Evaluation on Comprehensive Benefit of Natural Forest Protection Project in Southwest China

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Abstract According to the problem of seriously degraded natural forest in Southwest China prior to the implementation of Natural Forest Protection Project, under the guidance of principle of practicality and systematicness, we establish the comprehensive-benefit evaluation index system of restoring the degraded natural forest in Southwest China, including 3 second-level indices, 12 third-level indices and 24 fourth-level indices. In addition, we use the method of Analytic Hierarchy Process to conduct comprehensive-benefit evaluation on implementation of Natural Forest Protection Project in Southwest China. The results show that since ten years of implementation of Natural Forest Protection Project in Southwest China, it has gained considerable comprehensive benefit. The comprehensive evaluation index of Natural Forest Protection Project in Southwest China is 83.08; the ecological benefit index of Natural Forest Protection Project in Southwest China is 56.75; the economic benefit index of Natural Forest Protection Project in Southwest China is 19.05; the social benefit index of Natural Forest Protection Project in Southwest China is 7.28. The effect of construction of Natural Forest Protection Project in Southwest China is good. The evaluation index system and research results in this paper will provide the empirical guidance for comprehensive-benefit evaluation of Natural Forest Protection Project in China, and especially in Southwest China.

Key words Southwest China, Comprehensive-benefit evaluation, Index system, Analytic Hierarchy Process

Ecological environment is the basic condition for the survival and development of human. The ecological damage can inflict enormous losses and catastrophe on humankind, and can lead to the collapse of one nation or race. Forest is the biggest ecological system on the earth, the existence and development status of which will have a great impact on the life quality of the national people and sustainable development of the national economy. Natural Forest Protection Project, the great strategic disposition conducted by the Chinese Party Central Committee and the State Council, aimed at improving the ecological environment of China, is the fundamental project of realizing the sustainable development of economy, society, and ecological environment in China. The comprehensive benefits of Natural Forest Protection Project include ecological benefit, economic benefit, social benefit and so on. The goal of implementing Natural Forest Protection Project is to protect and restore natural forest resources, and realize sustainable operation of forests. The unification of ecological benefit, economic benefit and social benefit of forests is the core of sustainable operation of forests[1]. Objective, dynamic and scientific evaluation on comprehensive benefit of forests is of great significance in promoting the awareness of environmental protection in whole nation, elevating the level of forest management and operation, and correctly dealING with the relationship between socio-economic development and ecological environmental protection.

Based on the actual situation, by establishing a set of quantifiable Natural Forest Protection Project benefit evaluation index system, we are to conduct evaluation on the comprehensive benefit of restoring seriously degraded natural forest in Southwest China, so as to provide theoretical basis and practice instruction for the forest management in Southwest China.

1 Overview of the study area

Southwest China, located in the southwestern border of China and southeastern Qinghai-Tibet Plateau, geographically includes the southeast of Qinghai – Tibet Plateau, Sichuan Basin and a large proportion of Yunnan – Guizhou Plateau. The geographical location of this region is 97°21′ – 110°11′ E, 21°08′ – 33°41′ N, with vast land, diverse climate types, abundant soil types, diverse forest types, and distinct three-dimensional distribution. Southwest China is the most abundant and unique wild animals and plants treasure in China. The total area of this region is 1.137 4 million square kilometers, accounting for 11.84% of land area of China. According to the data of the sixth investigation of forest resource, it indicates that the total area of forestry land in this region is 58.197 8 million hm^2, and area of woodland is 36.27 million hm^2, accounting for 62.23% of the area of forestry land, with the forest coverage rate of 36%.

Before the implementation of Natural Forest Protection Project, due to the need of national construction, Southwest China ignores the function of forests and the role of forests in sustainable development. Excessive and concentrated felling and use of forest resources inflict severe damage on the formerly intact primitive natural forest ecological system. In addition to forest fires, deforestation, and reclamation, the ecological environment in upstream of Yangtze River deteriorates, which impacts the sustainable socio-economic development in Southwest China. After the implementation of Natural Forest Protection Project, the natural forest rests and builds up

Received: June 23, 2011 Accepted: July 2, 2011
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strength, and the forest accumulation, forest area and forest coverage rate increase prominently. The forest structure tends to be more rational and the forest quality is also improved significantly, which are of great significance in improving regional ecological environment, reducing soil erosion and other natural disasters, and guaranteeing sustainable regional development of society and economy.

2 Establishment and evaluation method of comprehensive evaluation index system of Natural Forest Protection Project

2.1 Establishment of evaluation index system

2.1.1 Principles of establishing evaluation index. The evaluation index selection of Natural Forest Protection Project should take into account the implementation background and stage target of Natural Forest Protection Project. On the basis of the local actual situation, we are to mainly consider the principles of evaluation index, namely combination of completeness and scientificity, combination of pertinency and feasibility, combination of consistency and comparability, and combination of practicality and systematicness.

2.1.1.1 Completeness and scientificity. The index system of Natural Forest Protection Project must first be established on a scientific basis, that is, to fully reflect the internal mechanism of sustainable development of forests and sustainable management of forests. It should also reflect the general characteristics of the forest ecosystem and overview of regional economy and society. In terms of content, it should not only reflect index of forest resources, index of ecology, index of economy and index of society, but also reflect the dynamic index and static index of forest resource development.

2.1.1.2 Pertinency and feasibility. The index system must have a clear objective in the process of establishment, and it should be operable and feasible in practice. It should also take into account the difficulty of obtaining the basic index data and reliability of the basic index data and representativeness of the basic index data.

2.1.1.3 Consistency and comparability. As the statistical indices of all regions have great disparity in the process of collecting indices, and there is a great difference among index units in the index system, therefore, in the course of collecting and processing indices, we should not only guarantee the comparability of all indices in different time, different regions, and different industries, but also guarantee the spatial-temporal consistency of index.

2.1.1.4 Practicality and systematicness. We require that the established index system should have clear connotation; the index system can easily obtain the statistical data, investigation and research data and experimental data, and the index system can be calculated easily; we require that the established index system should have completeness and structural hierarchy; we require that the established index system should reflect the ecological benefits, economic benefits and social benefits of Natural Forest Protection Project systematically; we require that the established index system should be an interrelated organic whole with clear aim and definite structure.

2.1.2 The method of selecting evaluation indices. In terms of evaluation index selection, first, through extensive reading of references, this paper absorbs the excellent indices from the research results of others; second, based on reality and the actual situation of the evaluation object, this paper advances the evaluation indices that can reflect the nature; third, by soliciting opinions from the experts extensively, this paper repeatedly revises the established evaluation index system. The methods of selecting index in this research are as follows: the method of personal judgment, the method of theoretical analysis, the method of frequency analysis, Delphi method, and the method of investigation and research analysis[2]. The method of theoretical analysis is to conduct analysis and comparison on the status of completion of stage target of Natural Forest Protection Project, changes of forest resources, ecology, economy, society and so on in Southwest China before and after the implementation of Natural Forest Protection Project, and then it designs construction effect evaluation index system of Natural Forest Protection Project. The method of frequency analysis is to select those indices with high use frequency, representativeness, pertinence and data availability, from the relevant literatures at home and abroad, concerning comprehensive-benefit evaluation of restoring degraded natural forests, so as to establish the construction effect evaluation index system of Natural Forest Protection Project. Delphi method and the method of investigation and research analysis are to conduct statistical analysis on the quantitative information and qualitative information obtained by investigation and research. On the basis of this, by using expert consultation method, according to the opinions of experts, we are to revise the evaluation index system. The indices recognized by more than 70% of the experts are listed into the index system, so as to form the comprehensive-benefit evaluation index system of restoring the degraded natural forest in Southwest China, including 1 overall-layer index, 3 system-layer indices, 12 standard-layer indices and 24 index-layer indices, which can be seen in Table 1.

2.2 Evaluation method and calculation of evaluation indices

2.2.1 Calculation method of evaluation index weight. The weight determination method of evaluation index is mainly Analytic Hierarchy Process (AHP), and we are to determine index weight through the method of expert opinion consultation[2,3]. Analytic Hierarchy Process (AHP) is a kind of multi-criteria qualitative and quantitative decision-making method advanced by well-known American operational research expert Thomas. l. Saaty and the like, in the 1970s[4]. It is a kind of decision-making method that we decompose related elements of decision-making problems into objective, guideline, program and other levels, use certain scale to conduct objective quantification on subjective judgments of human, and based on this, conduct qualitative analysis and quantitative analysis.

The determination of evaluation index weight has great impact on the evaluation results in the comprehensive-benefit evaluation. According to the steps of Analytic Hierarchy Process

(AHP), the relevant experts are invited to calculate the weight of all indices in each evaluation unit, in accordance with the order of first-level evaluation unit, second-level evaluation unit and third-level evaluation unit established from the objective layer to index variable layer. In order to mitigate the impact of the human factor as far as possible, first, the experts are invited to select each undetermined index preliminarily, and divide each undetermined index into four levels, namely very important, important, ordinary and unimportant; second, the weight of selected indices is directly determined; third, according to the hierarchical structure, the experts compare the importance of sub-level indices subordinate to each superior-level index pairwise, so as to get judgment matrix. Then we calculate out the largest eigenvalue and eigenvectors, conduct consistency test, and finally calculate and determine the weight of all factors of comprehensive-benefit evaluation of restoring natural forest in Southwest China. The weight of all evaluation indices can be seen in Table 1.

Table 1 The comprehensive-benefit evaluation index system of restoring the degraded natural forest in Southwest China and weight

Overall layer	System layer		Standard layer		Index layer	
Index	Index	Weight	Index	Weight	Index	Weight
The comprehensive-benefit evaluation index system of restoring the degraded natural forest in Southwest China (A)	Ecological benefit index (B_1)	0.567 5	Index of water conservation function (C_1)	0.123 7	Regulate water (D_1)	0.645 7
					Purify water (D_2)	0.354 3
			Index of soil conservation benefit (C_2)	0.237 0	Conserve soil (D_3)	0.690 0
					Fixate fertilizer (D_4)	0.310 0
			Index of carbon fixation and oxygen release benefit(C_3)	0.167 0	Fixation amount of CO_2 (D_5)	0.354 3
					Emission amount of O_2 (D_6)	0.645 7
			Accumulate nutrient(C_4)	0.064 6	Nutrient accumulation of wood (D_7)	1.000 0
			Purify atmospheric environment(C_5)	0.094 0	Provide anion(D_8)	0.213 4
					Absorb pollutants (D_9)	0.288 1
					Reduce noise (D_{10})	0.274 1
					Hold the dust down(D_{11})	0.224 4
			Forest protection (C_6)	0.103 9	Forest protection(D_{12})	1.000 0
			Index of biological diversity (C_7)	0.140 2	Species tending (D_{13})	1.000 0
			Tourism value of forests (C_8)	0.069 6	Tourism value of forest(D_{14})	1.000 0
	Economic benefit index (B_2)	0.272 6	Direct economic benefit (C_9)	0.598 7	Benefit of forest produce(D_{15})	0.425 1
					Benefit of forest byproducts (D_{16})	0.249 4
					The annual income of workers (D_{17})	0.325 6
			Indirect economic benefit (C_{10})	0.401 3	Total output value of forestry (D_{18})	0.325 6
					Change of industrial structure (D_{19})	0.425 1
					Use rate of investment (D_{20})	0.249 4
	Social benefit index (B_3)	0.159 9	Quantifiable social benefit (C_{11})	0.598 7	The ratio of forestry value and regional economy (D_{21})	0.598 7
					Employment rate of forestry workers (D_{22})	0.401 3
			Potential social benefit (C_{12})	0.401 3	People's cognition of Natural Forest Protection Project (D_{23})	0.598 7
					Engel coefficient(D_{24})	0.401 3

2.2.2 Calculation method of composite index. As for the calculation of composite index, by using linear weighted average method, we conduct integration of evaluation index[3], and the function expression is as follows:

$$Y=\sum_{i=1}^{m}\left[\sum_{j=1}^{n}\left(\sum_{k=1}^{l}(K_f\times P_k)\times R_j\right)\times W_i\right]$$

Where Y is the comprehensive-benefit evaluation index system of restoring the degraded natural forest in Southwest China; m is the number of system-layer indices; n is the number of standard-layer indices in certain system layer; l is the number of index-layer indices in certain standard layer; F_k is the evaluation value of index in index layer; P_k is the weight of index in certain index layer; R_j is the weight of index in certain standard

layer; W_i is the weight of index in certain system layer.

2.2.3 Calculation of index evaluation value in index layer. According to the impact and action of all indices (including all indices in all evaluation layers) on research system objective, this paper divides the research indices into direct indices and inverse indices, and we use different methods in the process of calculation[5]. The calculation method of direct indices is as follows: $F_k = P_k / S_k$, and the calculation method of inverse indices is as follows: $F_k = S_k / P_k$, where F is the value of index evaluation level; P is actual value; S is reference value; F_k reflects the proximity degree of index value and reference value; when $F_k \geqslant 1.00$, it indicates that the evaluation value has reached the ideal value, namely 1.00.

The calculation method of all index survey factors in index layer and the actual value (P) can be shown in Table 2, and reference value (S) is determined according to the following cases: first, when State Forestry Administration has formulated planning objective, it should be based on the planning objective; second, reference value, easy to determine in theory, is calculated according to the theoretical value, which exists in theory, but in practice, it is not easy to grasp, and it should be determined according to the actual situation.

Table 2 The survey factor of all indices

Index layer	Survey factor	Actual calculation method
Regulate water (D_1)	Precipitation, amount of evaporation and area of forest stand	$G_{regulation} = A(P - E - C)$
Purify water (D_2)	Precipitation, amount of evaporation and area of forest stand	$G_{water\ quality} = A(P - E - C)$
Conserve soil (D_3)	Soil erosion modulus and soil bulk density	$G_{soil\ conservation} = A(X_2 - X_1)$
Fixate fertilizer (D_4)	Content of organic matter, N, P and K in soil	$G_{fertilizer} = AN(X_2 - X_1)$; $G_P = AP(X_2 - X_1)$; $G_K = AK(X_2 - X_1)$
Fixation amount of CO_2 (D_5)	Forest accumulation amount, carbon content of forest and carbon content of soil	$G_{plant\ carbon\ fixation} = 1.63R_{carbon}\ A\ B_{year}$ $G_{soil\ carbon\ fixation} = AF_{soil}$
Emission amount of O_2 (D_6)	Forest accumulation amount and oxygen release amount of forest stand	$G_{oxygen} = 1.19AB_{year}$
Nutrient accumulation of wood (D_7)	Quantification of nitrogen fixed, phosphorus fixed and potassium fixed of forests	$G_{nitrogen} = AN_{nutrition}\ B_{year}$; $G_{phosphorus} = AP_{nutrition}\ B_{year}$; $G_{potassium} = AP_{nutrition}\ B_{year}$
Provide anion(D_8)	Annual absorption value	$G_{anion} = 5.256 \times 10^{15} \times Q_{anion}\ AH / L$
Absorb pollutants (D_9)	Annual absorption value	$G_{sulfur\ dioxide} = Q_{sulfur\ dioxide}\ A$; $G_{fluoride} = Q_{fluoride}\ A$; $G_{nitrogen\ oxide} = Q_{nitrogen\ oxide}\ A$; $G_{heavy\ metal} = Q_{heavy\ metal}\ A$
Reduce noise (D_{10})	Annual absorption value	$G_{noise} = K_{noise}\ A$
Hold the dust down(D_{11})	Directly measured by forest eco-station, unit: dB	$G_{dust\ holding} = Q_{dust\ holding}\ A$
Forest protection(D_{12})	Area of shelter forest, shielding agricultural crops and grass yield	$G_{shielding} = AQ_{shielding}\ C_{shielding}$
Species tending (D_{13})	Area of forest stand and value of species tending	$G_{biology} = S_{biology}\ A$
Tourism value of forest(D_{14})	Tourism revenue and ticket proceeds	Direct value and indirect value
Benefit of forest produce(D_{15})	Output of timber	Output of timber × price
Benefit of forest byproducts (D_{16})	Output of forest byproducts	Output × price
The annual income of workers (D_{17})	Income of workers	Annual income of workers
Total output value of forestry (D_{18})	Total output value of forestry	Total output value of forestry
Change of industrial structure (D_{19})	The output value of the primary industry, the secondary industry, and the tertiary industry	The output value ratio of the primary industry, the secondary industry, and the tertiary industry
Use rate of investment (D_{20})	Input capital and investment completed	The ratio of input capital and investment completed
The ratio of forestry value and regional economy (D_{21})	Forestry income and total income	The ratio of forestry income and total income
Employment rate of forestry workers (D_{22})	Workers at their posts and employees enrolled	The ratio of workers at their posts and employees enrolled
People's cognition of Natural Forest Protection Project (D_{23})	Quantity of supporters and quantity of respondents	The ratio of quantity of supporters and quantity of respondents
Engel coefficient(D_{24})	Consumer spending of food and total consumer spending	The ratio of consumer spending of food and total consumer spending

3 Results and analysis

3.1 Weight assignment and determination of actual value and evaluation value of indices As for the determination of the actual value in this paper, the ecological indices are mainly based on the monitoring data in 8 sampling sites established by four provinces (cities) in Southwest China, and the ecological indices refer to the standard of related industries released by the state; indices of economic benefit and social benefit are based on the data from the sixth, and seventh forest resources investigation in Southwest China and the relevant data obtained through investigation and research. According to determination method of index weight in all layers, and determination method of reference value and actual value of all indices in index layer, we calculate the 24 indices of the comprehensive-benefit evaluation of Natural Forest Protection Project in Southwest China (Table 3).

Table 3 Variables of the comprehensive-benefit evaluation index system of restoring the degraded natural forest in Southwest China

Overall layer	System layer	Weight	Standard layer	Weight	Index layer	Weight	Evaluation value
The comprehensive-benefit evaluation index system of restoring the degraded natural forest in Southwest China (A)	Ecological benefit index (B_1)	0.567 5	Index of water conservation function (C_1)	0.123 7	Regulate water (D_1)	0.645 7	1.00
					Purify water (D_2)	0.354 3	1.00
			Index of soil conservation benefit (C_2)	0.237 0	Conserve soil (D_3)	0.690 0	1.00
					Fixate fertilizer (D_4)	0.310 0	1.00
			Index of carbon fixation and oxygen release benefit(C_3)	0.167 0	Fixation amount of CO_2(D_5)	0.354 3	1.00
					Emission amount of O_2(D_6)	0.645 7	1.00
			Accumulate nutrient (C_4)	0.064 6	Nutrient accumulation of wood (D_7)	1.000 0	1.00
			Purify atmospheric environment(C_5)	0.094 0	Provide anion(D_8)	0.213 4	1.00
					Absorb pollutants (D_9)	0.288 1	1.00
					Reduce noise (D_{10})	0.274 1	1.00
					Hold the dust down (D_{11})	0.224 4	1.00
			Forest protection (C_6)	0.103 9	Forest protection (D_{12})	1.000 0	1.00
			Index of biological diversity (C_7)	0.140 2	Species tending (D_{13})	1.000 0	1.00
			Tourism value of forests (D_8)	0.069 6	Tourism value of forest(D_{14})	1.000 0	1.00
	Economic benefit index (B_2)	0.272 6	Direct economic benefit (C_9)	0.598 7	Benefit of forest produce(D_{15})	0.425 1	0.21
					Benefit of forest by-products (D_{16})	0.249 4	1.00
					The annual income of workers (D_{17})	0.325 6	1.00
			Indirect economic benefit(C_{10})	0.401 3	Total output value of forestry (D_{18})	0.325 6	1.00
					Change of industrial structure (D_{19})	0.425 1	1.00
					Use rate of investment (D_{20})	0.249 4	0.00
	Social benefit index (B_3)	0.159 9	Quantifiable social benefit (C_{11})	0.598 7	The ratio of forestry value and regional economy (D_{21})	0.598 7	0.64
					Employment rate of forestry workers (D_{22})	0.401 3	−0.06
			Potential social benefit (C_{12})	0.401 3	People's cognition of Natural Forest Protection Project (D_{23})	0.598 7	1.00
					Engel coefficient (D_{24})	0.401 3	0.00

3.2 Evaluation on the comprehensive benefit of Natural Forest Protection Project in Southwest China

3.2.1 Determination of evaluation level. By using composite index method, according to weighting and assignment of indices, and principles and methods of the hierarchical aggregation, we can calculate the scores of comprehensive benefit of Natural Forest Protection Project, and give overall evaluation. After checking the overall scores of all evaluation indices, we need to determine the grading level. According to research results at home and abroad, and standard of acceptance inspection and assessment method of Natural Forest Protection Project, coupled with the opinions of related experts, we divide the construction of Natural Forest Protection Project into four levels, that is, fail when the score below 60 points; pass when the score in between 60 – 79 points; good when the score in between 80 – 89 points; excellent when the score above 90 points.

3.2.2 Evaluation results. After checking, by using the calcu-

lation function of the composite index, we calculate out that the overall evaluation index of Natural Forest Protection Project in Southwest China is 83.08. The comprehensive benefit of Natural Forest Protection Project is good. Index of ecological benefit is 56.75; index of economic benefit is 19.05; index of social benefit is 7.28. It indicates that the construction effect of Natural Forest Protection Project in Southwest China is good.

4 Conclusion and discussion

This research adopts expert evaluation method and Analytic Hierarchy Process (AHP) to establish the comprehensive-benefit evaluation index system of restoring the degraded natural forest in Southwest China, including 24 indices and 3 layers. The overall objective layer is comprehensive benefit of Natural Forest Protection Project in Southwest China. The criteria layer is economic benefits, social benefits and ecological benefits. The index layer is composed of 24 indices.

We conduct weight analysis on the comprehensive-benefit evaluation index system of restoring the degraded natural forest in Southwest China. Then we get the weight of all evaluation indices in comprehensive-benefit evaluation index system of Natural Forest Protection Project in Southwest China, and conduct consistency test and analyze the results. The results are that the comprehensive benefit of Natural Forest Protection Project in Southwest China is 83.08%, wherein ecological benefits account for 56.75%, economic benefits account for 19.05%, and social benefits account for 7.28%.

Since the implementation of Natural Forest Protection Project in Southwest China, it has played significant role in guaranteeing ecological safety of land and improving the ecological environment; laid foundation for economic and social sustainable development; made important contributions to construction of ecological barrier in Southwest China. Due to the limitations in the process of collecting data, it will be impacted by the subjective factors when using Analytic Hierarchy Process (AHP) to determine weight, which will influence the scientificity of the evaluation index system to some extent. Therefore, since the implementation of Natural Forest Protection Project in Southwest China, the all-around and scientific evaluation on the comprehensive benefit is yet to be further researched.

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areas, the proportion of private investment by people in urban areas is larger than that of residents in rural areas and the same to the marginal investment trend. All of which are the important factors resulting in great disparities of private investment by urban and rural residents. Therefore, government should change its policies to put more emphasis on countryside from the previous urban areas in the private investment on human capital and focus on the rural human capital.

(3) The automatic price elasticity and depending price elasticity in rural areas of private investment on human capital by residents are larger than that by residents in urban areas. Therefore, keeping the steady of local prices helps a lot in keeping steady of private investment on human capital. And at the same time, the improvement of rural residents' income can help to accelerate the private investment on human capital in rural areas.

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