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Connotation of forest degradation and the measure of forest degradation in China

Hui-Min Chen *
Department of Economics
Hunan Institute of Engineering
Xiangtan 411104
Hunan
China

and

School of Economics
Huazhong University of Science & Technology
Wuhan 430074
China

Yun-Bao Xu †
School of Management
Hunan Institute of Engineering
Xiangtan 411104
Hunan
China

Abstract

Forestry ecological profit or deficit index is chosen for measuring the degree of forest degradation in China. Calculating results of the whole regions' and provinces' forest degradation shows: on the whole, China's forest resources appears a tendency of degradation, however it is relatively stable before 1990, then the deficit gradually is expanding; forest degradation in regions behaves much difference, the Central Regions and the East Regions of China exists deficit, the West Regions of China appears surplus in some years; in individual provinces, there are 17 provinces in deficit, 14 provinces in surplus which experience decrease.

Subject Classification: *62P12, 65K05.*
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*E-mail: chenhuiming0218@126.com (Corresponding Author)
†E-mail: xyb@hnie.edu.cn

Introduction

Living Planet Report 2016 shows the ecological footprint of global per capita is about 2 global hectares in 2012, biological capacity of per capita is about 1.2 global hectares, and ecological deficit is 0.8 global hectares; Global Footprint Network shows In 2016 human demand for ecological resources cannot be maintained unless there are about 1.6 earths. The data from Global ecological network in 2016 states Chinese ecological demand is about 3.3 global hectares in 2012,and ecological supply is about 0.8 global hectares, so the ecological deficit is about 2.5 global hectares. Overall, the world's resources are excessively overloading, including China's.From the overall data it is hard to tell the specific conditions of the forest ecological supply and demand in the world and China, but it can be expected that world and China's forest resources would have great pressure.The data from *China statistics yearbook 2015*, states China's forest coverage rate reached 21.63%, and forest stock is about 15.1 billion m^3; while China,s forest coverage rate is only 16.55% in 2000, and the forest stock is about 11.2 billion m^3. It suggests that China's forest protection is strengthening, and the number of forest resources is increasing.Combined with the literature research result, this paper puts forward the definition of forest degradation,and has a contrast analysis on common measures, finally determines using the theory of ecological footprint to measure the forest degradation degree in China and it's provincial (municipalities) area. This paper aims to know about China's forest resources status, and to provide some references for production practice and academic research.

1. Definition of Forest Degradation

On forest degradation,the domestic scholars mainly define it from the perspective of the forms,forest growth process and causes of degradation. LI Zhi-yu,PANG Yong(2011)[1]define the forest degradation as "the decreasing of forest coverage, the loss of forest structure function, and the decline in quality", and think that human disturbance effect is much greater than the natural disturbance;ZHU Jiao-jun,LI Feng-qin(2007)[2] define the forest degradation as "the abnormal state such as biological function decline in growth process, slow development, or death, fall in production and soil fertility decline"; MA Jiang-ming et al. (2010) [3] think that forest degradation is the comprehensive representation of disorder in forest structure, function, productivity and ecological processes caused by man-made or natural disturbance.

Foreign scholars commonly use five core words:degradation, fragmentation, disturbance, devegetation, decline to describe the process of decline or degradation , and often collocate them with the core words such as forest, range, land, and ecosystem,biological to define the degradation process of forests, forest range, forest land, forest ecology, forestry biology[4-6].

There is still no unified definition on the forest degradation among the domestic scholars, international organizations, foreign scholars .But a unified comparison basis must be needed in order to credibly measure forest degradation,thereby, this paper attempts to summarize the definition of forest degradation as : forest degradation (including decline) is a trend of forest coverage rate drop, biodiversity decrease, and the forest ecological function weakening (reversible or irreversible) resulting from the fact that the long-term supply of forest resources can't satisfy the human demand for forest resources due to nature factors and human factors or a combination of both , is a concrete manifestation of ecological resources impoverishment, and this trend can be measured by forest ecological deficit.

2. Comparison and selection of forest degradation measure index

Because of no consensus on the definition of forest degradation, and different forest managements and the management goals in different countries, the selection of forest degradation measure index from scholars and practitioners has strong arbitrariness. At present commonly used index are the normalized difference vegetation index (NVDI), the forest coverage rate, and living wood growing stock per unit area, etc. The normalized difference vegetation index determines the vegetation distribution by using remote sensing satellite imaging technology to measure the reflectance of near infrared and red channel, hereby, the density of the vegetation spatial distribution and growth state can be reflected. But the index is easy to be affected by the weather and the clouds, and easy to be overestimated[7].Forest coverage rate index is widely used in various statistical literature, but is difficult to timely and continuously monitor dynamic changes of forest resources due to long measurement cycle. Living wood growing stock per unit area has the same defects with the forest coverage rate. Considering that deforestation is a comprehensive concept related to the economic development and environmental needs of human society , the theory of ecological footprint comes to be mature and can be applied to specific forestry department, and the continuous data of

trade, consumption, production can be easily obtained from the statistical department, this paper selects the forest ecological surplus and loss index to measure forest degradation.

Forest ecological profit and loss is the difference between ecological carrying capacity of forest resources and forest ecological footprint. The positive difference shows the ecological surplus occurs, forest degradation is decreasing, forest ecological function is rehabilitating and strengthening, and the forest is in a state of sustainable development; the negative difference indicates forest degradation is increasing, forest ecological function is weakening, and the forest is in a state of non-sustainable development.Ecological footprint refers to the total ecological productive land area, denoted by biological productive land or waters , which is needed by production of the consumed natural resources by a certain amount of population and is needed by the absorption of wastes arising from the consumption[8-11], and which include six types of land area:cultivated land, grassland, forest land, waters, fossil energy land and construction land.The ecological carrying capacity refers to the number of resources or energy which can be supplied from certain regional ecological productive land [12].

3. China forest degradation measure based on the theory of ecological footprint

3.1 *National forest degradation measure (1961-2015)*

3.1.1 Calculation formula

The main methods of Calculating the ecological footprint are product land use matrix method and the input-output method, with the measuring unit of global hectare, regional hectare and national hectare. For building the comparable continuous data , global hectare is used for the national level to facilitate international comparison, and national hectare is used for state (or provincial) level. This paper adopts the method proposed by Wackernagel and Rees to measure the forest ecological footprint, and the specific index is mainly calculated on the basis of the following three formulas[13-15]:

Forest ecological footprint = (timber production ÷ global forests output) × forest equilibrium output factor;

forest ecological capacity = forest area × forest output factor × forest equilibrium output factor;

Forest ecological profit and loss = forest ecological footprint – forest ecological carrying capacity.

$$EF_c = EF_p + EF_i - EF_e \quad (1)$$

$$EF_p = YF \times EQF \times IYF \times P \div Y \quad (2)$$

$$EF_p = EQF \times IYF \times P \div Y_w \quad (3)$$

$$Y^d = Y^p \times EXTR \quad (4)$$

EF_c is the ecological footprint about the forest good and waste related to consumption; EF_p is the ecological footprint about the forest good and waste related to production; EF_i is the ecological footprint about the forest good and waste related to import; EF_e is the ecological footprint about the forest good and waste related to export;the measure unit of EF_c, EF_p, EF_i, EF_e is global hectare(gha).

YF denotes forest production factor, with the unit of the ratio of world woodland area to national woodland area (wha/ha); *IYF* denotes inter-temporal production factor, with the unit dimensionless *EQF* denotes Equilibrium output factor, with the unit of the ratio of the global hectares to the world forest land area(gha/wha); *P* denotes the quantity of the produced forest good or waste , with the unit of cubic meter per year (m^3 yr 1); *Y* denotes the national average output of forest good production or waste absorption ,with the unit of cubic meter per hectare per year (m3 ha-1 yr 1); Y_w denotes the word average output of forest good production or waste absorption ,with the unit of cubic meter per year per world hectare (m3 wha - 1 yr 1).

Y^d is the secondary forest good production derived from primary good, with the unit of cubic meter per hectare per year (derivative m3 ha - 1 yr 1); Y^p is represented as primary forest good production with the unit of cubic meter per hectare per year (primary m3 ha - 1 yr 1); *EXTR* is the conversion rate of primary forest good into secondary good ,with the unit of (derivative m3) (primary m^3- 1) .

$$BC = A \times YF \times IYF \times EQF \quad (5)$$

BC is the ecological carrying capacity of forest land, with the unit of global hectare (gha); *A* is the woodland area, with the unit of hectare (ha); the connotation and unit of *YF*, *IYF*, *EQF* are identical to the formula (2).

3.1.2 Determination of parameter values and their data source

(1) Determination of parameter values. Forest equilibrium output factor values as follows: due to lack of calculation data in 1961-1989, set equilibrium output factor value as 1;Parameter value in 1990-1991 is set as 1.32[16]; set 1.65[17]in 1992-1995; set 1.78[18] in 1996; set 1.56 in 1997-1998 (average of 1996 and 1999); set 1.35[19] in 1999; set 1.38 in 2000 (average of 1999 and 2001); set 1.4[20] in 2001; set 1.37 in 2002 (average of 2001 and 2003); set 1.34[21] in 2003; set 1.33 in 2004 (average of 2003 and 2005); set 1.26[22] in 2007-2015. Respectively set the inter-temporal production factor and the conversion rate of forest derivatives as 1 and 1.84[23] . Forest output factor is: 0.91[24] in 1961-2000, 0.95[25] in 2001-2003, 0.55[26] in 2004, 0.60[27]in 2005-2006 from the calculating value of Chenmin et al. (2005), 0.91[28] in 2007-2009, 0.86[29] in 2010-2015 .

(2) Data source. Calculating data origin from forestry resources statistical libraries[30] of the United Nations Food and Agriculture Organization.

3.1.3 Measure results

By calculation of STATA 14 software and analysis on it, it is found that: 1) China forestry ecological footprint in 1961-1990 is stable, roughly keeping 500 million global hectares, then presents the rising trend-up to 1781.3million global hectares in 2015; 2) forest ecological carrying capacity in 1961-1990 is stable, roughly keeping about 11.343 thousand hectares, then is followed by a slightly higher level and keeping roughly stable; 3) China forest is in the state of ecological deficit- it is relatively stable 1990 years ago, then a trend of gradually expanding occurs.[31]

By analysis from the perspective of import and export trade,it is found that 1) the ecological footprint of Chinese forest good export is roughly stable, about 25.05 million global ha on average; 2) before 1980 the ecological footprint of forest good import is stable in 29 million global hectares, afterwards,it has the sharp rise; 3) generally, the ecological footprint data on foreign trade of forest good reflect China has occupied the productive land of other countries. If 10 years is set as stage calculating mean, China's per capita forest ecological footprint is shown as table 1.

Table 1

Stage data on China forestry ecological footprint(Global hectares per capita)

Stage	Import Ecological Footprint	Export Ecological Footprint	Net Ecological Footprint	Ecological Footprint of Consumption	Carrying Capacity	Ecological Deficit
1961—1970	0.034	0.003	0.031	0.571	0.143	–0.428
1971—1980	0.036	0.002	0.034	0.455	0.113	–0.342
1981—1990	0.113	0.002	0.111	0.461	0.109	–0.351
1991—2000	0.200	0.031	0.168	0.590	0.198	–0.392
2001—2010	0.563	0.047	0.516	0.859	0.158	–0.701
2011—2015	0.879	0.066	0.813	1.266	0.175	–1.091

3.2 *Regional forest degradation measure (1980-2015)*

3.2.1 Difficulty and extension of Measure

There is much difficulty to precisely measure the forest ecological footprint of China's 31 provinces (municipalities) by using global hectare , and it is shown as: 1) the lack of the forest goods import and export data in provinces, autonomous regions and municipalities; 2) difficulty to precisely measure output factor and equivalence factor of all kinds of forest good because of the great regional difference of forest good and obvious productivity difference; 3) no continuous time series data on the land area of forest good production. In order to depict China regional characteristics of forest degradation from the actual situation, the paper will have an extension on the basis of the theory of ecological footprint: 1) national and provincial hectare take the place of global hectare for the unit; 2) forest output factor is adjusted by using the average growth rate of forest growing stock, namely,it is adjusted by the average growth rate of of forest growing stock in 1978-2015 multiplied by the data in table 1.

3.2.2 Determination of the scope of the forest good

In consideration of data continuity, stability, availability, and representativeness, based on *China statistics yearbook* and *China forestry statistics yearbook,* the main forest goods are determined as 8 kinds of primary goods : wood, bamboo, rubber, resin, raw lacquer, tung seed, tea seed, walnut, not including the related secondary goods. Such decision results from the following facts: 1) the wood and bamboo are key woody forest goods in each area at the provincial level , and its ecological footprint can basically represent the use status of forest land (forest degradation degree); 2) the choice of these 6 kinds of primary goods results from the role of artificial forest in forest land use;3) not involving the use of secondary goods mainly results from the incompleteness and discontinuity of data, which makes it hard to calculate conversion rate of secondary goods to primary goods.

3.2.3 Determination of all kinds of output factor and equivalence factor

The parameters in 3.1.2 section are adopted for measurement data to make the calculation unified and the benchmark consistent.

3.2.4 Data sources and processing

*The d*ata of 8 kinds of primary goods origin from past years *China Statistics Yearbook, China Forestry Statistics Yearbook, China Forestry Yearbook, National Forestry Statistics Data* , and the national forest land data origin from all previous forest inventory and parts or all of *China Land Resources Bulletin* and *China Land Resources Statistical Yearbook* in1980-2014;The forest land area data of the provinces, autonomous regions and municipalities are gotten from the 1980-2014 forest land area of the provinces (municipalities) statistical yearbook plus afforestation area, the land area data of the provinces, autonomous regions and municipalities are gotten from *A Brief Account of Administrative Divisions the People's Republic of China · 2012*, and bamboo forest area data origin mostly from *National Forestry Statistical Data* in 1949-1949 and *China Statistical Yearbook 2002*, partly from the calculating information released by the local forestry department.

Because the data of some provinces (municipalities) in some years are missing, combined with its change trend, the adjacent data are selected instead to keep the analysis integrity.

Forest land can be classified into five major types: timber land, bamboo forest, tea forest, fruit forest, and economic forest, among which

the existing statistical data are adopted for the first four types , and economic forest area data are obtained from the woodland area minus the other 4 types area.

3.2.5 Measure results

According to 1980-2015 forest land occupancy data of the provinces (municipalities) calculated by using STATA14 statistical software,it is found by analysis that:1) In the period of calculation there are the eight provinces (autonomous regions and municipalities) where the forest is in a state of ecological deficit, including Tianjin, Jilin, HeiLongjiang, Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Shandong, and Henan; 2) since the early 1990s, the forest in Hunan province has been in a state of ecological deficit; 3) the forest in Liaoning, Jiangxi, Hubei, Hainan, Guangxi,and Guangdong has been in a state of ecological deficit since the early 21st century.Since 2000, there have been a total of 17 provinces (autonomous regions and municipalities) where the forest has been in a state of ecological deficit, and 14 provinces (autonomous regions and municipalities) where the forest has been in a state of ecological surplus, but surplus degree has been a trend of decline.

According to the regional division standard from National Statistics Bureau, the 31 provinces (autonomous regions and municipalities) are divided into three regions: 1) the East, the Central and the West , from the analysis it is found that:in the East except Beijing and Hebei in the forest ecological surplus state, Tianjin, Liaoning, Shanghai,Jiangsu, Zhejiang, Fujian,Shandong, Guangdong, and Hainan are in the forest deficit (degradation) state, and the number of provinces, autonomous regions and municipalities in the forest degradation state is 29% of the country's, and up to about 53% of all provinces (autonomous regions and municipalities) in a state of forest degradation; 2) in the central except the Shanxi Province in forest ecological surplus, since the early 1990s, Jilin, HeiLongjiang, Anhui,Jiangxi, Henan, Hubei, and Hunan have been in a state of forest deficit (degradation), which account for about 23% of the country's forest, and about 41% of all provinces (autonomous regions and municipalities) in a state of forest degradation; 3) in the West except that Guangxi has been in a state of deficit (degradation)since 2001, Inner Mongolia, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shanxi, Gansu, Qinghai, Ningxia and Xinjiang are in forest ecological surplus, but overall it tends to decline.

Table 2

Forest ecological index of the East, the Central and the west(National hectare)

Stage	the East			the Central			the West			Total(country)		
	ECC	EF	EP/L	ECC	EF	EP/L	ECC	EF	EP/L	ECC	EF	EP/L
1980—1989	2.35	1.25	1.11	2.67	3.08	–0.41	23.76	6.59	17.18	10.91	28.79	17.88
1990—1999	3.32	2.40	0.92	3.54	4.25	–0.71	28.16	12.62	15.53	19.28	35.02	15.74
2000—2009	2.41	3.19	–0.77	2.40	3.67	–1.27	23.15	11.45	11.70	18.31	27.97	9.66
2010—2015	2.43	4.02	–1.59	2.42	2.77	–0.35	21.59	14.24	7.35	21.03	26.44	5.42
1980—2015	2.67	2.48	0.18	2.82	3.56	–0.74	24.62	10.69	13.93	16.74	30.10	13.37

Notes: ECC denotes Ecological carrying capacity; EF denotes Ecological Footprint; EP/L denotes Ecological profit or loss.

To clearly analyze its trend, setting 10 years as time period, the forest ecological index average in the East, the Central and the West can be calculated as (see Table 2), and it is found that:1) as to the eastern forest ecosystem, 1990-1999 is turning interval, and before it forest ecosystem is surplus , but after it forest ecosystem is in a state of deficit with the strong trend of degradation. 2) the central forest ecosystem is in forest ecological deficit state, as the turning interval of 2000-2009, expanding before it, and shrinking after it; 3) the western forest ecosystem is in forest ecological surplus, but surplus is showing a trend of shrinking;4) on the whole,China's forest ecology is surplus, but surplus is gradually decreasing.

4. Conclusion

It is concluded from measures that there are two inconsistent points. Firstly, China's forest ecological surplus measured by national hectare is not consistent with the conclusion released from the official media and global ecological footprint network; Secondly, the conclusion of national forest ecology measured by national hectare is not consistent with that measured by global hectare. The results of the first case come from two

aspects. (1) there are many differences between data base and data size:the database used in global ecological footprint network (GFN) origins mainly from direct trade organization database, global land use database, global agricultural ecological sections data, etc., with wide data sources and great data size; the data base used in this paper is based on all serials of data related to forestry from the United Nations Food and Agriculture Organization and the land area released by China Statistics Bureau, which are professional but not too many; the data official media often adopt in report are forest coverage rate calculated from the measure data.(2) there is the difference in data processing method:the data in the global ecological footprint network (GFN) origin from wide resources with large quantity, so the fusion processing will be conducted on data with complex methods; in this paper the smoothing processing method is used for some missing data;As to the forest coverage rate adopted by the official media, the statistical method is mainly used for dealing with measurement error, so the data processing method is easy to lead to being overvalued and undervalued. The results of the second case come from three sides.(1) the used units are not consistent:the used unit in table 1 is global hectare, and the unit in table 2 is national hectare.(2) There is a difference in data sources:the data in Table 1 mainly come from the database of the United Nations Food and Agriculture Organization, and the data in Table 2 come from the Statistics Bureau of the state, the provinces and cities.(3) There is a difference in measure methods.The data on the last column of Table 1 are directly calculated from the database of the United Nations Food and Agriculture Organization, and the data on the last column of Table 2 are obtained from the mean value of the measurements on the East, the Central and the West .

As to global hectare unit, compared with the global ecological footprint,the result from this paper has a certain advantage due to the consistency of the data (the database of the United Nations Food and Agriculture Organization used in this paper is submitted by the own country on the basis of forest land area of the own country, so the data is consistent;while the consistency can not be kept easily due to wide resources of the global ecological footprint network data). As to national hectare unit, the national ecological surplus index reflects forest resources status on the quantity and quality, while the forest coverage rate (the official media often use) just reflects the quantity feature, so the surplus index is superior to the forest coverage rate index. Measuring the forest degradation from the perspective of the whole and the regions not only is conductive to people's right recognition on the history and present status

of forest resource, also contributes to promoting the cooperation between the forestry sectors home and abroad, and promoting the progress of forest resources protection and reasonable development.

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