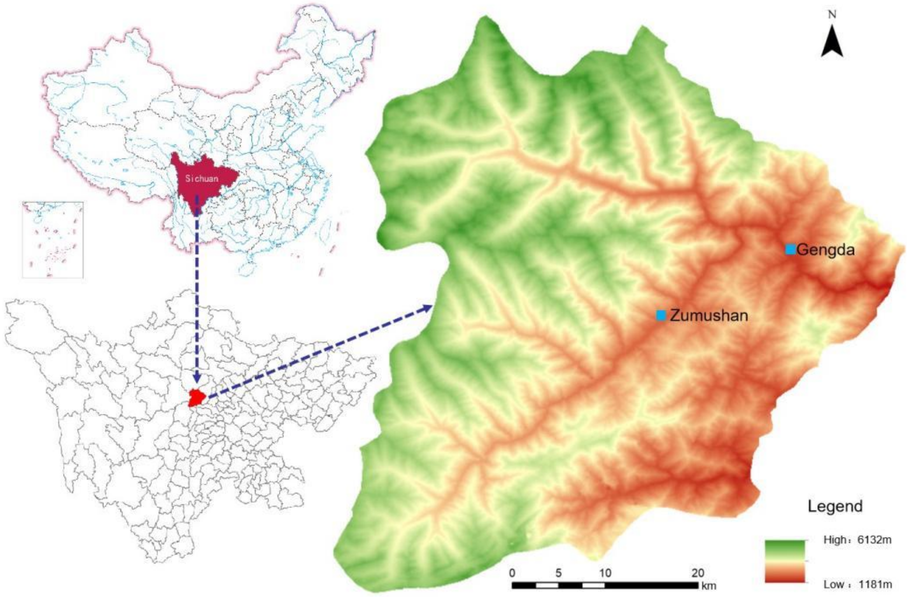


Figure 2. Location of Wolong Reserve and interview villages.

The town of Wolong has jurisdiction over three administrative villages (Zumushan, Wolongguan, and Zhuangjinglou) and nine groups of villagers, belonging to the Tibetan, Qiang, and Han ethnic communities. The town of Gengda also has jurisdiction over three administrative villages (Gengda, Xingfu, and Longtan) and 17 groups of villagers. We selected two villages from each of the two towns for our survey, namely, Zumushan and Gengda, because these two villages belong to different towns, but their development situation is not the same, making the comparison in the study more meaningful. Through field investigation, we summarized the utilization of forest resource in these two villages, as shown in Table 1.

Table 1. Utilization of the forest resources in the villages of Gengda and Zumushan.

Forest Resource Utilization	Gengda	Zumushan
Wild plant collection	The development of local tourism has led to an increase in the collection of wild vegetables. The collection of herbaceous wild plants has little effect on the natural environment, but woody wild plants can cause damage to the natural environment. At present, no large-scale mining has been implemented, and it is mainly collected by local farmers who open farmhouses.	Due to the development of ecotourism, many farmers have chosen to collect wild vegetables and traditional Chinese medicine to sell to tourists.
Fuelwoods collection	The implementation of returning farmland to forests and natural forest protection projects has restricted the collection of fuelwoods.	The implementation of electricity instead of firewood and the prohibition of raising pigs have reduced the use of fuelwood by local farmers.
Traditional timber utilization	Traditionally, farmers have been allowed to harvest timber around their houses, but they have to apply to the government to do so.	The demand for timber is mainly for coffins, and still follows the traditional taboos.
Alternative livelihoods	From traditional forest resource utilization to the development of ecological tourism.	From traditional forest resource utilization to the development of an economic forest industry.

3.2. Data Sources and Processing

The data in this paper were derived from a questionnaire conducted by the research group from July 2018 to May 2019 and form cross-sectional data. This questionnaire was distributed to 17 randomly selected reserves in Sichuan and Shaanxi provinces, which involved different levels of reserves, resulting in 943 returned questionnaires of peasant households, providing the basis for this study. The specific research area and sample distribution are shown in Table 2.

Table 2. Study area and sample distribution.

Province	Reserve	Survey Sample Size
Shaanxi	Huangguan Mountain Reserve	66
	Huangbaiyuan Reserve	30
	Niuwei River Reserve	32
	Taibai Mountain Reserve	70
	Changqing Reserve	58
Sichuan	Qianfo Mountain Reserve	38
	Fengtongzhai Reserve	62
	Tangjia River Reserve	61
	Anzi River Reserve	64
	Heishui River Reserve	61
	Laohegou Reserve	62
	Xiaohegou Reserve	60
	Longxi-Hongkou Reserve	60
	Wolong Reserve	63
	Daxiangling Reserve	62
	Wawu Mountain Reserve	64
	Yele Reserve	30
Total	17	943

Based on the summary of the selected 17 giant panda nature reserves, descriptive statistics of their forest resource utilization were obtained, as shown in Table 3.

Table 3. Descriptive statistics of forest resource utilization in the selected 17 reserves.

Variables	Mean	Standard Error	Min	Max
Households living in protected areas	0.397	0.489	0	1
Households using forest resource	0.817	0.386	0	1
Households using forest resource (5 years ago)	0.867	0.340	0	1
Collection in the reserve	0.455	0.499	0	1
Collection in the reserve (5 years ago)	0.565	0.498	0	1
Per capita economic forest income (yuan)	1000.975	7018.046	0	187,500
Per capita timber forest income (yuan)	849.204	5795.231	−4050	145,000
Per capita fuelwood collection amount (kg)	551.174	893.102	0	14,000
Per capita amount of fuelwood collected (5 years ago) (kg)	717.951	1011.743	0	14,000
Per capita amount of WHF collected (kg)	33.512	245.844	0	4166.667
Per capita amount of WHF collected (5 years ago) (kg)	27.317	300.297	0	8333.334
Per capita energy consumption expenditure (yuan)	1878.961	3746.321	0	75,200
Per capita energy consumption expenditure (5 years ago) (yuan)	1691.733	8255.486	0	166,931.7
Household energy dependence	0.258	0.260	0	1
Household energy dependence (5 years ago)	0.393	0.348	0	1

Note: The current year in this survey refers to 2018 and five years ago to 2013. Forest resource utilization includes timber logging, economic forest logging, fuelwood collection, and wild harvestable flora (WHF) collection. Household per capita energy consumption expenditure includes electricity, liquefied gas, coal, gasoline and diesel, as well as firewood and straw. The amount of firewood and straw collected by farmers for their own use was converted into the local market price. Energy dependence refers to the portion of energy sources provided by forests, i.e., fuelwood expenditure as a proportion of the total household energy expenditure.

Table 3 summarizes the general situation of farmers' forestry resource utilization and the time change trend over the past five years. First, 39.7% of the rural households still live in protected areas. The average income of the farmers' forestry (including economic forest income and timber forest income) is 1855 yuan, which still occupies an important position in the composition of their income. In addition, from the perspective of the time trend, compared to five years ago, farmers' forestry resource utilization behavior has decreased from 0.867 to 0.817; meanwhile, the per capita household energy consumption expenditure has increased with the improvement of living standards in recent years. However, due to the policy of "replacing fuelwood with electricity," villagers are subsidized with electricity (0.1 yuan /KWH), which has greatly reduced their demand for fuelwood, so the amount of fuelwood collected has decreased from 717.951 to 551.174 kg; correspondingly, the household energy dependence has decreased from 0.393 to 0.258. In contrast, it is noteworthy that the per capita amount of WHF collected has increased from 27.317 to 33.512 kg, indicating that the farmers' forest resource utilization patterns have changed during the past five years.

According to the descriptive statistical results in Table 3, it can be found that there are large individual differences in the utilization of forestry resources among farmers, as well as differences in time variations. Although the farmer survey of this project covers many aspects of farmers' production and life in a wide range of areas, it cannot provide more support to explain this phenomenon. Moreover, fixed questionnaires can't make more free conversations and supplementary inquiries with farmers on this issue, and it is difficult to make valuable complex discussions within the limited interview time. Semi-structured interview has a high degree of flexibility, which can adjust the interview questions according to the interview outline or ask in-depth questions according to the interviewees' answers. It is more suitable for qualitative research on the motivation of resource utilization behavior.

In order to further explore the transformation of peasant household forest resource utilization patterns, our research group selected one representative nature reserve from the 17 previously investigated nature reserves and conducted semi-structured interviews in 2019. Wolong Nature Reserve was selected because of its early development time and the relatively mature and stable forestry resource utilization mode formed by stakeholders around the nature reserve in the long-term. Therefore, this reserve serves as a representative sample, making the conclusion more valuable for use and promotion.

Due to the reasons above, this paper conducted in-depth interviews with different stakeholders in two villages of Wolong Nature Reserve. Table 4 shows the basic characteristics of the stakeholders.

Table 4. Seminar stakeholder types and number.

Type of stakeholders	Village	Gender	Age	Ethnicity	Education
Wolong Nature Reserve management personnel	Zumushan	Male	36	Tibetan	University degree
	Gengda	Male	29	Tibetan	University degree
Village cader	Zumushan	Female	45	Tibetan	Lower middle school degree
	Zumushan	Male	40	Qiang	Upper middle school degree
	Gengda	Female	31	Tibetan	College degree
NGO representative	Gengda	Male	43	Tibetan	College degree
	Zumushan	Male	35	Tibetan	University degree
	Gengda	Male	54	Tibetan	College degree
Ecotourism operator	Zumushan	Male	22	Tibetan	University degree
	Gengda	Male	34	Tibetan	Upper middle school degree

Village elder	Zumushan	Male	93	Tibetan	None
	Gengda	Female	79	Tibetan	None
Farmer	Zumushan	Female	33	Tibetan	Upper middle school degree
	Zumushan	Female	45	Tibetan	Lower middle school degree
	Gengda	Male	43	Han	Lower middle school degree
	Gengda	Male	50	Tibetan	Lower middle school degree

3.3. Participatory Scenario of Forest Resources Utilization

The participatory scenario method is often used to imagine what the future will look like and to explain the uncertainty associated with it [45]. This method requires participants with different backgrounds to participate in the process of interactive dialogue, exchanging their views and cultivating their ability to communicate and think together; through this participatory situational seminar, different possible future situations can be simulated and the best situation can be chosen [46].

The participatory scenario analysis framework adopted in the article should ensure that the generated scenario interacts among the factors that promote forest resource utilization decision making, the factors that affect the behavior of farmers, and the factors of social and economic development, and should also ensure that the expectations of future development results are consistent. At the core of situation construction is "exploring the potential future under various conditions" [47], which starts from a set of assumptions about the initial state of the researched object and its environment, and builds a situation based on a chain of reasoning rooted in logic, empirical rules, models, etc. The final situation is composed of state, specific operation steps, and results, and the state of the situation should be assumed to be within a fixed time range. The implementation steps are shown in Figure 3.

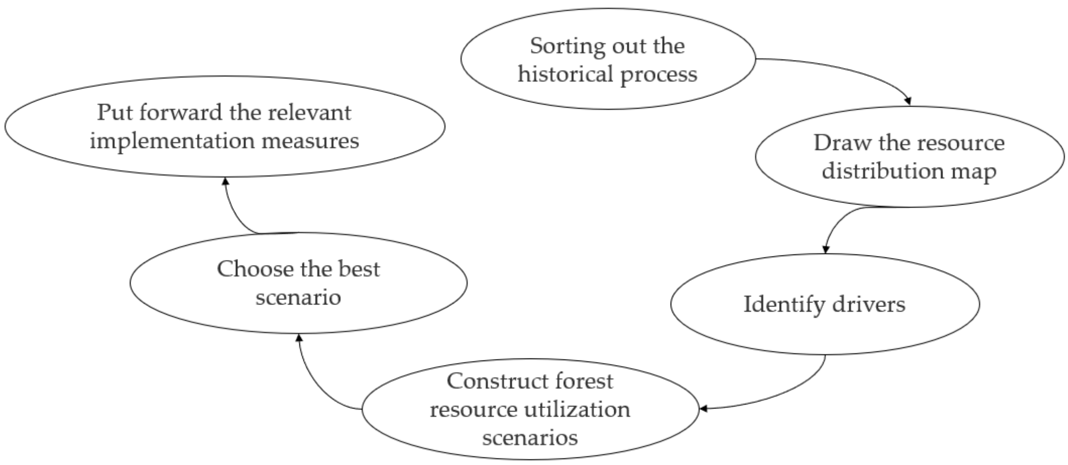


Figure 3. The implementation steps of participatory scenario analysis for the utilization of forest resource.

Since different stakeholders have different goals for forest resource utilization and they make different decisions for different influencing factors, the construction of forest resource utilization scenarios is divided into five steps. The first is sorting out the historical process of village development, at which nodes of the time axis and the changes that have taken place have played an important role in the utilization of forest resources. Second is summarizing the utilization of forest resources in the village, involving all stakeholders present in the production of the map, letting them once again systematically sort out the details of the village, and further reviewing the differences and changes in the use of forest resources in the village. Third is integrating the key driving factors considered by different stakeholders to cause changes in the use of forest resources. Fourth is simulating possible forest resource utilization scenarios. The final step is determining the situation chosen by most stakeholders and discussing, with ordinary farmers in groups, the best way to achieve the conditions that the optimal situation should have.

3.4. Method of Data Analysis

Due to the complexity and uncertainty of scenario simulation and the vagueness of stakeholder thinking in decision making in forest resource utilization scenarios, the decisions made by stakeholders often cannot be expressed in specific numerical values, and interests are related. Differences in an individual's own conditions and external environment produce different behavioral preferences, leading to different decision-making results [48], so this article attempted to introduce the multi-attribute decision-making theory on the basis of the participatory scenario analysis framework. When the attribute weight is completely unknown, the behavioral preference problem should be considered in decision making, and then the uncertain multi-attribute decision-making problem in which the behavior matrix and the preference information matrix are both triangular fuzzy numbers should be studied and the situational decision should be reflected in a more objective way.

First, the behavior matrix method is used [48,49], which is a way to organize the forest management profession. In the construction of the behavior matrix, we need to distinguish between different types of stakeholders and combine a descriptive and easy-to-trace method to provide ways to change the way forest resource are used, and to simulate the forestry development model. In the initial behavior matrix, different combinations of forest resource utilization methods can be subjectively formed from different sources of information, such as stakeholder types, stakeholder attitudes toward forest resource utilization, stakeholder beliefs and behaviors, and local traditional knowledge. The statistical results can simulate different situations and can be compared to the status quo.

In actual scenario simulation, four to five scenarios are simulated according to the specific situation. The method proposed in this article is based on the assumption of structural stability, that is, the rationality of stakeholders and their social structure will not undergo sudden major changes in the future. Next, quantitative analysis is performed based on the behavior matrix.

For a multi-attribute decision problem, assuming that the solution matrix is $U = \{u_1, u_2, \cdots, u_n\}$, the attribute matrix is $S = \{s_1, s_2, \cdots, s_m\}$, the solution u_j with an attribute value $\widetilde{a_{ij}}$ under the condition of attribute is s_i, and $\widetilde{a_{ij}} = \left[a_{ij}^L, a_{ij}^M, a_{ij}^U\right]$ is a triangular fuzzy number, which forms a decision matrix $A = \left(a_{ij}\right)_{m\times n}$. Decision-makers have certain subjective preferences for the solution $u_j \in U$. Let the subjective preference value also be the triangular fuzzy number p_j, $p_j = \left[p_j^L, p_j^M, p_j^U\right]$, and $0 \le p_j^L \le p_j^M \le p_j^U \le 1$. Common attribute types include the benefit and cost types. In this study, we considered the normalized treatment results of the benefit type, because we needed to find a way to maximize the benefits of forest resource utilization for farmers in the reserves. Let I be the benefit-type subscript set, and $M = \{1,2,\cdots,m\}$, $N = \{1,2,\cdots,n\}$. To eliminate the influence of different physical dimensions on decision-making results, according to the standardized processing method, we can obtain the normalized matrix $R = \left(r_{ij}\right)_{m\times n}$, $r_{ij} = \left[r_{ij}^L, r_{ij}^M, r_{ij}^U\right]$, and:

$$\begin{cases} r_{ij}^L = a_{ij}^L \Bigg/ \sqrt{\sum_{j=1}^{n} \left(a_{ij}^U\right)^2} \\ r_{ij}^M = a_{ij}^M \Bigg/ \sqrt{\sum_{j=1}^{n} \left(a_{ij}^M\right)^2} \\ r_{ij}^U = a_{ij}^U \Bigg/ \sqrt{\sum_{j=1}^{n} \left(a_{ij}^L\right)^2} \\ i \in I, j \in N \end{cases} \tag{1}$$

The attribute value r_{ij} here can be regarded as the objective preference value of the decision-maker for the solution u_j under the attribute s_i.

As described above, the fuzzy decision matrix $A = \left(a_{ij}\right)_{m\times n}$ is transformed into the normalized decision matrix $R = \left(r_{ij}\right)_{m\times n}$ according to Formula (1).

Then, the normalized decision matrix $R = \left(r_{ij}\right)_{m\times n}$ can be transformed into a decision matrix with behavioral preferences in Formula (2).

$$F(\lambda) = \begin{bmatrix} F_{11}(\lambda) & F_{12}(\lambda) & \cdots & F_{1n}(\lambda) \\ F_{21}(\lambda) & F_{22}(\lambda) & \cdots & F_{2n}(\lambda) \\ \vdots & \vdots & \vdots & \vdots \\ F_{m1}(\lambda) & F_{m2}(\lambda) & \cdots & F_{mn}(\lambda) \end{bmatrix} \tag{2}$$

and

$$F_{ij}(\lambda) = \left[(1-\lambda)r_{ij}^L + r_{ij}^M + \lambda r_{ij}^U\right]/2 \tag{3}$$

$F_{ij}(\lambda)$ can be regarded as the objective preference value of the solution u_j under the attribute s_i when the decision-maker's behavioral preference is λ.

The subjective preference value $p_j = \left[p_j^L, p_j^M, p_j^U\right]$ can also be transformed into the subjective preference value with behavioral preference:

$$p_j(\lambda) = \left[(1-\lambda)p_j^L + p_j^M + \lambda p_j^U\right]/2 \tag{4}$$

The weight vector of each attribute $S = \{s_1, s_2, \cdots, s_m\}$ can be determined, supposing the weight vector $w = (w_1, w_2, \cdots, w_m)$ has been obtained. Then, the comprehensive attribute value of each scheme is:

$$z_j(\lambda) = \sum_{i=1}^{m} \left[F_{ij}(\lambda) w_i\right], j \in N \tag{5}$$

Due to various conditions, there is often a certain deviation between the subjective and objective preferences of decision-makers. If the bias between the objective preference for the property $F_{ij}(\lambda)$ and the subjective preference for $p_j(\lambda)$ is expressed as the variance $\delta_{ij}^2(\lambda)$:

$$\delta_{ij}^2(\lambda) = \left(F_{ij}(\lambda) - p_j(\lambda)\right)^2 \tag{6}$$

Then, the total deviation between objective preference value $F_{ij}(\lambda)$ and subjective preference value $p_j(\lambda)$ for all attributes of solution u_j is $\delta_j^2(\lambda) = \sum_{i=1}^{m}\left[\delta_{ij}(\lambda) w_i\right]^2$. In order to make the decision reasonable, the choice of attribute weight vector p should minimize the total deviation between the decision-maker's subjective and objective preferences. To this end, the following single-objective optimization model was established:

$$min\delta(p) = \sum_{j=1}^{n} \delta_j^2(\lambda) = \sum_{i=0}^{n} \sum_{i=0}^{n} \left[\delta_{ij}(\lambda) w_i\right]^2 \quad (7)$$

$$s.t. \sum_{i=1}^{m} w_i = 1, w_i \geq 0 \quad (8)$$

For the solution of this model, the partial derivative of the Lagrange function $L(w,x) = \sum_{i=1}^{m} \sum_{j=1}^{n} \delta_{ij}^2(\lambda) w_i^2 + 2x(\sum_{i=1}^{m} w_i - 1)$ is taken, and the order is:

$$\begin{cases} \dfrac{\partial L}{\partial w_i} = 2\sum_{j=1}^{n} \delta_{ij}^2(\lambda) w_i + 2x = 0, i\epsilon M \\ \dfrac{\partial L}{\partial x} = \sum_{i=1}^{m} w_i - 1 = 0 \end{cases} \quad (9)$$

and the solution is

$$w_i = \frac{1}{\sum_{j=1}^{n} \delta_{ij}^2(\lambda)} \cdot \frac{1}{\sum_{i=1}^{m} \frac{1}{\sum_{j=1}^{n} \delta_{ij}^2(\lambda)}} \quad (10)$$

According to Formulas (3) and (8), the comprehensive attribute evaluation value of each solution u_j can be obtained:

$$z_j(\lambda) = \sum_{i=1}^{m} \left[F_{ij}(\lambda) w_i\right], j \in N \quad (11)$$

According to the different behaviors of decision-makers, and according to the comprehensive attribute evaluation value $z_j(\lambda)$, the various solutions are sorted and selected by $j\epsilon N$, and the larger the better.

4. Results

4.1. Participatory Situation Construction of Forest resource Utilization

First, according to the implementation steps of the participatory context method, different stakeholders in the two villages were selected in the study area to construct the forest resource utilization scenarios. The types and number of stakeholders of seminar are shown in Table 5.

Table 5. Seminar stakeholder types and number.

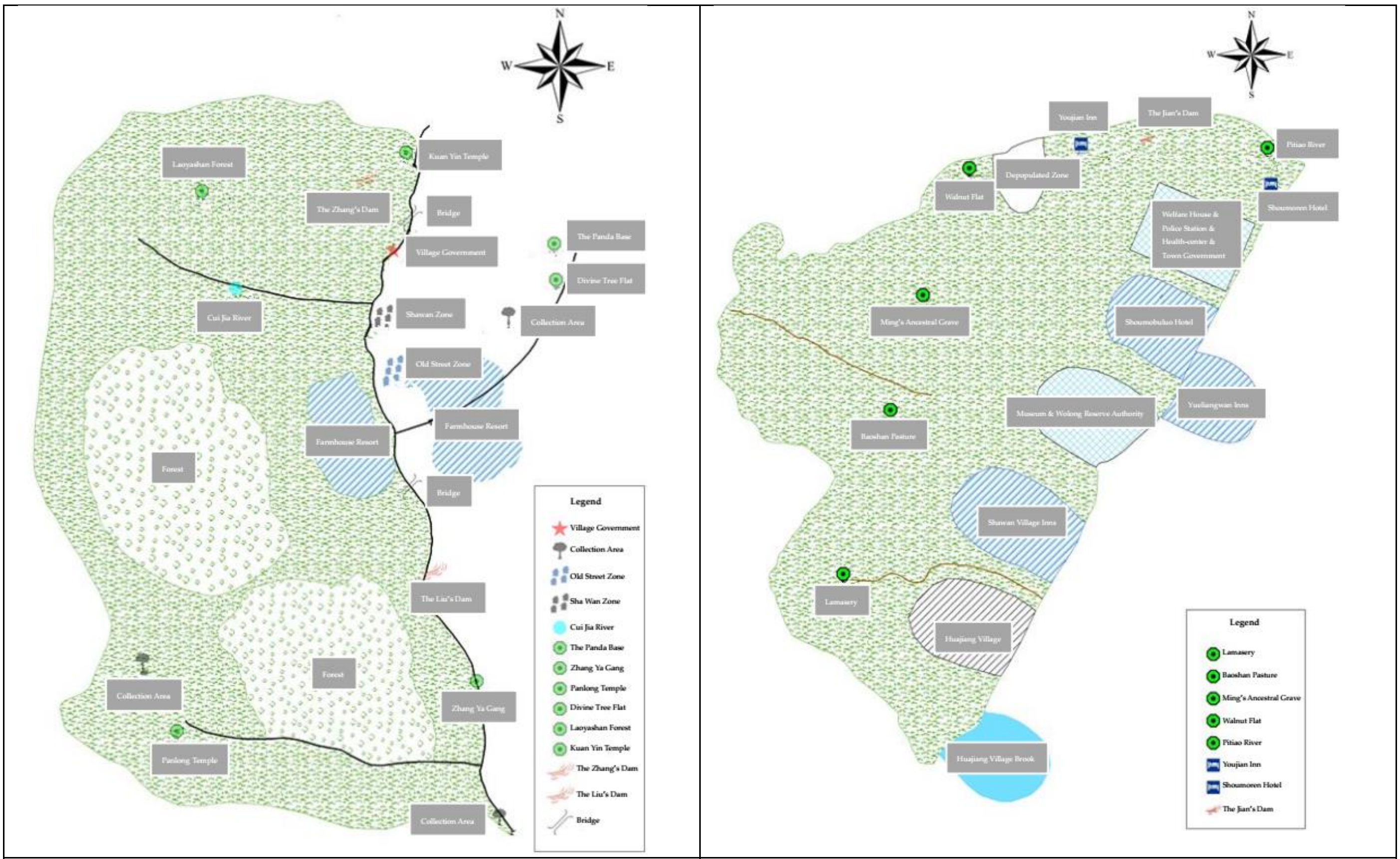
Type of Stakeholders	Number
Wolong Nature Reserve management personnel	1
Village cadre	2
NGO representative	1
Ecotourism operator	1
Village elder	1
Farmer	2
Total	8

Through interviews with stakeholders, the historical timeline related to the use of forest resources in the two villages was plotted, and the historical nodes that they believe have played a significant role in the use of forest resources were marked, as shown in Table 6.

Table 6. Historical timeline in the villages of Gengda and Zumushan.

Year	Gengda	Zumushan
1963	Establishment of Wolong Nature Reserve	
1973	No logging in Wolong Nature Reserve	
1975	Expansion of Wolong Nature Reserve	
1980	Establishment of the China Giant Panda Research Center	
1983	Delimitation of the Wolong Special Administrative Region	
1984		Building of a small hydropower station
1986		Implementation of the Project to Return the Grain Plots to Forestry
1988	Illegal logging	
2000		Establishment of an ecological power station
2002	Stopping hair subsidies of the Project to Return the Grain Plots to Forestry	Implementation of the Project to Return Farmland to Bamboo
2003	Implementation of the Policy of Replacing Firewood with Electricity	
2005	Natural Forest Protection Project I	
2006		Natural Forest Protection Project I and development of the economic forest industry
2008	Damage to forest resources by the Wenchuan earthquake	
2009	Establishment of an ecological power station	Affirmation of Woodland Rights
2015	Natural Forest Protection Project II	
2016		Natural Forest Protection Project II

By recalling the major historical points since the establishment of the reserve, the villagers also actively discussed the reasons for the changes in the utilization of local forest resources, and then participated in mapping the current resource distribution of their village, see Figure 4 for details.



(**a**) (**b**)

Figure 4. Resource maps of the villages of (**a**) Gengda and (**b**) Zumushan in the town of Wolong.

To fully invoke enthusiasm of every stakeholder regarding involvement, we distribute small pieces of paper to each stakeholder and asked them to write down four to five key factors that they believe have an impact on the use of forest resources, and then we integrated the key driving factors considered by different stakeholders to cause changes in forest resource utilization. The key drivers are summarized in Table 7.

Table 7. Key drivers of changes in forest resource utilization.

Factor Categories	Key Drivers
Social factors	Government support policy, Village infrastructure
Economic factors	Tourism development, Standard of living/income, Livelihood transformation
Ecological factors	Awareness of ecological protection

The villagers' understanding of the driving factors of forest resource utilization changes is relatively consistent. In terms of government support policies, stakeholders believe that the reserve's policy of "replace firewood with electricity" has a greater impact. The implementation of this policy will not only change the way local farmers use energy, but will also have an ecological impact. Conservation also allows local farmers more free time to manage economic forests or develop ecotourism and improve their livelihoods in other ways. For village infrastructure construction, the opening of roads and the construction of related tourism facilities are paving the way for the development of ecotourism. Only by doing a good job in the construction of village infrastructure can the tourism industry be better developed and the living standards of farmers be improved. Among the driving factors that cannot be ignored is the ecological protection awareness of local farmers. With the continuous deepening of ecological civilization construction, farmers' awareness of the protection of the ecological environment has also been improved, and there is a sense of "only by protecting the environment will more tourists be attracted."

Through the key driving factors obtained, we simulated the following scenarios for four forest resource utilization modes in Table 8.

Table 8. The scenario simulation of the utilization mode of forest resource.

Drivers	Scenario A	Scenario B	Scenario C	Scenario D
	Maintain the Present Status	**Ecologically Dominance**	**Balance Ecology and Economy**	**Economic Dominance**
Tourism development	The status quo	Limit	The status quo	Improve
Government support policy	The status quo	Promulgated ecological protection policies	Promulgated policies for ecological protection and economic support	Promulgated economic support policies
Awareness of ecological protection	The status quo	Improve	Improve more	The status quo
Standard of living/livelihood transformation	The status quo	The status quo	Improve	Improve
Village infrastructure	The status quo	The status quo	The status quo	Improve

The stakeholders voted for different scenarios. According to the choices of most of the stakeholders, the economic-led use of forest resources in scenario D is the best choice.

4.2. Integrative Assessment Using the Multi-Attribute Decision Theory

Based on the above participatory situation analysis of the villages of Gengda and Zumushan in Wolong Nature Reserve, we used a multi-attribute decision-making method to determine the optimal situation with a quantitative method. Tourism development, government support policies, awareness of ecological protection, living/livelihood transformation, and village infrastructure represent the five attributes $\mathrm{S} = \{s_1, s_2 \cdots s_5\}$. The stakeholders scored the various indexes, after which statistical processing was performed, and finally, the four forest resource utilization scenarios $u_j (j = 1,2,3,4)$ were determined.

Since the attribute values given by the stakeholders for the same situation were not completely the same, the attribute values of each situation under each index after statistical processing are given in the form of triangular fuzzy numbers. The behavior matrix composed of the attribute values of each situation under each index is given in Table 9.

Table 9. The attribute value of forest resource utilization scenario under each index.

Attributes(s_i)	**Forest resource utilization scenarios(u_j)**			
	u_1	**u_2**	**u_3**	**u_4**
s_1	[0.43,0.69,0.86]	[0.32,0.57,0.76]	[0.8,0.87,0.93]	[0.69,0.84,1]
s_2	[0.35,0.74,0.9]	[0.19,0.4,0.63]	[0.87,0.92,0.98]	[0.67,0.83,0.92]
s_3	[0.75,0.85,0.93]	[0.88,0.93,1]	[0.82,0.88,0.95]	[0.19,0.48,0.8]
s_4	[0.29,0.53,0.78]	[0.18,0.54,0.77]	[0.8,0.86,0.9]	[0.87,0.91,1]
s_5	[0.19,0.48,0.8]	[0.23,0.45,0.7]	[0.8,0.85,0.9]	[0.8,0.87,0.9]

Suppose that the subjective preference values of the stakeholders for the four forest resource utilization scenarios $u_j (j = 1,2,3,4)$ are $p_1 = [0.2,0.29,0.4]$, $p_2 = [0.25,0.38,0.55]$, $p_3 = [0.45,0.6,0.75]$, and $p_4 = [0.4,0.67,0.9]$, respectively.

Since all evaluation indexes are benefit indexes, according to Formula (1), we can obtain the standardized decision matrix:

$$R = \begin{bmatrix} [0.24,0.46,0.73] & [0.18,0.38,0.64] & [0.45,0.58,0.82] & [0.39,0.56,0.84] \\ [[0.2,0.5,0.77] & [0.11,0.27,0.54] & [0.5,0.61,0.85] & [0.39,0.55,0.79] \\ [0.41,0.53,0.65] & [0.48,0.58,0.7] & [0.44,0.55,0.84] & [0.1,0.3,0.56] \\ [0.17,0.36,0.63] & [0.1,0.37,0.63] & [0.46,0.59,0.74] & [0.5,0.62,0.81] \\ [0.11,0.35,0.68] & [0.14,0.32,0.6] & [0.48,0.62,0.78] & [0.48,0.63,0.77] \end{bmatrix} \tag{12}$$

According to Formula (3), the decision matrix with behavioral preferences is calculated as:

$$F(\lambda) = \begin{bmatrix} 0.7+0.48\lambda & 0.56+0.46\lambda & 1.02+0.37\lambda & 0.95+0.46\lambda \\ 0.7+0.57\lambda & 0.38+0.43\lambda & 1.11+0.35\lambda & 0.94+0.4\lambda \\ 0.93+0.24\lambda & 1.05+0.22\lambda & 0.99+0.4\lambda & 0.4+0.46\lambda \\ 0.53+0.47\lambda & 0.47+0.52\lambda & 1.05+0.28\lambda & 1.12+0.31\lambda \\ 0.46+0.57\lambda & 0.46+0.46\lambda & 1.1+0.3\lambda & 1.11+0.29\lambda \end{bmatrix} \tag{13}$$

The subjective preference values with behavioral preferences are $p_1(\lambda) = 0.49 + 0.2\lambda$, $p_2(\lambda) = 0.63 + 0.3\lambda$, $p_3(\lambda) = 1.05 + 0.3\lambda$, and $p_4(\lambda) = 1.07 + 0.5\lambda$.

The results are reported in Table 10.

Table 10. The results of the scenarios ordered under different behavioral preferences.

Behavioral preference	Attribute Weight Vector	Synthetic Attribute Value of Each Scenario	Sorted Scenarios
0.1	(0.126,0.091,0.100,0.124,0.147)	(0.296,0.264,0.549,0.554)	u4 > u3 > u1 > u2
0.3	(0.068,0.054,0.064,0.082,0.100)	(0.291,0.263,0.550,0.558)	u4 > u3 > u1 > u2
0.5	(0.012,0.012,0.017,0.028,0.043)	(0.294,0.265,0.549,0.555)	u4 > u3 > u1 > u2
0.7	(0.418,0.441,0.440,0.422,0.396)	(0.301,0.268,0.549,0.548)	u3 > u4 > u1 > u2
0.9	(0.376,0.403,0.378,0.344,0.314)	(0.569,0.605,0.577,0.474)	u2 > u3 > u1 > u4

In previous studies, many scholars have posited that the decision-making process with behavioral preferences generally follows certain rational logic; specifically, decision-makers try their best to choose the most conducive one for realizing their preference among the possible expected results from multiple alternatives [50,51]. According to fuzzy set theory, we divided decision-makers' behavioral preferences into optimistic, neutral, and pessimistic. "Multi-objective optimization is a commonly encountered problem to simultaneously tackle conflicting objectives," so in order to obtain a valid optimal solution under the constraints of existing conditions, we divided behavioral preferences into five parameters: 0.1, 0.3, 0.5, 0.7, 0.9. These five parameters represent the behavioral preferences of pessimism, neutrality, and optimism, respectively.

According to the endowment effect, the behavioral preferences of stakeholders are affected by the initial resource endowment; however, the different endowments of the stakeholders in the reserve resources they can obtain are different [52].

When the behavioral preferences of stakeholders increase from 0.1 to 0.9, the comprehensive attribute value of each situation also changes, and the ranking results of each situation are therefore different. When the behavior of stakeholders tends to be pessimistic or conservative (such as $\lambda = 0.1$ or 0.3), the best situation is u_4. When the stakeholders' behavior is biased toward mild or neutral (such as $\lambda = 0.5$), the best situation is u_4. When the behavior of stakeholders is more optimistic or aggressive (such as $\lambda = 0.7$), the best situation is u_3. When the behavior of stakeholders tends to be extremely optimistic or radical (such as $\lambda = 0.9$), the best situation is u_2. The situation u_1 does not change regardless of the preferences of stakeholders.

5. Discussion

This paper applied the participatory scenario and the multi-attribute decision-making method to study the selection of forest resource utilization modes of stakeholders in nature reserves. It was found that when the behavioral preferences of stakeholders are pessimistic, cautious, or neutral, they tend to choose economically dominant forest resource utilization, which is consistent with the participatory scenario selection results.

However, when the behavioral preferences of stakeholders tend to be optimistic or radical, according to their different degrees, they choose to consider more ecological dominance. The difference in behavioral preferences of different stakeholders results in a certain deviation between the two methods. However, it is this deviation that explains the importance of stakeholders' behavioral preferences in terms of forest resource utilization and management, and also enhances the feasibility and rationality of this study. The following discussion draws three conclusions from this application of the participatory scenario approach.

5.1. Stakeholders' Participation in Scenarios Development Is Influenced by Their Preferences

In scenario settings, nature reserve staff, government officials, and ordinary villagers are all taken into consideration, because their different status and backgrounds lead to differences in their choices. Based on previous studies, the combination of local knowledge and scientific application is necessary in scenario simulation. The information provided by stakeholders can only be combined with practical evidence as far as possible to obtain a more realistic situation [53]. However, a scenario requires a considerable number of elements, most of which are unquantifiable and easily omitted [54,55]. Therefore, it is particularly important to consider the behavioral preferences of stakeholders when planning forest resource utilization schemes.

5.2. The Influencing Factors of Economic-Oriented Forest Resource Utilization

According to the results of multi-attribute decision making, local farmers and government officials pay more attention to local economic development. Based on our field survey, they are more concerned about how to introduce suitable tree species to improve economic returns and how to develop local ecotourism, so they tend to choose economically oriented forestry resource utilization schemes. Therefore, the economic contribution of forest resource utilization cannot be ignored [56,57]. By improving the traditional use of forest resource, the development of local tourism is promoted, such as experiencing traditional food culture, picking wild vegetables and wild fungi, selling ecological products, and allowing tourists to visit and experience the beautiful natural environment; as a result, farmers can gain benefits. This will further promote the coordinated development of the local ecology and economy.

5.3. The Influencing Factors of Ecological-Oriented Forest Resource Utilization

The results showed that the more optimistic the behavioral preferences of stakeholders, the more they attach importance to the ecological conservation attributes of forest resource utilization scenarios. For those who choose ecologically oriented forest resource utilization, they believe that economically oriented forest resource utilization is not conducive to the sustainable development of local communities and will also destroy the local biodiversity level [58]. Due to the particularity of giant panda nature reserves, local reserve officials and scholars devoted to ecological protection tend to use the forest resources dominated by ecological protection, such as the implementation of the policy of returning cultivated land to bamboo, but this greatly affects the interests of local farmers. Thus, we need to provide alternative livelihoods for farmers to become optimists. Providing sustainable development projects can reduce their economic dependence on forest resources and increase their awareness and motivation for ecological conservation.

6. Conclusions

Based on the theory of political ecology, this paper constructed an analytical framework that can quantify stakeholders' preferences for forest resource utilization. In this framework, we comprehensively considered political, economic, and ecological factors, placed different stakeholders in equal rights, and investigated the forest resource utilization plans selected by them according to their behavioral preferences. In order to achieve this process, we used the participative scenario and multi-attribute decision-making methods to conduct case studies in the villages of Gengda and Zumushan in Wolong Nature Reserve.

The results showed that stakeholders form different behavioral preferences by judging their own resource endowments, which affects their choice of forest resource utilization schemes. Specifically, pessimistic ($\lambda = 0.1$), cautious ($\lambda = 0.3$), or neutral ($\lambda = 0.5$) stakeholders tend to choose economically dominant forest resource utilization schemes; however, optimistic ($\lambda = 0.7$) or even radical ($\lambda = 0.9$) stakeholders pay more attention to the ecological conservation attributes of the scheme.

Different stakeholders have different behavioral preferences for different forest resource utilization schemes, which ultimately affects the actual effect of ecological protection. Therefore, they need to be recognized and given equal rights to participate in decision making when planning forest resource utilization. Local community residents are often the most knowledgeable group and the most dependent on the local environment and resources. However, these are the very same people whose voices are the hardest to hear in government policy making, resulting in their disadvantage in the allocation of natural and social resources. With increasing climate change, local community people who are disadvantaged in resource allocation and face high livelihood vulnerability are more likely to adopt short-sighted survival strategies that are harmful to the environment [59]. The sustainable development of ecological and forestry resources involves complex systems, which require cooperation and knowledge sharing among stakeholders. Moreover, decision-makers listen more to the voices of local people, which also helps to mobilize farmers' awareness of ecological environmental protection in government-led environmental protection practices, and form incentive compatibility between local economic development and forestry resource protection.

Forest resources are of great economic importance to the local people. Therefore, policies should focus on improving the traditional utilization of forest resources and on exploring the sustainable utilization of forest resources, so as to change the resource endowment of the stakeholders of protected areas and guide their behavioral preferences in order to improve the results of forest protection. These efforts will further promote the coordinated development of the local ecology and economy. For example, farmers can be guided to engage in ecotourism or sell eco-products. In addition, in the future development of forest resource utilization, the cultivation of understory economic plants, such as artificial cultivation of edible wild vegetables and planting of medicinal materials, can be explored and developed in the experimental areas of protected areas, so as to avoid picking wild vegetables and medicinal materials as much as possible, thus minimizing the damage to the ecological environment and biodiversity.

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