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Measurement of Forest Ecological Benefits of Liangshui National Nature Reserve of Heilongjiang Province

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Abstract: Along with the socioeconomic development as well as the development and utilization of forest resources, the forest ecological environment has become more and more valuable, and its impact on the national economy has also become increasingly wide. Forest has significant ecological service function. Because the forest has obvious diversion and blocking effect on the surface runoff, it can greatly delay the surface runoff duration, effectively reduce the runoff flood peak and adjust the flood to dry season, so it can better reduce the flood disaster and river runoff; because the canopy can intercept a considerable amount of precipitation, reduce the intensity of rainstorm, and reduce the mechanical damage of raindrops on the soil, the root system can fix the soil. The litter can protect the soil surface layer, so it can form a good forest microclimate and have a good impact on the surrounding farmland, grassland and other ecosystems. It protects the wild animals and plants in the system to grow well, absorbs a large amount of carbon dioxide in the air, produces oxygen, purifies the atmosphere, conserves water resources, reduces floods and droughts, suppresses wind and sand, and reduces noise. Firstly, based on the modern statistical model, the seemingly unrelated forest model was constructed, and the dependent variable and independent variable set of standardized forest ecological benefit were determined, and the seemingly unrelated forest ecological benefit model was established. Then, according to the alternative market method and market approximation theory, the first and second monetary models of forest ecological benefit value are constructed. After that, the whole diffusion model was established to estimate the physical amount of forest ecological benefits. The annual forest ecological benefits of Liangshui National Nature Reserve were calculated based on the monetary model of generalized forest ecological benefits by using the forest big data of the third forest management survey in Liangshui National Nature Reserve which spent a lot of manpower, material and financial resources in 2009. The economic value is 94.31 million RMB¥.
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Key words: National nature reserve; Forest ecological benefits; Measurement

The service function of forest ecosystem is multifaceted, first of all, the utilization of forest biological resources. Forest is the only important resource that can provide wood, and wood is the only renewable material among the four major raw materials (wood, steel, cement, plastic), which is closely related to human production and life. On the other hand, forest has significant ecological service function. Because the forest has obvious diversion and blocking effect on the surface runoff, it can greatly delay the surface runoff duration, effectively reduce the runoff flood peak and adjust the flood to dry season, so it can better reduce the flood disaster and river runoff; The canopy can intercept a considerable amount of precipitation, reduce the intensity of rainstorm, and reduce the mechanical damage of raindrops on the soil, the root system can fix the soil. The litter can protect the soil surface layer, so it can form a good forest microclimate and have a good impact on the surrounding farmland, grassland and other ecosystems. It protects the wild animals and plants in the system to grow well, absorbs a large amount of carbon dioxide in the air, produces oxygen, purifies the atmosphere, conserves water resources, reduces floods and droughts, suppresses wind and sand, and reduces noise.

Pearce D W, Moran D (1994) [1] firstly studied the economic value of biodiversity. The Costanza research team in the United States has carried out a series of researches on ecosystem service functions. The most influential paper was published in nature by Costanza et al. (1997) [2]. This paper classifies and evaluates the global scale ecosystem services, and divides them into 17 types. Costanza (1998) published a paper on the value of ecosystem services again [3]. David C (2012) also studied the service value of ecosystem [4]. Calder I. R (2007) [5], Simone Novotny (2010) [6], Barkley J. (2013) [7] respectively studied the ecological benefits of forests.

In China, Zhou Xiaofeng (1994) used the hypothetical market method to evaluate the ecological value of forests in Heilongjiang Province [8]. Lang Kuijian et al. (2000) published the article "10 kinds of forest ecological benefit measurement theory and method of Forestry Ecological Engineering" [9]. Sun Jihua et al. Published the general estimation of the seemingly unrelated model of generalized forest ecological benefits [10]. After that, Meng Xiangjiang et al. (2010) [11], Wang Bing et al. (2011) [12], Zhu Min et al. (2012) [13] studied the ecological value of forests. Some Chinese scholars have published articles on the ecological value of China's forests abroad [14].

A unified evaluation system has not yet been formed, and the professional degree of research results is biased, and the value of different scholars is quite different. Opsehoor et al. found the assessment results unconvincing (Meng Xiangjiang et al., 2010). However, there are few researches on forest ecological benefits of national nature reserves at home and abroad. In this paper, the forest big data of National Nature Reserve which spent a lot of manpower, material and financial resources for forest management survey was used to construct the forest seemingly unrelated model based on the modern statistical model to measure the forest ecological benefits of Liangshui National Nature Reserve.

1. Seemingly uncorrelated model of forest ecological benefit

Tang Shouzheng et al. (2009) [15] based on the modern statistical model, assumed that the random variable $Y_1,\ldots,Y_q$, and some factors satisfy the linear statistical relationship:

$$\mathbf{Y}_j = \mathbf{x}_j \beta^{(j)} + \mathbf{e}_j \quad 1 \le j \le q \qquad (1)$$

In general, we can assume that the mean value of error matrix is 0, and its rows are uncorrelated (independent), that is:

$$\mathbf{E}(\mathbf{e}) = \mathbf{0} \qquad (2)$$

$$\operatorname{cov}(\mathbf{e}_{i\bullet}) = \sigma^2 \underset{q\times q}{\Sigma} \qquad (3)$$

$$\operatorname{cov}(\mathbf{e}_{i\bullet}, \mathbf{e}_{j\bullet}) = \underset{q\times q}{0} \quad 1 \le i \ne j \le n \qquad (4)$$

From formula（1）-（4）, we can get the flowing linear model:

$$\begin{cases} \underset{n\times 1}{\mathbf{Y}_j} = \underset{n\times p_j}{\mathbf{x}_j} \underset{p_j\times 1}{\beta^{(j)}} + \mathbf{e}_{\bullet j} \\ \mathbf{E}(\mathbf{e}_{\bullet j}) = \mathbf{0} \\ \operatorname{cov}(\mathbf{e}_{i\bullet}) = \sigma^2 \underset{q\times q}{\Sigma} \\ \operatorname{cov}(\mathbf{e}_{i\bullet}, \mathbf{e}_{i'\bullet}) = \underset{q\times q}{\mathbf{0}} \end{cases} \qquad (5)$$

$$1 \le i \ne i' \le n, \quad 1 \le j \le q$$

Where: $\mathbf{e}_{i\bullet} = (e_{i1},\cdots,e_{iq})$.

Formula (5) is called seemingly unrelated linear models.

Based on Tang Shouzheng's seemingly unrelated model, this study will define various classic concepts of forest ecological benefits according to the unique biological characteristics of forests, plus the relatively easy to obtain independent variable sets such as stand, meteorological factors and geographical location factors that affect the growth of forests, and take various ecological benefits of forests as dependent variables to construct complex forest ecological benefits Related models.

1.1 Dependent variable of standardized forest ecological benefits

y_1 is the annual ecological benefit of forest canopy interception (hm^2. a); y_2 is the forest litter water holding capacity (hm^2. a); y_3 is the annual ecological benefit of forest soil non capillary pore water storage (hm^2. a); y_4 is the annual ecological benefit of forest soil consolidation (hm^2. a); y_5 is the annual ecological benefit of forest fertilizer retention (hm^2. a); y_6 is the annual ecological benefit of forest carbon dioxide absorption (m^3. a); y_7 is the annual ecological benefit of forest releasing oxygen (m^3. a); y_8 is the annual ecological benefit of forest controlling wind sand (hm^2. a).

1.2 Independent variable set of forest ecological benefits

LF is qualitative variable, response value of forest classification: Korean pine forest is 1, coniferous forest is 2, mixed forest is 3, hard broad-leaved forest is 4, soft broad-leaved forest is 5, and sub arbor forest is 6; LZ is qualitative variable, age group response value: young forest is 1, middle-aged forest is 2, mature forest is 3; JY is precipitation (mm); YB is canopy density (0, 0.1, 0.2,... 1); JD is longitude (°); WD is latitude (°); HB is altitude (m).

1.3 Seemingly unrelated linear model of forest ecological benefit

The above dependent variables and independent variable sets of forest ecological benefits can be combined to write equations:

$$
\begin{cases}
ln\,(y_{i1})=a_{11}+b_{11}LF_{i1}+b_{21}LF_{i2}+b_{31}LF_{i3}+c_{11}LZ_{i1}+c_{21}LZ_{i2}+c_{31}LZ_{i3}+d_{11}\times ln\,(JY_i)+d_{21}YB_i+e_{i1}\\
y_{i2}=a_{12}+b_{12}LF_{i1}+b_{22}LF_{i2}+b_{32}LF_{i3}+c_{12}LZ_{i1}+c_{22}LZ_{i2}+c_{32}LZ_{i3}+d_{32}JD_i+d_{42}WD_i+d_{52}HB_i+e_{i2}\\
y_{i3}=a_{13}+b_{13}LF_{i1}+b_{23}LF_{i2}+b_{33}LF_{i3}+d_{33}JD_i+d_{43}WD_i+d_{53}HB_i+e_{i3}\\
y_{i4}=a_{14}+c_{14}LZ_{i1}+c_{24}LZ_{i2}+c_{34}LZ_{i3}+d_{14}JY_i+d_{24}YB_i+d_{34}JD_i+d_{44}WD_i+e_{i4}\\
y_{i5}=a_{15}+c_{15}LZ_{i1}+c_{25}LZ_{i2}+c_{35}LZ_{i3}+d_{15}JY_i+d_{25}YB_i+d_{35}JD_i+d_{45}WD_i+e_{i5}\\
y_{i6}=a_{16}+c_{16}LZ_{i1}+c_{26}LZ_{i2}+c_{36}LZ_{i3}+d_{16}JY_i+d_{26}YB_i+d_{36}JD_i+d_{46}WD_i+e_{i6}\\
y_{i7}=a_{17}+c_{17}LZ_{i1}+c_{27}LZ_{i2}+c_{37}LZ_{i3}+d_{17}JY_i+d_{27}YB_i+d_{37}JD_i+d_{47}WD_i+e_{i7}\\
y_{i8}=a_{18}+c_{18}LZ_{i1}+c_{28}LZ_{i2}+c_{38}LZ_{i3}+d_{18}JY_i+d_{28}YB_i+d_{38}JD_i+d_{48}WD_i+e_{i8}
\end{cases} \tag{6}
$$

Writing in seemingly unrelated linear model, the standard type is as flows:

$$
\begin{cases}
y_{i1}=\beta_{11}+\beta_{21}X_{i1}+\beta_{31}X_{i2}+\beta_{41}X_{i3}+\beta_{51}X_{i4}+\beta_{61}X_{i5}+\beta_{71}X_{i6}+\beta_{81}X_{i7}+\beta_{91}X_{i8}+e_{i1}\\
y_{i2}=\beta_{12}+\beta_{22}X_{i1}+\beta_{32}X_{i2}+\beta_{42}X_{i3}+\beta_{52}X_{i4}+\beta_{62}X_{i5}+\beta_{72}X_{i6}+\beta_{10,2}X_{i9}\\
+\beta_{11,2}X_{I,10}+\beta_{12,2}X_{I,11}+e_{i2}\\
y_{i3}=\beta_{13}+\beta_{23}X_{i1}+\beta_{33}X_{i2}+\beta_{43}X_{i3}+\beta_{10,3}X_{i9}+\beta_{11,3}X_{i,10}+\beta_{12,3}X_{i,11}+e_{i3}\\
y_{i4}=\beta_{14}+\beta_{54}X_{i4}+\beta_{64}X_{i5}+\beta_{74}X_{i6}+\beta_{8,4}X_{i7}+\beta_{9,4}YB_{i8}+\beta_{10,4}X_{i9}+\beta_{11,4}X_{i,10}+e_{i4}\\
y_{i5}=\beta_{15}+\beta_{55}X_{i4}+\beta_{65}X_{i5}+\beta_{75}X_{i6}+\beta_{8,5}X_{i7}+\beta_{9,5}YB_{i8}+\beta_{10,5}X_{i9}+\beta_{11,5}X_{i,10}+e_{i5}\\
y_{i6}=\beta_{16}+\beta_{56}X_{i4}+\beta_{66}X_{i5}+\beta_{76}X_{i6}+\beta_{8,6}X_{i7}+\beta_{9,6}YB_{i8}+\beta_{10,6}X_{i9}+\beta_{11,6}X_{i,10}+e_{i6}\\
y_{i7}=\beta_{17}+\beta_{57}X_{i4}+\beta_{67}X_{i5}+\beta_{77}X_{i6}+\beta_{8,7}X_{i7}+\beta_{9,7}YB_{i8}+\beta_{10,7}X_{i9}+\beta_{11,7}X_{i,10}+e_{i7}\\
y_{i8}=\beta_{18}+\beta_{58}X_{i4}+\beta_{68}X_{i5}+\beta_{78}X_{i6}+\beta_{8,8}X_{i7}+\beta_{9,8}YB_{i8}+\beta_{10,8}X_{i9}+\beta_{11,8}X_{i,10}+e_{i8}
\end{cases} \tag{7}
$$

Note: in the above formula, the second corner of the variable is the random variable number, and the first one is the variable number. Considering that their real meaning is not uniformly numbered, each random variable can have its own variable set.

2. Monetary structure model of forest ecological benefits

2.1 Classification of monetary quantity construction model

There are two alternative market technologies for forest ecological benefits:

(1) Alternative market technology for alternative goods. According to various classical definitions of forest ecological benefits, this paper seeks for appropriate alternative commodities and alternative prices, and constructs the monetary quantity construction model, which is called the first type of monetary quantity construction model.

(2) Direct substitution of market technology. According to the field measurement data of external economy (or external non economy) generated by forest ecological benefits, the monetary structure model of forest ecological benefits is directly constructed, which is called the second type of monetary structure model.

2.2 The first kind of monetary quantity construction model

$$
E_{\mathrm{i}}(\mathrm{t})=\sum P_{\mathrm{j}}\times R_{\mathrm{j}}\times C_{\mathrm{j}}\times Y_{ij}(t)\times S_{ij}(t) \qquad \mathrm{i}=1,\ 2\ldots\ldots6 \tag{8}
$$

Where: E_i is the monetary amount of forest for water conservation, soil consolidation, fertilizer conservation, carbon dioxide absorption, air purification and sand control by forest; Pj is effective area coefficient; R_j is market approximation coefficient; C_j is price of substitute commodity; Y_{ij} is dependent variable (physical quantity) of forest ecological benefit; S_{ij} is vector of certain forest resources; t is time; Σ is sum according to stand sub-compartment j [16].

2.3 The second kind of monetary quantity construction model

The reason why the second kind of monetary quantity construction model is produced is that its physical quantity does not exist or it is difficult to find substitute goods. For example, there are more than ten kinds of benefit physical quantity of forest improving microclimate, but no suitable substitute commodity can be found for each. Forest noise reduction can be reduced decibel (DB) as its physical quantity, but there is no substitute commodity. There are too many physical quantities of wildlife in forest protection to establish its overall diffusion model. Forest recreation itself has direct use value and is a widened forest ecological benefit, without physical quantity and without substitute commodity [16]. The second type of monetary structure model is shown in table 1.

Table 1 Model parameters of second type money of forest ecological benefit

Forest ecological benefit	Pi	Ri	Construction model of money (¥/hm^2)
Improving microclimate	0.4	0.8	$E_i(t)=\sum P_j\times R_j\times S(t)\times 67.99605\times LZ^{0.4931957}$
Reducing flood and drought	1.0	0.9	$E_i(t)=\sum P_j\times R_j\times S(t)\times 311.6941\times LZ^{0.6183988}$
Recreation resource	0.6	0.4	$E_i(t)=\sum P_j\times R_j\times S(t)\times 12.33866\times LZ^{0.8235893}$
Wild animal protection	1.0	0.9	$E_i(t)=\sum P_j\times R_j\times S(t)\times 21.39681\times LZ^{0.8760093}$
Wild plant protection	1.0	0.9	$E_i(t)=\sum P_j\times R_j\times S(t)\times 64.11374\times LZ^{0.82359.8}$
Reducing noise	0.1	0.8	$E_i(t)=\sum P_j\times R_j\times S(t)\times 62.74023\times LZ^{0.2500285}$

*LZ is stand age group, others are the same as above.

3 Overall diffusion models

3.1 Canopy interception

According to the characteristics of forest ecological benefits, it is difficult to measure the forest ecological benefits. Therefore, the measurement of forest ecological benefits must be based on the sample. This sample can not be random, and the observation value of ecological positioning station is often used. The sampling ratio is much smaller than that of forest resources. This kind of data should be gradually expanded from micro observation layer by layer.

There are many dependent variables and independent variables in all kinds of forest ecological benefits. Using this multi to multi linear model to measure the forest ecological benefits, the model that satisfies the overall compatibility and has independent variables is called the global diffusion model.

The overall diffusion model of canopy interception is as follows:

$$I = \alpha \times EXP[a + \sum_i b_i \times LF + \sum_i c_i \times LZ + d\ln(JY) + f \times YB] \quad (9)$$

Where: I is canopy interception (t / hm^2. a); LF is qualitative variable, response value of forest classification: Korean pine forest is 1, coniferous forest is 2, mixed forest is 3, hard broad-leaved forest is 4, soft broad-leaved forest is 5, and sub arbor forest is 6; LZ is qualitative variable, age group response value: young forest is 1, middle-aged forest is 2, mature over mature forest is 3; JY is precipitation (mm); YB is canopy density (0, 0.1, 0.2,...1) α, a, b_i, c_i, d, f are the parameters to be estimated.

The estimated values of the above model parameters are: α = 6.9; a = -0.7849; b_1 = 0.0052, b_2 = -0.1834, b_3 = 0; c_1 = -0.4921, c_2 = -0.1919, c_3 = 0; d = 0.7612; f = 1.2388; sample number = 181.

3.2 Water holding capacity of litter

The overall diffusion model of litter water holding capacity is as follows:

$$K = \alpha + \beta[a + \sum b_i \times LF + \sum c_i \times LZ + dJD + fWD + gHB] \quad (10)$$

Where: K is litter water holding capacity (t / hm^2. a); JD is longitude (°); WD is latitude (°); HB - altitude (m); α, β, g are parameters to be estimated; other symbols are the same as above.

The estimated values of the above model parameters are: α = 25.374; β = 16.542; a = 68.58; b_1 = 4.83, b_2 = -1.81, b_3 = 0; c_1 = -7.42, c_2 = -3.04, c_3 = 0; d = -0.59; f = 0.4415; g = 0.0015; sample number = 181.

3.3 Soil capillary pore water storage

The overall diffusion model of capillary pore water storage in forest soil is as follows:

$$Q = a + \sum b_i \times LF + cJD + dWD + fHB \quad (11)$$

Where: Q is water storage capacity of capillary pores of forest soil (t / hm^2. a); other symbols are the same as above.

The estimated values of the above model parameters: a = - 5085.55; b_1 = - 254.8, b_2 = - 72.462, b_3 = 0; c = 79.80; d = - 91.8; f = 0.75; sample number = 181.

3.4 Soil consolidation

The overall diffusion model of forest soil consolidation is as follows:

$$Y_1 = a + \sum b_i \times LZ + dJD + CWD + EJY + fYB \quad (12)$$

Where: Y_1 is the amount of soil fixed by forest (t / hm^2. a), Y_1 = 0 in sparse forest land; JY is precipitation (mm); YB is canopy density (0, 0.1, 0.2,...) 1) C, E, f are the parameters to be evaluated; other symbols are the same as above.

The estimated values of the above model parameters: a = 4; b_1 = 6, b_2 = -2.567, b_3 = 0; d = -0.28445; C = 0.87825; E = 0.01762; f = 17; sample number = 181.

3.5 Fertilizer allowance

The overall diffusion model of forest fertilizer retention is as follows:

$$Y_2 = a + \sum b_i \times LZ + dJD + CWD + EJY + fYB \quad (13)$$

Where: Y_2 is the amount of forest fertilizer (t / hm^2. a), and Y_2 = 0 in sparse forest land; other symbols are the same as above.

The estimated values of the above model parameters: a = - 1.5; b_1 = -3.3125, b_2 = -0.89391, b_3 = 0; d = 0.05195; C = 0.00039; E = 0.00009; f = 0.5; sample number = 181.

3.6 Absorption of carbon dioxide

The overall diffusion model of forest carbon dioxide absorption benefits is as follows:

$$Y = a + \sum b_i \times LZ + dJD + CWD + EJY + fYB \quad (14)$$

Where: Y is carbon dioxide absorbed by forest (t / m^3. a); other symbols are the same as above.

The estimated values of the above model parameters: a = -0.13631; b_1 = 0.07890, b_2 = 0.02197, b_3 = 0; d = 0.00252; C = -0.00293; E = -0.00002; f = 0.00236; sample number = 30.

3.7 Purification of the atmosphere

The overall diffusion model of oxygen released from forest is as follows:

$$Y = \alpha\,(a + \sum b_i \times LZ + dJD + CWD + EJY + fYB) \quad (15)$$

Where: Y is the amount of oxygen released by forest (t / m^3. a); other symbols are the same as above.

The estimated values of the above model parameters are: α = 0.702; a = -0.13631; b_1 = 0.07890, b_2 = 0.02197, b_3 = 0; d = 0.00252; C = -0.00293; E = -0.00002; f = 0.00236; sample number = 30.

3.8 Sand control

The model of forest controlling wind sand diffusion is as follows;

$$Y_1 = a + \sum b_i \times LZ + dJD + CWD + EJY + fYB - 1 \quad (16)$$

And

$$Y_2 = \alpha\,(a + \sum b_i \times LZ + dJD + CWD + EJY + fYB - 1) \quad (17)$$

In the formula: Y_1 is the area of wind fixation restrained by forest (hm^2 / hm^2. a); Y_2 is the amount of sand fixation restrained by forest (t / hm^2. a); other symbols are the same as above.

The estimated values of the above model parameters are as follows: α=28.7; a =1.68262; b_1=0.10423, b_2=0.06526, b_3=0; d= 0.01376; C=-0.03955; E=-0.00067; f=0.41924; sample number =30。

4. Measurement of forest ecological benefits

4.1 Estimation of physical total amount of forest ecological benefits

The modeling data of this study are mainly from the database of the third forest management survey of Liangshui National Nature Reserve in 2009. The parameters of forest ecological physical quantity model are shown in table 2.

Table 2 Model parameters of forest ecological benefits physics

Items	Canopy interception	Water holding Capac. of litt.	Soil holding water	Soil consolid.	Fertilizer allowance	Absorption of CO_2	Atmosphere Purification	Sand control	Sand control	General Eco-benefits
Para.1	6.9	25.374	-5085.55	4	-1.5	0.95355	0.702	1.68262	28.7	0.4
Para2	-0.7849	16.542	-254.8	6	-3.3125	-0.13631	-0.13631	0.10423	1.68262	0.8
Para3	0.0052	68.58	-72.46	-2.567	-0.89391	0.0789	0.0789	0.06526	0.10423	122.6
Para4	-0.18340	4.83	0	0	0	0.02197	0.00293	0	0.06526	1
Para5	0	-1.81	79.8	-0.28445	0.05195	0	0	0.01376	0	0.9
Para6	-0.4921	0	-91.8	0.87825	0.00039	0.00252	0.00252	-0.03955	0.01376	91
Para7	-0.1919	-7.42	0.75	0.01762	0.00009	-0.00293	-0.00293	-0.00067	-0.03955	0.6
Para8	0	-3.04		17	0.5	-0.00002	-0.00002	0.41924	-0.00067	0.4
Para9	0.7612	0				0.00236	0.00236		0.41924	60.1
Para10	1.2388	-0.59								1
Para11		0.4415								0.3
Para12		0.0015								129
Effective area coeff.	1.8	1.8	1.8	1.5	1	1.3	1	0.5	0	0.1
Market Approx.coeff.	0.8	0.8	0.8	0.9	0.1	1	0.2	0.8	0	1
Price	0.66024	0.66024	0.66024	14.88	843.7	128.33	1269.7	450	0	71

Collection of total forest ecological benefit physics is showed in Table 3.

Table 3 Collection of total forest ecological benefit physics

Age group	Stand	Total Area hm^2	Total Volume m^3	Total physics	Water source cultivation y	water source cultivation Total	Soil consolidation y	Soil consolidation Total	Fert lizer allow ance y	Fert lizer allow ance Total	CO_2 absorption y	CO_2 absorption Total	Atmosphere purification y	Atmosphere purification Total	Sand y	Sand Total
		6334	1820433	14516716	2215.8	14034662	33.2	210462	4.7	29972	15	94913	8.8	55794	0.003	3167.9
Young		748	120026	1441877	1838.5	1375208	40.1	29961	2.3	1724	17.7	13235	13	9743	0.854	418.4
	Korean pine	35	6778	67724	1839.2	64373	40.2	1407	2.3	81	21.4	748	15.7	551	15	19.7
	Coniferous	312	63908	598553	1820.2	567912	40.4	12595	2.3	722	22.6	7054	16.6	5193	0.567	176.9
	Mixed	203	33853	412405	1941.7	394158	39.8	8080	2.3	466	18.4	3731	13.5	2747	0.941	112.3
	Hard broad-leaved	15	585	27137	1745.5	26183	38.7	581	2.3	34	4.3	64	3.1	47	7.467	8
	Soft broad-leaved	182	14852	334685	1765.1	321248	39.9	7268	2.3	419	9	1638	6.6	1206	2.159	101.3
	Sub arbor	1	50	1374	1335	1335	29	29	2	2					14	0.3
Middle		2418	796924	5427877	2165.9	5237228	31.5	76219	4.7	11424	18.5	44632	9.2	22206	0.003	1260.2
	Korean pine	720	402608	1622049	2155.2	1551730	31.3	22524	4.7	3397	31.3	22539	15.6	11212	0.14	371
	Coniferous	999	276356	2240161	2167.7	2165508	31.7	31666	4.7	4725	15.5	15487	7.7	7708	0.137	525
	Mixed	366	71227	862443	2288.9	837720	31.5	11540	4.7	1729	10.9	3991	5.4	1986	0.437	190.8
	Hard broad-leaved	26	3172	56855	2124.9	55247	31.8	826	4.7	123	6.8	178	3.4	88		13.7
	Soft broad-leaved	307	43562	646369	2042.4	627023	31.5	9664	4.7	1450	7.9	2437	3.9	1212		159.7
Mature		3168	903483	7646962	2342.9	7422227	32.9	104283	5.3	16824	11.7	37047	7.5	23845		1489.1
	Korean pine	668	224243	1636089	2374.1	1585905	33.5	22405	5.4	3586	13.6	9092	8.9	5914		320
	Coniferous	1368	392493	3299191	2340.8	3202150	33.3	45524	5.4	7383	11.3	15491	7.5	10306		638.9
	Mixed	838	232454	2084974	2417.7	2026065	32.3	27084	5.2	4364	12	10017	7.4	6174		392.7
	Soft broad-leaved	294	54294	626709	2068.4	608108	31.5	9270	5.1	1491	8.3	2448	4.9	1450		137.4

4.2 Measurement of forest ecological benefits

In recent years, forest ecological benefits have been extended to the value of forest selection and existence. For example, there is no physical benefit of forest protection, for example, there is no physical benefit of forest protection. Therefore, we directly determine the annual forest benefit per unit forest area as its value.

[Definition] Under the effect of atmospheric circulation, forest provides indirect forest selection value and existence value for the earth biosphere composed of life and environment, which generally does not have measurable ecological benefits, physical quantity or physical quantity is too much, forest wildlife protection with "substitute commodity" characteristics cannot be found, and public welfare effects such as forest improving microclimate benefit are called "General forest ecological benefits".

The economic value calculated by the generalized forest ecological benefit model is shown in Table 4.

Table 4 Generalized forest ecological money benefit Unit: 10 thousands RMB¥

Age group	Stand	Total area hm^2	Total volume m^3	Total money	Water source cultivation	Soil consolidation	Fertli zer allowance	CO_2 Absorp tion	Atmosphere purification	Sand control	Improv ing microclimate	Reducing water disaster	Recreation	Living things	Redu cing noise
		6334	1820433	9431	2402	761	455	2850	2550	103	45	93	16	147	8
Young		748	120026	1263	235	108	26	397	445	14	5	11	2	17	1
	Korean pine	35	6778	67	11	5	1	22	25	1		1		1	
	Coniferous	312	63908	624	97	46	11	212	237	6	2	5	1	7	
	Mixed	203	33853	355	67	29	7	112	126	4	1	3	1	5	
	Hard broad-leaved	15	585	12	4	2	1	2	2						
	Soft broad-leaved	182	14852	204	55	26	6	49	55	3	1	3		4	
	Sub arbor	1	50												
Middle		2418	796924	3860	896	276	173	1340	1015	41	17	36	6	56	3
	Korean pine	720	402608	1635	266	81	52	677	512	12	5	11	2	17	1
	Coniferous	999	276356	1440	371	114	72	465	352	17	7	15	3	23	1
	Mixed	366	71227	446	143	42	26	120	91	6	3	5	1	8	
	Precious hard broad-leaved	26	3172	25	9	3	2	5	4					1	

	Soft broad-leaved	307	43562	313	107	35	22	73	55	5	2	5	1	7	
Mature		3168	903483	4308	1270	377	255	1112	1090	48	22	47	8	74	4
	Korean pine	668	224243	993	271	81	54	273	270	10	5	10	2	16	1
	Coniferous	1368	392493	1849	548	165	112	465	471	21	10	20	4	32	2
	Mixed	838	232454	1148	347	98	66	301	282	13	6	12	2	19	1
	Soft broad-leaved	294	54294	319	104	34	23	74	66	4	2	4	1	7	

It can be seen from table 4 that the benefits of water conservation, soil consolidation, fertilizer conservation, carbon dioxide absorption, air purification and sand control in Liangshui National Nature Reserve are 24.02 million RMB¥, 7.61 million RMB¥, 4.55 million RMB¥, 28.5 million RMB¥, 25.5 million RMB¥ and 1.03 million RMB¥ respectively. The broad ecological benefits include improving microclimate, reducing flood and drought, recreation, wildlife protection and noise reduction, respectively. The annual total forest ecological benefit is 94.31 million RMB¥.

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