Measurement on Forest Ecological Benefits in Forest Industry Group of Heilongjiang Province

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Abstract: The integral diffusion models were established using standardized ecological benefit dependent variable, regional independent variables and stand independent variables. Three important parameters including effective area coefficient, market approximation coefficient and conversion factors (According to the law of substitute goods, State Statistical Yearbook gets a reasonable price of the substitute goods and converts physical forest ecological benefit volume to money factors.). Then forest ecological benefits including water reservation, soil fixation, fertility reservation, C02 absorption, atmosphere purify, microclimate improvement, wind sand suppression, flood and draught mitigation, forest recreation, animal protection, plant protection and noise elimination n Forest Industry Group of Heilongjiang Province were calculated. The total ecological benefit in study area was 17.91 billions RMB ¥.

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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.

Heilongjiang Forest Industry Group occupies 10.054 million hm^2. The geographical coordinates is 120º40´-135º5´E and 43º41´-53º5´N. There are 40 forestry bureaus. The area is 8.893 million hm^2, which contains forbidden-cutting area 2.683 million hm^2, restricted-cutting area 3.878 million hm^2, and commercial forest area 2.332 million hm^2. Volume of standing tree is 567.09 million m^3, which contains forbidden-cutting forest 152.31 million m^3, restricted-cutting forest 247.68 million m^3, and commercial forest 166.73 million m^3. Many plantations of this area have been in the harvest-cutting period at the beginning of this century.

2 The integral diffusion model and monetary construction model

After calculating the forest ecological benefit of 40 Forestry Bureaus in Heilongjiang Provincial Forest Industrial Region, the analysis is shown as follows:

2.1 Variable description:

(1) Standardized ecological benefit dependent variable Y, Unit: Ecological benefit per hectare per year

(2) Regional independent variables:

JY —Average annual rainfall, unit: mm;

JD —Longitude (°);

WD—Latitude (°);

HB—Altitude, (m).

(3) Stand independent variables:

LF—Stand reaction value, qualitative variables, divided into: 1. coniferous forest 2.

broadleaf forest 3. mixed forest.

LZ —Age group, qualitative variables, divided into: 1. young, 2. medium 3. old;

YB — Canopy closure, qualitative variables, divided into 0.1, 0.2, 0.3….

(4) Three important parameters:

R —Effective area coefficient;

P —Market approximation coefficient;

C —According to the law of substitute goods, State Statistical Yearbook gets a reasonable price of the substitute goods and converts physical forest ecological benefit volume to money factors.

2.2 The integral diffusion model of forest water reservation

(1) The independent variable set of forest water reservation benefit is:

$$Y = I + K + Q \quad (1)$$

Where:

Y—Forest water reservation quantity(t/hm^2.a);

I —Canopy interception quantity(t/hm^2.a);

K —Water capacity of litters(t/hm^2.a);

Q —Storage capacity of forest soil non-capillary interstice(t/hm^2.a).

(2) The integral diffusion model of crown interception.

$$I = 6.9 \times EXP[-0.7849 + \sum b_i \times LF + \sum c_i \times LZ + 0.7612 \times \ln(JY) + 1.2388 \times YB] \quad (2)$$

Where:

b_i—Stand reaction value, parameter b_1= 0.0052, b_2= -0.1834,b_3=0;

c_i—Age group reaction value, c_1=-0.4921, c_2=-0.1919, c_3=0.

(3) The integral diffusion model of litter water capacity

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$$K = 25.374 + 16.542[68.58 + \sum b_i \times LF + \sum c_i \times LZ - 0.59JD + 0.4415WD + 0.0015HB] \quad (3)$$

Where:

b_i—Stand reaction value,

b_1= 4.83, b_2=-1.81, b_3=0;

c_i—Age group reaction value, c_1=-7.42, c_2=-3.04, c_3=0.

(4) The integral diffusion model of water storage capacity of forest soil capillary interstice

$$Q = -5085.55 + \sum b_i \times LF + 79.8JD - 72.462WD + 0.75HB \quad (4)$$

Where:

b_i—Stand reaction value,

b_1=-254.8,b_2=-72.462,b_3=0。

(5) The economic structure model of forest water reservation is:

$$E_i = \sum Pj \times Rj \times Cj \times \sum Yj(t) \times Sj(t) \qquad j=1, 2, 3, \ldots, n, \quad (5)$$

Where:

E_i—Forest water reservation money supply;

Yj—Forest water reservation dependent variable;

Sj—Forest resources and environment vector;

Cj = 0.652, RMB ¥/t

2.3 The integral diffusion model of soil and water conservation benefit of forest

(1) The integral diffusion model of forest soil fixation

$$Y_1 = 4 + \sum c_i \times LZ - 0.28445JD + 0.87825WD + 0.01762JY + 17YB \quad (6)$$

Where:

Y_1— Forest soil fixation (t/hm^2·a), woodland Y_1=0.

c_i—Age group reaction value, c_1= 6, c_2=-2.567, c_3=0.

(2) The integral diffusion model of forest fertility (including organic fertilizer, nitrogen, phosphorus, potassium).

$$Y_2 = -1.5 + \sum c_i \times LZ + 0.05195JD + 0.00039WD + 0.00009JY + 0.5YB \qquad (7)$$

Where:

Y_2—Forest fertility (t/hm^2.a), woodland ,

Y_2=0;

c_i—Age group reaction value, c_1=-3.3125, c2=-0.89391, c3=0;

A—Longitude.

(3) The economic structure model of soil and water conservation benefit of forest is:

$$E_i = \sum P_j \times R_j \times C_j \times \sum Y_j(t) \times S_j(t) \qquad \text{j=1, 2, 3, …, n (stand numbers)} \qquad (8)$$

Where:

R_j—Market approximation coefficient, R_1=0.4-0.6, R_2=R_1×0.05 (forest fertility effect is far away from the market).

C_j—Money conversion factor: C_1=14.89 RMB ¥/t, C_2=840.5 RMB ¥/t.

2.4 The integral diffusion equation of CO_2 absorption

(1) The integral diffusion equation of CO_2 absorption

This model is based on photosynthesis equation, and it is deducted from a series of hypothesis, deduction and regression:

$$Y = 0.95355 \times (-0.13631 + \sum c_i \times LZ + 0.00252JD - 0.00293WD - 0.00002JY + 0.00236YB) \qquad (9)$$

Where:

Y—CO_2 absorption (t/m^3.a)

c_i—Age group reaction value, c_1=0.07890, c_2=0.02197.

(2) The economic structure model of CO_2 absorption benefit is:

$$E_i = \sum P_j \times R_j \times c_j \times \sum Y_j(t) \times S_j(t) \qquad \text{j=1, 2, 3, …, n, (stand numbers)} \qquad (10)$$

Where: c_j =872.2 RMB ¥/t.

When using this formula, one should multiply hectare growing stock and convert to CO_2 absorption per hectare.

2.5 The integral diffusion equation of atmosphere purification

(1) The integral diffusion equation of atmosphere purification.

$$Y = 0.702 \times (-0.13631 + \sum c_i \times LZ + 0.00252JD - 0.00293WD - 0.00002JY + 0.00236YB) \qquad (11)$$

Where:

Y—Forest oxygen release (t/m^3.a);

c_i—Age group reaction value, c_1=0.07890, c_2=0.02197, c_3=0.

(2) The economic structure model of atmosphere purification of forest is:

$$E_i = \sum P_j \times R_j \times c_j \times \sum Y_j(t) \times S_j(t) \qquad (12)$$

Where:

Cj=1269.7 RMB ¥/t.

2.6 The integral diffusion equation of forest sand suppression

(1) The integral diffusion equation of sand suppression of forest is:

$$Y = 1.68262 + \sum c_i \times LZ + 0.01376JD - 0.03955WD - 0.00067JY + 0.41924YB \qquad (13)$$

Where:

Y — Forest sand fixation area($hm^2/hm^2.a$);

c_i — Age group reaction value, c_1=0.10423, c_2=0.06526, c_3=0.

(2) The economic structure model of sand suppression of forest is:

$$E_i = \sum P_j \times R_j \times c_j \times \sum Y_j(t) \times S_j(t) \qquad (14)$$

Where: Cj=450 RMB ¥/t.

2.7 The economic structure model of microclimate improvement of forest

Microclimate improvement of forest has eleven physical benefits, such as wind speed reduction and humidity improvement, but substitute goods cannot be found, so the money amount of its increased benefit is used to build the model.

$$E_i = \sum P_j \times R_j \times S \times 67.99605 LZ^{0.4931957} \text{ RMB ¥/hm}^2 \qquad (15)$$

Where:

Ei—Money amount of microclimate improvement of forest;

S—Forest resources and environment vector.

2.8 The economic structure model of flood and draught mitigation benefit of forest

The model is based on big flood information in 1998, and it is built after attentive hypothesis, deduction and argumentation. The model is mighty and widely open.

$$E_i = \sum 0.3 \times P_j \times R_j \times S \times 311.6941 LZ^{0.6183988} \text{ RMB ¥/hm}^2 \qquad (16)$$

2.9 The economic structure model of recreation resources benefit of forest

$$E_i = \sum P_j \times R_j \times S \times 12.33866 LZ^{0.8235893} \text{ RMB ¥/hm}^2 \qquad (17)$$

Where:

Pj=0.1 (forest park ration), Rj=0.2 (in total forest park benefit, forest is only 20%).

2.10 The economic structure model of wild plant conservation benefit of forest

$$E_i = \sum P_j \times R_j \times S \times 21.39681 LZ^{0.8760093} \text{ RMB ¥/hm}^2 \qquad (18)$$

2.11 The economic structure model of wild animal and plant conservation benefit of forest

$$E_i = \sum P_j \times R_j \times S \times 64.1137 LZ^{0.823598} \text{ RMB ¥/hm}^2 \qquad (19)$$

2.12 The economic structure model of noise elimination benefit of forest

$$E_i = \sum P_j \times R_j \times S \times 62.74023 LZ^{0.2500285} \text{ RMB¥/hm}^2 \qquad (20)$$

2.13 The economic structure summary model of general forest ecological benefit

There are different dimensions of physical forest ecological benefits but its economic volume has same dimension. So we can accumulate the money amount of each twelve ecological benefits and conclude the generalized economic model of forest ecological benefit:

$$E = \sum P_{ij} \times R_{ij} \times C_{ij} \times Y_{ij}(t) \times S_{ij}(t) \qquad i=1, \dots, 12, j=1, 2, 3, \dots, n \qquad (21)$$

3 The overall measurement of forest ecological benefit

The forest ecological benefit of forestry bureaus in Heilongjiang Province are shown in table 1.

Table 1. Forest ecological benefits of forestry bureaus in Heilongjiang Province Unit:10000 RMB ¥

Forestry bureau	water reservation	Water and soil reservation		CO_2 absorption	Atmosphere purify	Microclimate improvement	Wind sand suppression	Flood and draught mitigation	Forest recreation	Wild living things protection		Noise elimination	Total money
		Soil fixation	Fertility reservation							Animal protection	Plant protectio		
Total	619781	162194	58055.71	422358	452647	1525.3	5962.9	45034.6	174.8	6016.9	17451.7	6.5	1791208
Tanwang he	21750.4	6776	2346.3	11076.7	11871.1	43.1	163.6	1273.3	4.7	170.1	493.4	0.2	55968.9
Xinqing	16444.4	5147.3	1782.3	12621.6	13526.7	49.1	186.4	1450.9	5.4	193.8	562.2	0.2	51970.3
Youhao	21295.4	5897.1	2041.9	14460	15497	56.3	213.6	1662.2	6.2	222.1	644.1	0.2	61996.1
Shanggan ling	6489.6	1797.1	622.3	4406.6	4722.6	17.2	65.1	506.6	1.9	67.7	196.3	0.1	18893.1
Wuying	5959.4	1650.3	571.4	4046.6	4336.8	15.8	59.8	465.2	1.7	62.1	180.3	0.1	17349.5
Hongxing	20393.5	6353.3	2199.9	10385.8	11130.6	40.4	153.4	1193.9	4.4	159.5	462.7	0.2	52477.59
Cuiluan	10585.7	2931.4	1015	7187.9	7703.4	28	106.2	826.3	3.1	110.4	320.2	0.1	30817.7
Wumahe	6104.1	1690.4	585.3	4144.9	4442.1	16.1	61.2	476.5	1.8	63.7	184.6	0.1	17770.8
Meixi	11397.3	3156.1	1092.8	7739	8294	30.1	114.3	889.6	3.3	118.9	344.7	0.1	33180.2
Tieli	10826.5	2998	1038.1	7351.4	7878.6	28.6	108.6	845.1	3.1	112.9	327.5	0.1	31518.5
Taoshan	8688.7	2406.1	833.1	5899.9	6322.9	23	87.1	678.2	2.5	90.6	262.8	0.1	25295
Langxiang	20037	5548.6	1921.3	13605.6	14581.2	53	201	1564	5.8	209	606.1	0.2	58332.8
Nanca	14049.1	3890.5	1347.1	9539.7	10223.8	37.2	140.9	1096.6	4.1	146.5	425	0.2	40900.7
Jinshan tun	9414.9	2607.2	902.8	6393	6851.4	24.9	94.4	734.9	2.7	98.2	284.8	0.1	27409.3
Shuang feng	6304.6	1745.9	604.5	4280.9	4587.9	16.7	63.2	492.1	1.8	65.8	190.7	0.1	18354.2
Wuyiling	15886.7	4399.4	1523.3	10787.5	11561.1	42	159.3	1240	4.6	165.7	480.5	0.2	46250.3
Xinglong	19295.5	4661.9	1714.6	13919.5	14917.7	47.3	189.3	1395.9	5.2	186.5	540.9	0.2	56874.5
Qinghe	8801.8	2126.5	782.1	6349.5	6804.8	21.6	86.4	636.8	2.4	85.1	246.8	0.1	25943.9
Fangzheng	15402.2	3721.3	1368.6	11111	11907.8	37.7	151.1	1114.3	4.1	148.9	431.8	0.2	45399
Yabuli	21150.3	5110	1879.4	15257.5	16351.7	51.8	207.5	1530.1	5.7	204.4	592.9	0.2	62341.5
Weihe	11528.2	2785.3	1024.4	8316.3	8912.7	28.3	113.1	834	3.1	111.4	323.2	0.1	33980.1
Shanhetun	11309	2732.3	1004.9	8158.2	8743.2	27.7	111	818.1	3.1	109.3	317	0.1	33333.91
Tongbei	10687.5	3227	1076.3	6788.4	7275.2	30.2	112.5	892.6	3.3	119.3	345.9	0.1	30558.3
Zhanhe	42212.4	12745.5	4251	26812.1	28735	119.4	444.2	3525.6	13.1	471	1366.2	0.5	120696
Shuiling	9168.2	2538.8	879.1	6225.4	6671.9	24.2	92	715.6	2.7	95.6	277.3	0.1	26690.9
Hebei	25103.2	6951.6	2407.1	17045.6	18268.1	66.4	251.8	1959.4	7.3	261.8	759.3	0.3	73081.88
Heli	4204.2	1164.2	403.1	2854.7	3059.5	11.1	42.2	328.2	1.2	43.9	127.2	0	12239.5
Shuanya shan	6468.4	1791.2	620.2	4392.2	4707.2	17.1	64.9	504.9	1.9	67.5	195.7	0.1	18831.3
HUanan	6957.3	1926.6	667.1	4724.1	5062.9	18.4	69.8	543	2	72.5	210.4	0.1	20254.2
Dongfang hong	30935.7	6904.6	2639.6	23349.5	25023.9	71.5	291.4	2110	7.8	281.9	817.7	0.3	92433.9
Yingchun	15397.2	3436.5	1313.8	11621.4	12454.8	35.6	145.1	1050.2	3.9	140.3	407	0.1	46005.9
Linkou	13027.7	3147.5	1157.6	9397.9	10071.9	31.9	127.8	942.5	3.5	125.9	365.2	0.1	38399.5
Caihe	26051.3	6294.1	2314.9	18793	20140.7	63.8	255.6	1884.7	7	251.8	730.3	0.3	76787.49
Hailin	7723	1865.9	686.2	5571.3	5970.8	18.9	75.8	558.7	2.1	74.6	216.5	0.1	22763.9
Bamian tong	7364.8	1779.4	654.4	5312.8	5693.8	18	72.3	532.8	2	71.2	206.5	0.1	21708.1
Dahailin	20568.1	4969.3	1827.6	14837.5	15901.6	50.4	201.8	1488	5.5	198.8	576.6	0.2	60625.4
Muling	19803.3	4784.6	1759.7	14285.8	15310.2	48.5	194.3	1432.6	5.3	191.4	555.2	0.2	58371.1
Shuiyang	28456.3	6007.3	2355.8	21569	23115.8	65	273.9	1918.3	7.1	256.3	743.4	0.3	84768.49
Dongjing cheng	40299.3	9570.9	3753.3	22909.2	24552.2	69	290.9	2037.5	15.1	272.2	789.6	0.3	104559.5
Dailing	7678.4	1855.1	682.3	5539.1	5936.4	18.8	75.4	555.5	2.1	74.2	215.3	0.1	22632.7
others	4560.4	1101.8	405.2	3289.8	3525.7	11.2	44.7	329.9	1.2	44.1	127.9	0	13441.9

Ten forest ecological benefits of Forest Industry Group in Heilongjiang Province are shown in table 2.

Table 2 Forest ecological benefits of Forest Industry Group in Heilongjiang Province

Ecological benefit	Physical volume (t/hm^2)	Money volume (RMB ¥ $/hm^2$)	Area (hm^2)	Physical total (10,000t)	Total money volume (10,000RMB ¥)
		2014.2	8892772		1791208
water reservation	1796.5	696.9		1597578	619780.7
Soil fixation	30.1	182.4		26750.3	162194.1
Fertility reservation	3.9	65.3		3456	58055.9
$C0_2$ absorption	5.4	474.9		4806.1	422357.8
Atmosphere purify	4	509		3538.2	452646.7
Climate improvement	0	1.7		0	1525.2
Wind sand suppression	0.2	6.7		134.6	5963.1
Flood and draught mitigation	0	50.6		0	45034.5
Forest recreation	0	0.2		0	175
Animal protection	0	6.8		0	6016.6
Plant protection	0	19.6		0	17451.5
Noise elimination	0	0		0	6.1

*The zero in the table is not real zero but a relatively small digit.

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