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Original Research Paper

Measurement of Ecological Footprint Productivity in China

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ABSTRACT

Based on the traditional concept of productivity and from the environmental protection perspective, this paper put forward the concept of ecological footprint productivity (EFP), analysed its connotation, probed into its computation steps, and measured China's EFP. Results showed that EFPs of cultivated land, forest land, grassland, water areas, and whole land have displayed a tendency of increasing since 2001, showing the development track of the right half of the U-shaped curve. By contrast, the EFPs of fossil energy land and building land had shown no apparent tendency. The EFP of all kinds of lands in China was estimated to show a continuous accelerated growth trend in the coming years.

INTRODUCTION

As the environmental pollution becomes increasingly serious and resources become increasingly scarce, more and more researchers turn to the concept of green development. For a long time, people have paid more attention to economic growth and neglected its impact on natural resources and environmental protection. The destruction of the environment will restrict the development of the economy, and may even cause irreversible damage to society. The traditional productivity concept is not suitable for green development. Ecological footprint productivity, a new idea to measure the degree and intensity of human's use of natural resources, will play a more important role.

Ecological footprint is a measure of the degree of environmental sustainable development. The concept was first proposed in 1990s (William 1992, Wackernagelet al. 1991, 1997). Matjaz et al. (2010) calculated the yield rate of land area based on agricultural footprint research, aiming to find a feasible substitute to reduce the impact of climate change on agriculture. Some researchers took the ecological system of the African continent as an example and discussed models that can be used to measure the sustainability of the environment and the ecosystem (Safwat et al. 2013). Moreover, Weihua Meng used the concept of ecological footprint in sustainable development to introduce the concept of ecological footprint to economics, especially to the economic growth model, and showed its economic implications (Meng 2007). Zhang et al. (2013) used ecological footprint model to calculate ecological footprint of six provinces in Central China. Zhang et al. (2014) used the modified ecological footprint model to measure the ecological footprint of 31 provinces in China. Jin et al. (2014) adopted the Grey relationship analysis method to measure the relationship between ecological footprint of different land types, ecological footprint and economic growth. Furthermore, Wang et al. (2014) took the economical footprint as a variable based on the idea of green GDP account to measure the green technology efficiency in China from 2001 to 2010 with the SFA model. From the environmental protection perspective, the current paper will put forward the concept of ecological footprint productivity and calculate the ecological footprint productivity of different types of lands in China.

THE ECOLOGICAL FOOTPRINT PRODUCTIVITY

Concept of ecological footprint productivity: The ecological footprint of any known population (a person, a city, or a country) is the ecological productive area in the natural environment used to produce all resources consumed by the population and to receive all wastes produced. Compared with the biological productive land area to identify the sustainable development level, the ecological footprint model is used to measure the biological productive land area humans need. In the ecological footprint model, all resources used and wastes produced are transferred to six biological productive land areas (cultivated land, grass land, forest land, water area, building land and fossil energy land), which

Table 1: Selection of the ecological footprint indicators.

Account	The ecological footprint index	Consume resources
Biological resources account	Cultivated land	Cereal, beans, potato, cotton, oil plants, fibre crops, basudin, beet, tobacco, cocoon, tea, eggs
	Forest land	Wood, bancoul nut, tea seed, walnut, fruit
	Water area	Sea food
	Grass land	Pork, beef, mutton, milk, wool, honey
Energy resources account	Fossil fuel land	Coal, crude oil, natural gas
	Building land	Electric power

Note: These indicators come from the WWF classification standards.

Table 2: Basic information.

Year	GDP (billion yuan)	Year	GDP (billion Yuan)
2001	15781.27	2007	28627
2002	16537.02	2008	33702
2003	17381.72	2009	35226
2004	21412.73	2010	40533.6
2005	22420.00	2011	47486.21
2006	24040.00	2012	52373.63

Data source: China Statistical Yearbook 2013.

can produce these resources.

Productivity measures the output per unit of input. If we take ecological footprint into the measurement of productivity, we have the concept of ecological footprint productivity (EFP). In this concept, the input is the human's ecological footprint in the natural environment, not the traditional inputs. EFP is an economic output, which can be produced with a unit of ecological footprint. If we use GDP as an indicator of the level of economic development, EFP means that GDP can be produced with a unit of economic footprint.

Connotation of ecological footprint productivity from environmental protection perspective: EFP considers ecological footprint as the input and GDP as the output. The concept of ecological footprint includes six biological productive areas, which extensively cover all the resources used.

Productivity is the relation between the output and the input. EFP is the relation or ratio between output and ecological footprint. We can use this ratio to compare EFPs in different countries or areas, or to compare EFPs of the same country or area in different periods.

Measurement of the ecological footprint productivity: Before calculating the EFP, we need to calculate the ecological footprint first. The calculation of the ecological footprint is based on some facts. We may reserve most resources consumed and wastes produced, which could be transformed into biological productive land. The biological productive land can provide these functions. In the calculation of the ecological footprint, all resources and fossil consumption are converted into six ecological productive areas as mentioned above. Considering that these six different areas have different eco-productivities, we should translate them into areas with the same productivity to determine the ecological footprint and ecological carrying capacity.

The calculation of the ecological footprint model has three steps, namely, calculation of ecological footprint, calculation of ecological carrying capacity, and calculation of ecological surplus or deficit. When measuring ecological footprint productivity, only the ecological footprint is needed.

The model for computation of ecological footprint is:

$$EF = N \cdot ef = N\sum(\alpha a_i) = N\sum\left(\alpha \frac{c_i}{p_i}\right)$$

Where EF is the ecological footprint, N is the number of population, ef is the per ecological footprint $hm^2.cap^{-1}$, α is the proportional factor, i is the type of consumer goods and input, a_i is the per ecological productive area the ith consumer goods need to occupy, c_i is the per capita annual consumption of the ith consumer goods $kg.cap^{-1}$, and p_i is the average annual productivity $kg.hm^{-2}$ of the ecological productive area to produce the ith consumer goods.

The formula of EFP could then be:

$$PEF = \frac{GDP}{EF}$$

Where, PEF is the ecological footprint productivity and EF is the ecological footprint.

DATA SOURCES

The ecological footprint includes biological resources account and energy resources account, where biological resources account for four ecological footprint indicators (cultivated land, forest land, water area, grass land), whereas energy resources account covers two indicators (fossil fuel land, building land). In the present paper, the selection of ecological footprint indicators is made after the classifica-

Table 3: Consumption of biological resources between 2001 and 2012 (tons).

	Year	2001	2002	2003	2004	2005	2006
Cultivated land	Cereal	17758.03	17453.85	16065.56	17908.76	18058.84	18171.83
	Wheat	9387.30	9029.00	8648.80	9195.18	9744.51	10846.59
	Corn	11408.77	12130.76	11583.02	13028.71	13936.54	15160.30
	Beans	2052.81	2241.22	2127.51	2232.07	2157.67	2003.72
	Potato	3563.07	3665.87	3513.27	3557.67	3468.51	2701.26
	Peanut	1441.57	1481.76	1341.99	1434.18	1434.15	1288.69
	Rapeseed	1133.14	1055.22	1142.00	1318.17	1305.23	1096.61
	Sesame	80.41	89.52	59.28	70.38	62.54	66.17
	Cotton	532.35	491.62	485.97	632.35	571.42	753.28
	Fiber crops	68.14	96.37	85.30	107.36	110.49	89.09
	Sugarcane	7566.27	9010.69	9023.48	8984.94	8663.80	9709.22
	Beet	1088.86	1281.99	618.17	585.71	788.11	750.75
	Tobacco	234.96	244.65	225.74	240.60	268.30	245.56
	Tea	70.17	74.54	76.81	83.52	93.49	102.81
Forest land	Fruit	6658.00	6951.98	14517.41	15340.88	16120.09	17101.97
	Wood	4552.00	4436.10	4758.90	5197.30	5560.30	6611.78
	Bancoul nut	406716.00	389023.90	372645.00	381428.30	368688.00	382989.00
	Camellia seed	824731.00	854623.90	779492.00	874861.00	875022.00	919947.00
Grass land	Pork	4051.71	4123.10	4238.64	4341.00	4555.33	4650.45
	Beef	508.56	521.87	542.45	560.39	568.10	576.67
	Mutton	271.84	283.46	308.69	332.92	350.06	363.84
	Milk	1025.46	1299.78	1746.28	2260.61	2753.37	3193.41
	Goat hair	34240.52	35459.05	36691.65	37727.14	36903.88	40512.37
	Sheep wool	298254.17	307587.68	338058.23	373901.69	393171.59	388776.78
	Eggs	2210.10	2265.70	2333.07	2370.64	2438.12	2424.00
	Honey	25.16	26.46	28.88	29.32	29.32	33.26
Water area	Seawater aquatic products	2233.50	2298.45	2332.82	2404.47	2465.89	2509.63
	Freshwater aquatic products	1562.42	1656.40	1744.20	1842.09	1953.97	2073.97
	Year	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Cultivated land	Cereal	18603.40	19189.57	19510.30	19576.10	20100.09	20423.59
	Wheat	10929.80	11246.41	11511.51	11518.08	11740.09	12102.32
	Corn	15230.05	16591.40	16397.36	17724.51	19278.11	20561.41
	Beans	1720.10	2043.29	1930.30	1896.54	1908.42	1730.53
	Potato	2807.80	2980.23	2995.48	3114.12	3273.06	3292.78
	Peanut	1302.75	1428.61	1470.79	1564.39	1604.64	1669.16
	Rapeseed	1057.26	1210.17	1365.71	1308.19	1342.56	1400.73
	Sesame	55.72	58.63	62.20	58.66	60.54	63.94
	Cotton	762.36	749.19	637.68	596.11	659.80	683.60
	Fiber crops	72.83	62.49	38.80	31.75	29.55	26.12
	Sugar cane	11295.05	12415.24	11558.67	11078.87	11443.46	12311.39
	Beet	893.12	1004.38	717.90	929.62	1073.08	1174.04
	Tobacco	239.55	283.82	306.58	300.37	313.24	340.65
	Tea	116.55	125.76	135.86	147.51	162.32	178.98
Forest land	Fruit	18136.29	19220.19	20395.51	21401.41	22768.18	24056.84
	Wood	6976.65	8108.34	7068.29	8089.60	8145.92	8174.87
	Bancoul nut	361285.00	370966.00	367287.00	433624.00	437702.00	427048.00
	Camellia seed	939096.00	989859.00	1169289.00	1092243.00	1480044.00	1727708.00
Grass land	Pork	4287.82	4620.50	4890.76	5071.24	5060.40	5342.70
	Beef	613.41	613.17	635.54	653.06	647.49	662.26
	Mutton	382.62	380.35	389.42	398.86	393.10	400.99
	Milk	3525.24	3555.82	3518.84	3575.62	3657.85	3743.60
	Goat hair	38381.74	44406.09	49453.18	42713.79	44046.97	43924.12
	Sheep wool	363469.86	367687.43	364001.83	386768.29	393072.20	400057.00
	Eggs	2528.98	2702.20	2742.47	2762.74	2811.42	2861.17
	Honey	35.35	40.00	40.15	40.12	43.12	44.84
Water area	Seawater aquatic products	2550.89	2598.28	2681.56	2797.53	2908.05	3033.34
	Freshwater aquatic products	2196.63	2297.32	2434.85	2575.47	2695.16	2874.33

Data source: China Statistical Yearbook 2013.

Table 4: Consumption of energy resources between 2001 and 2012 (tons of standard coal).

	year	2001	2002	2003	2004	2005	2006
Fossil fuel land	Coal	102727.30	108413.08	128286.82	148351.92	167085.88	183918.64
	Crude oil	32788.51	35553.11	38963.90	45466.13	46727.41	49924.47
	Natural gas	3609.74	3826.34	4594.80	5336.40	6135.92	7501.60
Building land	Electric power	11280.45	11638.46	11946.48	14301.55	16047.80	17331.29
	Year	2007	2008	2009	2010	2011	2012
Fossil fuel land	Coal	199441.19	204887.94	215879.49	220958.52	238033.37	240913.51
	Crude oil	52735.50	53334.98	54889.81	61738.41	64728.37	68005.62
	Natural gas	9256.76	10783.58	11959.23	14297.32	17400.10	18810.06
Building land	Electric power	19074.54	22441.50	23918.47	27944.75	27840.16	34002.81

Data source: China Statistical Yearbook 2013.

Table 5: Consumption of average annual production of biological resources.

	Type	Average annual production of the world (kg/hm^2)		Type	Average annual production of the world (kg/hm^2)
Cultivated land	Cereal	2744	Forest land	Fruit	3500
	Wheat	2744		Wood	2
	Corn	2744		Bancoul nut	3000
	Beans	852		Camellia seed	3000
	Potato	12607	Grass land	pork	33
	Peanut	1856		Beef	33
	rapeseed	1856		Mutton	33
	Sesame	1500		Milk	502
	Cotton	1000		Goat hair	15
	Fiber crops	1500		Sheep wool	15
	Sugarcane	4893		Eggs	400
	Beet	4893		Honey	50
	Tobacco	1548	Water area	Seawater aquatic products	29
	Tea	566		Freshwater aquatic products	29

Table 6: Average global energy footprint and conversion coefficient of energy resources.

Energy resources	The average global energy foot print/(GJ.hm^{-2})	Conversion coefficient/(GJ^{-1})
Coal	55	20.934
Crude oil	71	41.868
Natural gas	93	38.979
Electric power	1000	11.840

tion by WWF (Table 1).

In this paper, the basic information ((i.e., GDP in Table 2, and consumption data of biological resources and energy in Table 3) comes from China Statistical Yearbook 2013. The world's average yield data for consumption resources (Table 5) and the world's average production data about the biological resources come from The Food and Agriculture Organization of the United Nations (FAO) database. When calculating the energy resources, the electricity is turned into the building land area, the other energy products are turned into the fossil fuel land area, the standard of average calorific value of the world's unit fossil energy production land area is used, and the reduction factor of fever used by the energy statistics (Table 6) is combined.

MEASUREMENT OF ECOLOGICAL FOOTPRINT PRODUCTIVITY

We can now calculate the ecological footprint of biological resources (Table 7). The formula is:

$$BEF = \overline{P}_B / \overline{P}_G$$

Where BEF is the biological resources' ecological footprint, $\overline{P_B}$ is the annual consumption of biological resources, and $\overline{P_G}$ is the global average annual production.

The formula of the ecological footprint of the energy resources account is:

$$EEF = Q \times c / EF_G$$

Where, EEF is the ecological footprint of the energy resources, Q is the total production quantity of energy, c is the convert coefficient, and EF_G is the average global energy footprint.

Table 7: Ecological footprint of the biological resources (10^4.hm^2).

	Year	2001	2002	2003	2004	2005	2006
Cultivated	Cereal	6471.59	6360.73	5854.80	6526.52	6581.21	6622.39
	Wheat	3421.03	3290.45	3151.90	3351.01	3551.21	3952.84
	Corn	4157.72	4420.83	4221.22	4748.07	5078.91	5524.89
	Beans	2409.40	2630.54	2497.08	2619.80	2532.48	2351.79
	Potato	282.63	290.78	278.68	282.20	275.13	214.27
	Peanut	776.71	798.36	723.05	772.73	772.71	694.34
	Rapeseed	610.53	568.55	615.30	710.22	703.25	590.84
	Sesame	53.61	59.68	39.52	46.92	41.69	44.12
	Cotton	532.35	491.62	485.97	632.35	571.42	753.28
	Fiber crops	45.42	64.24	56.87	71.57	73.66	59.39
	Sugarcane	1546.35	1841.55	1844.16	1836.28	1770.65	1984.31
	Beer	222.53	262.00	126.34	119.70	161.07	153.43
	Tobacco	151.78	158.04	145.83	155.43	173.32	158.63
	Tea	123.98	131.69	135.71	147.57	165.17	181.64
Forest land	Fruit	1902.29	1986.28	4147.83	4383.11	4605.74	4886.28
	Wood	2276000.00	2218050.00	2379450.00	2598650.00	2780150.00	3305889.30
	Bancoul nut	135572.00	129674.63	124215.00	127142.77	122896.00	127663.00
	Camellia seed	274910.33	284874.63	259830.67	291620.33	291674.00	306649.00
Grass land	pork	122779.02	124942.29	128443.68	131545.52	138040.23	140922.82
	Beef	15411.02	15814.34	16437.88	16981.41	17215.12	17474.90
	Mutton	8237.57	8589.75	9354.23	10088.58	10607.88	11025.36
	Milk	2042.74	2589.20	3478.65	4503.20	5484.81	6361.37
	Goat hair	2282701.33	2363936.67	2446110.00	2515142.67	2460258.73	2700824.33
	Sheep wool	19883611.33	20505845.33	22537215.33	24926779.33	26211439.47	25918451.80
	Eggs	5525.25	5664.26	5832.67	5926.60	6095.30	6060.01
	Honey	503.14	529.30	577.57	586.40	586.42	665.19
Water area	Seawater aquatic products	77017.22	79257.04	80442.10	82912.92	85030.79	86538.97
	Freshwater aquatic products	53876.72	57117.39	60144.88	63520.48	67378.32	71516.20
	Year	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Cultivated land	Cereal	6779.67	6993.28	7110.17	7134.15	7325.11	7443.00
	Wheat	3983.16	4098.54	4195.16	4197.55	4278.46	4410.47
	Corn	5550.31	6046.43	5975.72	6459.37	7025.55	7493.22
	Beans	2018.90	2398.22	2265.61	2225.98	2239.92	2031.14
	Potato	222.72	236.40	237.60	247.01	259.62	261.19
	Peanut	701.91	769.73	792.45	842.88	864.57	899.33
	Rapeseed	569.64	652.03	735.84	704.84	723.36	754.70
	Sesame	37.15	39.09	41.46	39.11	40.36	42.62
	Cotton	762.36	749.19	637.68	596.11	659.80	683.60
	Fiber crops	48.55	41.66	25.86	21.16	19.70	17.41
	Sugar cane	2308.41	2537.35	2362.29	2264.23	2338.74	2516.12
	Beet	182.53	205.27	146.72	189.99	219.31	239.94
	Tobacco	154.75	183.35	198.05	194.04	202.35	220.06
	Tea	205.92	222.19	240.04	260.61	286.79	316.21
Forest land	Fruit	5181.80	5491.48	5827.29	6114.69	6505.20	6873.38
	Wood	3488324.55	4054171.30	3534145.65	4044800.00	4072961.30	4087433.95
	Bancoul nut	120428.33	123655.33	122429.00	144541.33	145900.67	142349.33
	Camellia seed	313032.00	329953.00	389763.00	364081.00	493348.00	575902.67
Grass land	Pork	129933.85	140015.22	148204.71	153673.81	153345.45	161899.92
	Beef	18588.16	18580.85	19258.89	19789.56	19621.01	20068.53
	Mutton	11594.65	11525.75	11800.55	12086.58	11912.16	12151.18
	Milk	7022.40	7083.31	7009.63	7122.74	7286.55	7457.37
	Goat hair	2558782.37	2960406.20	3296878.73	2847585.73	2936464.73	2928274.87
	Sheep wool	24231324.26	24512495.13	24266788.93	25784552.87	26204813.00	26670466.80
	Eggs	6322.46	6755.49	6856.18	6906.84	7028.55	7152.93
	Honey	707.00	800.00	803.08	802.31	862.31	896.84
Water area	Seawater aquatic products	87961.66	89595.91	92467.43	96466.59	100277.54	104598.06
	Freshwater aquatic products	75745.94	79217.83	83960.29	88809.35	92936.56	99114.91

Table 8: Ecological footprint of energy resources (10^4.hm^2).

	Year	2001	2002	2003	2004	2005	2006
Fossil fuel land	Coal	39099.88	41263.99	48828.29	56465.44	63595.92	70002.78
	Crude oil	19335.06	20965.32	22976.63	26810.93	27554.69	29439.97
	Natural gas	1512.95	1603.73	1925.81	2236.64	2571.74	3144.14
Building land	Electric power	133.56	137.80	141.45	169.33	190.01	205.20
	Year	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Fossil fuel land	Coal	75910.94	77984.08	82167.66	84100.83	90599.83	91696.06
	Crude oil	31097.61	31451.11	32367.98	36406.53	38169.68	40102.24
	Natural gas	3879.78	4519.71	5012.46	5992.42	7292.89	7883.84
Building land	Electric power	225.84	265.71	283.19	330.87	329.63	402.59

Table 9: EFP of the biological and energy resources (Yuan.hm^2).

	Year	2001	2002	2003	2004	2005	2006
Cultivated land	Cereal	2438.55	2599.86	2968.80	3280.88	3406.67	3630.11
	Wheat	4613.02	5025.76	5514.69	6389.93	6313.35	6081.71
	Corn	3795.66	3740.70	4117.70	4509.78	4414.33	4351.22
	Beans	6549.88	6286.55	6960.81	8173.44	8852.98	10222.01
	Potato	55837.98	56871.14	62372.51	75878.36	81490.09	112196.60
	Peanut	20318.08	20713.62	24039.35	27710.66	29014.70	34622.90
	Rapeseed	25848.46	29086.41	28249.14	30149.35	31880.71	40687.49
	Sesame	294386.02	277086.20	439820.05	456335.76	537741.87	544931.13
	Cotton	29644.48	33637.68	35766.99	33862.10	39235.74	31913.82
	Fiber crops	347417.49	257407.75	305650.95	299171.40	304371.99	404767.86
	Sugarcane	10205.53	8979.96	9425.27	11660.91	12662.00	12115.06
	Beet	70916.04	63117.23	137582.33	178879.86	139195.29	156680.03
	Tobacco	103971.42	104635.31	119193.41	137766.51	129354.83	151547.90
	Tea	127293.87	125573.91	128076.29	145104.86	135739.65	132352.07
Forest land	Fruit	8295.95	8325.62	4190.56	4885.28	4867.84	4919.90
	Wood	6.93	7.46	7.30	8.24	8.06	7.27
	Bancoul nut	116.41	127.53	139.93	168.41	182.43	188.31
	Camellia seed	57.41	58.05	66.90	73.43	76.87	78.40
Grass land	Pork	128.53	132.36	135.33	162.78	162.42	170.59
	Beef	1024.02	1045.70	1057.42	1260.95	1302.34	1375.69
	Mutton	1915.77	1925.20	1858.17	2122.47	2113.52	2180.43
	Milk	7725.54	6386.92	4996.69	4755.01	4087.66	3779.06
	Goat hair	6.91	7.00	7.11	8.51	9.11	8.90
	Sheep wool	0.79	0.81	0.77	0.86	0.86	0.93
	Eggs	2856.21	2919.54	2980.06	3612.99	3678.24	3966.99
	Honey	31365.36	31243.42	30094.46	36515.86	38231.81	36139.95
Water area	Seawater aquatic products	204.91	208.65	216.08	258.26	263.67	277.79
	Freshwater aquatic products	292.91	289.53	289.00	337.10	332.75	336.15
Fossil fuel land	Coal	403.61	400.76	355.98	379.22	352.54	343.41
	Crude oil	816.20	788.78	756.50	798.66	813.65	816.58
	Natural gas	10430.80	10311.59	9025.65	9573.62	8717.82	7645.97
Building land	Electric power	118158.18	120007.92	122885.61	126455.36	117996.33	117152.57
	Year	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Cultivated land	Cereal	4222.48	4819.20	4954.31	5681.63	6482.66	7036.63
	Wheat	7187.00	8222.92	8396.83	9656.49	11098.91	11874.85
	Corn	5157.73	5573.87	5894.86	6275.16	6759.07	6989.46
	Beans	14179.50	14052.91	15548.16	18209.31	21199.92	25785.30
	Potatos	128534.83	142566.34	148254.83	164093.82	182905.04	200521.73
	Peanut	40784.34	43784.31	44451.84	48089.35	54924.85	58236.21
	Rapeseed	50254.34	51687.87	47871.97	57507.39	65646.70	69396.24
	Sesame	770587.65	862247.75	849560.61	1036401.74	1176473.28	1228718.07
	Cotton	37550.51	44984.70	55241.08	67996.48	71970.61	76614.71

Table cont...

....Cont. Table

	Fiber crops	589581.26	808938.55	1361918.70	1915157.87	2410401.47	3007500.75
	Sugarcane	12401.17	13282.38	14911.82	17901.72	20304.17	20815.21
	Beet	156833.59	164184.10	240091.75	213347.32	216526.27	218276.30
	Tobacco	184992.44	183814.69	177866.33	208896.52	234671.41	237997.36
	Tea	139020.88	151680.47	146748.88	155531.83	165580.13	165628.88
Forest land	fruit	5524.53	6137.14	6045.01	6628.89	7299.74	7619.78
	Wood	8.21	8.31	9.97	10.02	11.66	12.81
	Bancoul nut	237.71	272.55	287.73	280.43	325.47	367.92
	Camellia seed	91.45	102.14	90.38	111.33	96.25	90.94
Grass land	Pork	220.32	240.70	237.68	263.76	309.67	323.49
	Beef	1540.07	1813.80	1829.08	2048.23	2420.17	2609.74
	Mutton	2468.98	2924.06	2985.11	3353.60	3986.36	4310.17
	Milk	4076.53	4757.94	5025.37	5690.73	6516.97	7023.07
	Goat hair	11.19	11.38	10.68	14.23	16.17	17.89
	Sheep wool	1.18	1.37	1.45	1.57	1.81	1.96
	Eggs	4527.83	4988.83	5137.85	5868.61	6756.19	7321.98
	Honey	40490.66	42127.50	43863.62	50521.08	55068.36	58398.16
Water area	Seawater aquatic products	325.45	376.16	380.96	420.18	473.55	500.71
	Freshwater aquatic products	377.93	425.43	419.56	456.41	510.95	528.41
Fossil fuel land	Coal	377.11	432.17	428.71	481.96	524.13	571.17
	Crude oil	920.55	1071.57	1088.30	1113.36	1244.08	1306.00
	Natural gas	7378.51	7456.67	7027.68	6764.15	6511.30	6643.16
Building land	Electric power	126756.42	126838.81	124387.95	122507.64	144060.22	130090.67

Table 10: EFPs of six types of lands (Yuan.hm^2).

Year	Cultivated land	Forest land	Grass land	Water area	Fossil fuel land	Building land	Total
2001	1103236.47	8476.69	45023.15	497.82	11650.62	118158.18	1287042.94
2002	994762.10	8518.66	43660.94	498.18	11501.13	120007.92	1178948.91
2003	1309738.29	4404.69	41130.00	505.07	10138.12	122885.61	1488801.78
2004	1418873.79	5135.37	48439.43	595.36	10751.49	126455.36	1610250.79
2005	1463674.19	5135.20	49585.96	596.42	9884.02	117996.33	1646872.11
2006	1646099.90	5193.88	47622.54	613.94	8805.96	117152.57	1825488.78
2007	2141287.73	5861.90	53336.75	703.38	8676.18	126756.42	2336622.37
2008	2499840.06	6520.14	56865.60	801.59	8960.41	126838.81	2699826.61
2009	3121711.99	6433.08	59090.86	800.51	8544.69	124387.95	3320969.07
2010	3924746.62	7030.67	67761.82	876.59	8359.47	122507.64	4131282.82
2011	4644944.49	7733.12	75075.70	984.50	8279.52	144060.22	4881077.55
2012	5335391.70	8091.45	80006.46	1029.13	8520.33	130090.67	5563129.73

Data in Tables 1, 4, 5 and 6 are used to calculate the ecological footprint of energy resources (Table 8).

The analysis above gives the ecological footprint of the biological resources and energy resources. To calculate their *EFP*, we use the formula:

$$EFP = \frac{GDP}{EF}$$

The *EFP* of the biological and energy resources are given in Table 9.

The *EFP*s of the six types of lands are summarized in Table 10.

DEVELOPMENT TRACK OF THE ECOLOGICAL FOOTPRINT PRODUCTIVITY OF DIFFERENT LAND TYPES

We obtained the time series of *EFP* of all types of lands. We can now use Eviews to analyse and forecast these series.

The scatter diagrams of all seven time series show that, the *EFPs* of cultivated land (Fig. 1), forestry land (Fig. 2), grassland (Fig. 3), water areas (Fig. 4), and total land (Fig. 7) display an increasing tendency, which can be interpreted as the right half of the U-shaped curve. The *EFPs* of fossil energy land (Fig. 5) and building land (Fig. 6) display no

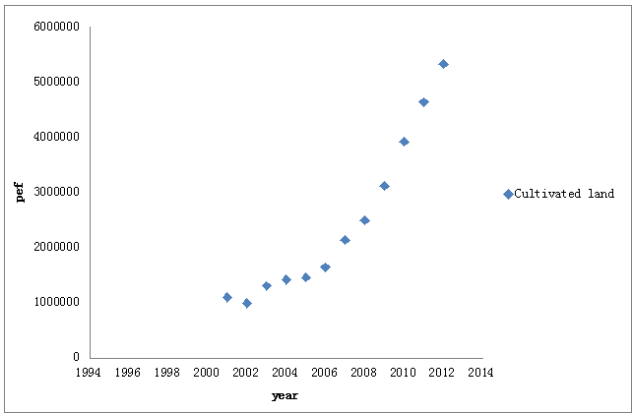

Fig. 1: EFP of cultivated land.

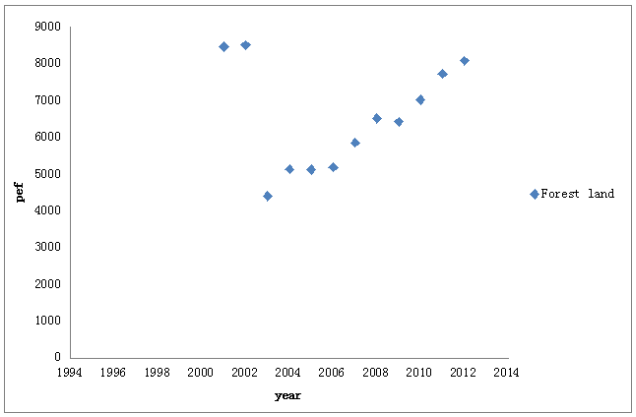

Fig. 2: EFP of forestland.

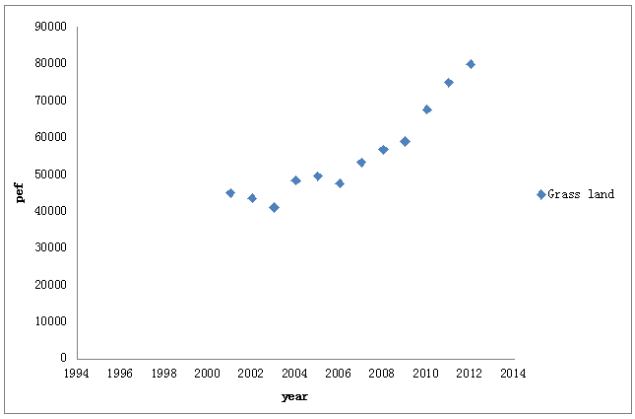

Fig. 3: EFP of grass land.

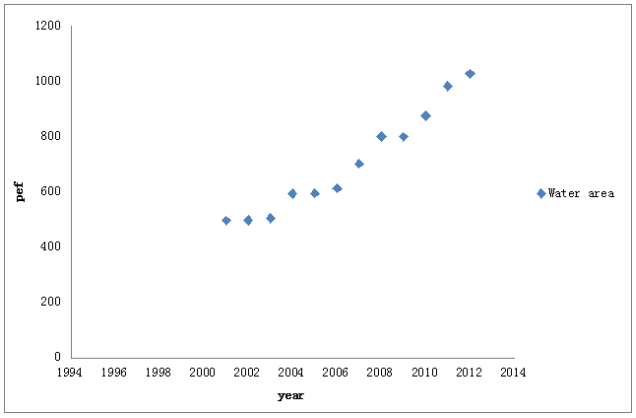

Fig. 4: EFP of water area.

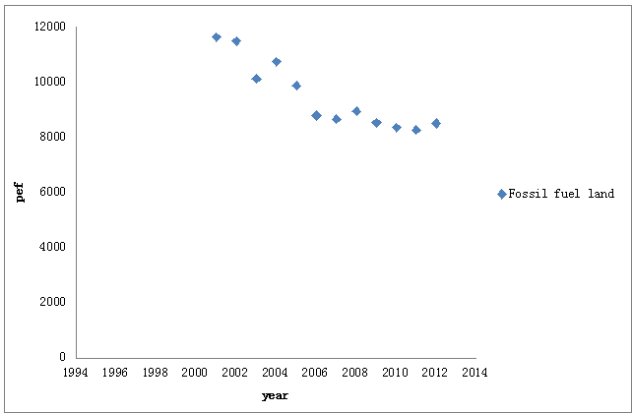

Fig. 5: EFP of fossil fuel land.

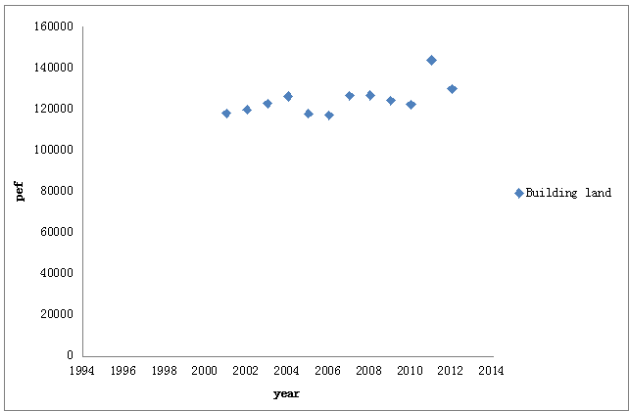

Fig. 6: EFP of building land.

apparent tendency.

These figures were attempted to fit with Eviews. The regression equations are summarized in Table 11.

Statistical tests show that all models are usable. Thus, we can use them to forecast *EFP* in the future. The forecast for 2013 to 2015 is depicted in Table 12.

CONCLUSION

Considering the increasingly serious problems of environmental pollution and the depletion and degradation of natural resources, based on the traditional concept of productivity and from the environmental protection perspective, the present paper put forward the concept of ecological foot-

Table 11: Regression equations.

Land type	Regression equation	*R2*	*F*-statistics	Prop (*F*)
Cultivated land	$\lambda_1 = 43871.4t^2 - 186313.8t + 1301695$	0.99	880.1	0.0000
Forest land	$\lambda_2 = 21.8t^2 + 60.4t + 43036$	0.98	204.8	0.0000
Grass land	$\lambda_3 = 375.9t^2 - 1618.7t + 4591.6$	0.98	191.3	0.0000
Water area	$\lambda_4 = 3.01t^2 + 11.7t + 469.1$	0.98	270.3	0.0000
Fossil fuel land	$\lambda_5 = 33.9t^2 - 755.6t + 12577.6$	0.93	57.6	0.0000
Building land	$\lambda_6 = 1927.5t + 109512.5$	0.78	35.9	0.0001
Total land	$\lambda = 44535.8t^2 - 190584.1t + 1490633$	0.99	861.3	0.0000

Table 12: Forecast of EFP in 2013-2015.

Year	Cultivated land	Forest land	Grass land	Water area	Fossil fuel land	Building land	Total EFP
2013	6293890.09	8775.74	88281.74	1130.59	8495.23	134570.49	6539590.95
2014	7292105.28	9425.19	96813.32	1223.62	8656.79	136498.03	7551473.54
2015	8378063.36	10118.27	106096.78	1322.66	8886.28	138425.57	8652427.73

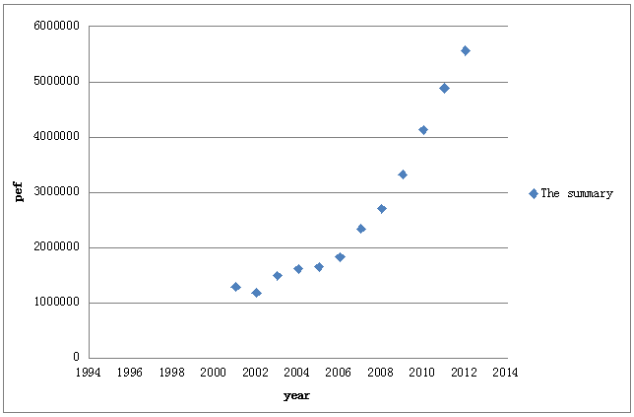

Fig. 7: EFP of all land types.

print productivity (*EFP*), analyzed its connotation, probed into its computation steps, and measured China's *EFP*.

The *EFP*s of cultivated land, forest land, grass land and water area have shown a steadily increasing tendency over the past decade. The *EFP*s will continue to increase in the coming years, which mean that the economic output per unit ecological footprint of these four types of biological resources land in the natural environment will grow steadily.

When it comes to the energy resources land, the *EFP*s of fossil fuel land and building land have not shown an obvious trend over the past decade. However, the regression equation shows that both land types will keep rising in the coming years, which means that per unit ecological footprint of economic output is growing.

The total *EFP* also shows a growing tendency, which means that people are paying more attention to environmental protection. This result implies that the growth rate of ecological footprint is less than that of GDP, and that the productivity per unit of ecological footprint is growing steadily.

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