Measurements for Forest Ecological Benefit in China

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Abstract: According to the analysis of the multiple ecological benefits of forest, the indexes of dependent variables of the measurement on the forest ecological benefits were defined. This index system includes water-reserving benefit, soil and water conservation benefit, wind and sand suppression benefit, microclimate improvement benefit, carbon dioxide assimilation benefit, atmosphere purification benefit, flood and drought mitigation benefit, tourism resource benefit and wild creature protection benefit. Meanwhile, main factors from the numerous factors that affect dependent variables were chosen as independent variables. The independent variables were divided into area independent variables (longitude, latitude, altitude, annual precipitation, mean annual wind speed, annual accumulated temperature ≥10□) and stand independent variables (forest accumulation and forest coverage rate). At last, we established the multivariate linear model of forest ecological benefit measurement. With this multivariate linear model the forest ecological benefit of China was calculated. The forest ecological benefit of China is 7238.16 hundred million RMB per year. And this benefit equals 23.07 % of the gross domestic product of China.

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Key words: Forest ecological benefit, Measurement index system, Multivariate linear model

1. Introduction

Studies on evaluation of forest ecological benefits started in 1950s. But estimation on economic value of forest ecological benefits was at the end of 1980s. Now many exports pay attention to these studies. Daily's book (1997) named "Nature's Service: Societal Dependence on Natural Ecosystem" was a mark. There are two main schools. One is that representative is Constanza's ecological economics (1997). He thought that ecological function value might be calculated by total value. He raised proper measurement methods: market price approach surrogate cost approach. Another is Pearce's environmental economics (1998). He thought that it was difficulty to measure total value for ecological function value. So the proper method to measure was worth to pay or hypothetical valuation method. Zhou et al. (1994) measured public benefit for Heilongjiang's forest. Hou et al (1995) calculated the water-reserving benefit, wind and sand suppression benefit, atmosphere purification benefit for Chinese forest. Lang ea al

(2000) posed a series of new concepts of forest ecological benefits. Sun et al (2004) used a method of apparently not related models with forest ecological benefits in broad sense. Li et al (2005) measured several forest ecological benefits in China.

At present, the study about forest ecological benefits is mainly on measurement of physical quantity, and less on measurement of economical quantity. There are still many problems of research on measurement of forest ecological benefits, such as, measurement units not unify, dependent variables and independent variables not clear. In this paper, the forest ecological benefit of China by establishing the multivariate linear model was measured.

2. Site and data collection

Three-north region

It includes north, northeast, northwest regions in China, located in E 73°26′～127°50′, N 33°30′～50°12′. The width of east-west is 4480 km, south-north is 1460km. The total land area is 4.069 million km2. It includes 551 counties of Sanxi, Ganshu, Ningxia, Qinghai, Xinjiang, Shanxi, Hebei, Beijing, Tianjin, Inner Mongolia, Liaoning, Jilin, Heilongjiang provinces. Relief of western region is higher than that of eastern region. Elevation is from 100 to 5000. Precipitation decreases from east to west and from south to north.

Middle and upstream region of Yangtze River

The length of Yangtze River is 6300 km. Drainage area is about 1.80 millionkm2。Forest coverage rate is 20.7%. In the mountain area of middle and upstream region, plateau occupies more than 90%. Hills and plains are less than 10%. Precipitation is from 800 to 1800 mm/a. The average is about 1100 mm/a.

Coast region

The coast region is located in east, southeast of China. Its geographic coordinates is N 18°～41°40′,E108°～124°30′.It includes 195 counties of Liaoning, Hebei, Tianjin, Shandong, Shanghai, Fujian, Zhejiang, Guangdong, Guangxi, Hainan provinces. Its length is 18000 km. The total area is 25.0696 million hm2. Precipitation is from 600 to 2800 mm/a. It increases from north to south.

Data collection

For the wide scope of our study, the data should cover large area. Leaded by this thought, lots of data were collected from different time, different areas and different stands of China in two years.

Three types of variables were used:

Dependent variables:

Y1=water-reserving benefit of forest, 100 million RMB per year

Y2=soil and water conservation benefit of forest, 100 million RMB per year

Y3=wind and sand suppression benefit of forest, 100 million RMB per year

Y4=microclimate improvement benefit of forest, 100 million RMB per year

Y5=carbon dioxide assimilation benefit of forest, 100 million RMB per year

Y6=atmosphere purification benefit of forest, 100 million RMB per year

Y7=flood and drought mitigation benefit of forest, 100 million RMB per year

Y8=tourism resource benefit of forest, 100 million RMB per year

Y9=wild creature protection benefit of forest, 100 million RMB per year

Regional independent variables:

X1=longitude（°）

X2=latitude（°）

X3=altitude, m

X4=annual precipitation, mm

X5=mean annual wind speed, m/s

X6=annual accumulated temperature ≥10□,□

Stand independent variables:

X7=forest accumulation, ten thousand m3

X8=forest coverage rate, %

The basic statistics were present on Table 1

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Table 1 The basic statistics for different variables

Variables	Mean	Minimum	Maximum
Longitude（°）	112.07	88.08	126.10
Latitude（°）	33.43	20.03	47.60
Altitude, m	602.25	4.50	3702.60
Annual precipitation, mm	979.65	275.90	2429.10
Mean annual wind speed, m/s	2.51	1.00	4.30
Annual accumulated temperature≥10□,□	4522.08	2037.30	7880.00
forest accumulation, ten thousand m3	32697.37	10.62	205379.80
forest coverage rate, %	19.47	0.35	50.60
Water-reserving benefit, 100 million RMB per year	47.42	0.17	142.82
Soil and water conservation benefit, 100 million RMB per year	52.05	0.21	157.30
Wind and sand suppression benefit, 100 million RMB per year	2.28	0.35	50.60
microclimate improvement benefit, 100 million RMB per year	32.35	2.25	82.64
carbon dioxide assimilation benefit, 100 million RMB per year	36.41	0.34	123.93
atmosphere purification benefit, 100 million RMB per year	34.82	0.33	118.70
flood and drought mitigation benefit, 100 million RMB per year	19.10	0.11	70.90
tourism resource benefit, 100 million RMB per year	0.88	0.0006	4.70
wild creature protection benefit, 100 million RMB per year	4.69	0.0006	23.40

Models

The multivariate linear model of forest ecological benefit is as following.

$$Y=BX+E$$

Where：

Y=[Y1，Y2，Y3，Y4，Y5，Y6，Y7，Y8，Y9]T

X=[X1，X2，X3，X4，X5，X6，X7，X8]T

B，E are coefficient matrix and constant matrix.

The parameter estimates are as following:

$$B=\begin{pmatrix} -0.4388 & -3.2096 & -0.0202 & 0.0120 & 0.0000 & 0.0000 & 0.0005 & 0.0000 \\ -0.0629 & -1.4154 & -0.0203 & -0.0004 & -9.8838 & 0.0000 & 0.0008 & 0.0000 \\ 0.0629 & 0.1487 & -0.00002 & 0.0000 & -1.1316 & 0.0000 & 0.00003 & 0.0608 \\ 0.2123 & 1.0068 & -0.0043 & 0.0275 & 0.0000 & 0.0016 & 0.0000 & 0.0016 \\ 0.5682 & -0.5609 & -0.0084 & 0.0000 & 0.0000 & 0.0000 & 0.0006 & 0.0000 \end{pmatrix}$$

0.5440	-0.5265	-0.0081	0.0000	0.0000	0.0000	0.0006	0.0000
0.1289	-0.1894	-0.0067	-0.0014	0.0000	0.0000	0.0003	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000008	0.0298
0.0319	0.1938	-0.0008	0.0000	0.0000	0.0000	0.0001	0.1267

$$E=\begin{pmatrix} 187.3964 \\ 116.5590 \\ -9.0108 \\ -58.1190 \\ -22.4565 \\ -21.8288 \\ 5.0718 \\ 0.0265 \\ -10.2038 \end{pmatrix}$$

The correlation coefficient and significance tests are given in Table 2.

Table 2 Correlation coefficient and significance tests

Dependent variables	Correlation coefficient	R0.05	R0.01	significance
Y1	0.736516609	0.5383	0.6105	**
Y2	0.856155423	0.5644	0.63324	**
Y3	0.815430587	0.5711	0.6403	**
Y4	0.603613173	0.5711	0.6403	*
Y5	0.818903159	0.5138	0.5906	**
Y6	0.8198676	0.5138	0.5906	**
Y7	0.8363208	0.5449	0.6175	**
Y8	0.517803377	0.4255	0.5142	**
Y9	0.844666427	0.5449	0.6175	**

The table 2 shows that the regression relationships of these variables are very significantly.

3. Results and discussion

With this model and the values of each independent variables of different provinces of China, the forest ecological benefits are able to be calculated. The results are present in Table 3 .

Table 3 Forest ecological benefits values

Province	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9
Beijing	15.64	27.71	2.33	30.48	21.39	20.57	11.64	0.48	3.13
Tianjin	17.52	23.80	1.25	29.70	22.25	21.38	11.91	0.25	2.05
Hebei	24.27	41.27	2.72	26.30	24.04	23.07	13.35	0.47	2.84
Shanxi	24.03	33.13	1.44	23.40	22.09	21.21	12.58	0.30	1.99
Inner mongolia	46.36	99.44	5.18	16.90	66.01	63.24	38.58	1.11	9.99
Liaoning	8.41	22.92	3.28	33.98	30.00	28.81	15.11	0.94	6.25
Jilin	31.94	62.28	4.62	33.05	66.06	63.34	36.13	1.63	12.74
Heilongjiang	56.30	112.6	6.86	33.06	100.5	96.28	56.47	2.16	18.35
Shanghai	40.36	33.91	0.01	21.57	29.02	27.79	14.05	0.10	0.02
Jiangshu	45.42	37.20	0.43	36.05	27.51	26.37	13.03	0.15	0.37
Zhejiang	56.95	52.67	3.30	32.50	34.72	33.46	16.32	1.38	5.70
Anhui	54.18	41.89	1.38	50.29	29.59	28.50	13.60	0.56	2.45
Fujian	85.59	70.89	2.92	33.11	49.69	48.32	23.29	1.79	7.88
Jiangxi	72.93	47.37	1.62	49.15	37.69	36.51	17.05	1.37	5.78
Shandong	38.04	26.45	1.01	55.16	26.44	25.41	11.86	0.36	2.14
Henan	31.00	26.96	0.56	27.01	22.91	22.08	11.49	0.38	1.71
Hubei	52.05	46.39	1.32	26.10	31.50	30.45	15.75	0.76	3.17
Hunan	53.36	45.78	2.19	38.23	30.55	29.64	15.22	1.13	5.16
Guangdong	88.54	69.27	2.02	40.72	38.65	37.33	18.13	1.25	4.17
Guangxi	86.28	70.03	2.44	51.06	37.84	36.71	17.64	1.25	4.74
Hainan	95.64	60.26	0.15	40.22	32.31	30.96	14.97	1.00	1.72
Sichuan	119.6	149.2	6.00	49.62	93.54	92.86	45.97	1.68	14.29
Guizhou	43.69	28.43	0.29	20.85	16.81	16.20	5.47	0.54	2.47
Yunnan	93.36	102.5	3.45	20.66	72.28	71.85	32.39	1.64	10.57
Xizhang	96.44	137.6	5.20	14.45	105.16	105.71	46.48	1.84	16.81
Shanxi	43.50	56.40	2.89	24.12	33.00	31.59	18.48	0.97	5.01
Gansu	12.83	28.02	2.63	11.61	8.43	8.08	5.51	0.29	1.42
Qinghai	2.16	3.41	1.11	12.63	2.92	1.69	1.09	0.06	0.27
Ningxia	0.63	7.83	1.52	12.42	3.51	3.38	1.42	0.08	0.09
Xinjiang	3.85	19.28	1.23	15.21	6.05	5.92	8.90	0.02	3.01
Taiwan	75.20	37.50	2.52	66.13	36.83	35.70	11.84	1.85	6.59

Because of the error caused by the model construction, when we calculate the ecological benefit of the areas with high altitude and low forest coverage rate, the value may be negative (here is Qinghai. province). Then we use observed value to take the place of predicted value.

By study and analysis we can construct the multivariate linear model of forest ecological benefit measurement as follows:

$$Y = BX + E$$

Calculating with this model, the forest ecological benefit of China is 7238.16 hundred million RMB per year. It equals 23.07 % of the gross domestic product of China.

In the forest ecological benefit of China, 10 benefit values are respectively:

The water-reserving benefit is 1516.07 hundred million RMB per year and the percentage is 20.95. The soil and water conservation benefit is 1622.39 hundred million RMB per year and the percentage is 22.42. The wind and sand suppression benefit is 73.87 hundred million RMB per year and the percentage is 1.02. The microclimate improvement benefit is 975.74 hundred million RMB per year and the percentage is 13.48. The carbon dioxide assimilation benefit is 1159.29 hundred million

RMB per year and the percentage is 16.02. The atmosphere purification benefit is 1124.41 hundred million RMB per year and the percentage is 15.53. The flood and drought mitigation benefit is 575.72 hundred million RMB per year and the percentage is 7.95. The tourism resource benefit is 27.79 hundred million RMB per year and the percentage is 0.38. The wild creature protection benefit is 162.88 hundred million RMB per year and the percentage is 2.25.

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