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Green GDP Accounting Model Prioritizing Sustainable Development

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Abstract: In today's highly developed economic and social context, humanity is increasingly realizing the importance of sustainable development alongside the full utilization of resources. Consequently, some scholars advocate for the adoption of Green Gross Domestic Product (GGDP) as a more reflective measure of economic health, replacing GDP, while also assessing the sustainability of economic and social development. This paper, taking into account the direction of human society towards sustainable development, refines previous research efforts. Using forestry as an example, it establishes a GGDP accounting model based on the principle of maximum sustainable development and demonstrates its validity.

1. Introduction

Since the 1970s, with the advancement of industrialization and the deepening of human environmental awareness, people have increasingly realized the important role of ecological environment in economic development. But as shown in Fig.1, the proportion of green GDP index in most cities is extremely low.

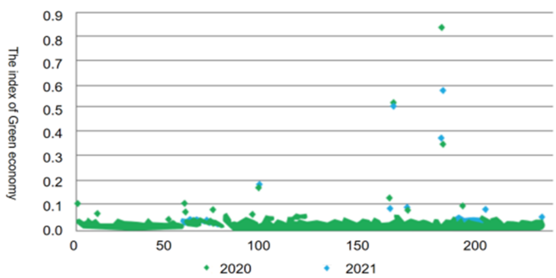

Fig.1. The green economy index of more than 200 cities in a country is generally low

However, by only counting those goods and services that are priced in the market, GDP, as an important indicator to measure economic, ignores a large number of economically valuable inputs and outputs that are not bought and sold in the marketplace such as the wide range of ecosystem service values associated with protected natural areas.[1] Green Gross Domestic Product (GGDP), as a new concept proposed in the ideology of sustainable development, and better reflects the health status of socioeconomic development compared to GDP. But there is still no unified accounting standard to date. In order to explore more reasonable indicators to measure the health status of economic development while ensuring the principle of sustainable development, this paper focuses on the "key industries" affecting economic sustainability, and discusses the optimal accounting method for GGDP. Main purposes of Green GDP accounting are to provide a more correct measure of welfare and to examine the sustainability of economy[2]. However, the measurement standards for sustainability vary by industry, such as determining the optimal rotation period using the growth cycle of forests, or determining the closed fishing season using the breeding cycle of fish. Taking forestry as an example, this paper explores the GGDP accounting method and its feasibility of implementation, and evaluates its impact on global climate mitigation.

2. Establishment of GGDP Accounting Model

2.1. Meaning of GGDP

Currently, the most widely used comprehensive economic growth indicator in the world is GDP and its growth rate. However, the inadequacy of GDP lies in its failure to fully reflect the relationship between resources, environment, and economy.

This paper selects appropriate research models by studying Wang Yuchen's Resource and Environment Improvement Benefit Model[3], Zhang Jiexia's County Forest Resource Ecological Environment Value Accounting Model[4], Zhang Ling's GGDP Forest Resource Accounting Model[5], Saša Stjepanović[6], Rui Pedro Mota[7], and others' GGDP accounting models. Building upon the traditional GDP and considering the principles of sustainable development, this paper proposes a GGDP accounting method that takes into account partial ecological benefits, with regional sustainable development potential as the primary indicator of regional economic health. Using forest resources as an example,

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this study demonstrates the calculation of global GGDP, while simplifying GDP measurement to the price of available forest stock, and converting the ecological benefits brought by forest sustainable development into measurable economic value based on certain principles as the basis for GGDP analysis.

2.2. Selection of GGDP Accounting Model Based on Maximizing Sustainable Development Principle

Through comparison with Wang Yuchen's Resource and Environment Improvement Benefit Model[3], Zhang Jiexia's County Forest Resource Ecological Environment Value Accounting Model[4], as well as Saša Stjepanović[6], Rui Pedro Mota[7], and others' Green GDP accounting models, the team found that Zhang Ling's GGDP Forest Resource Accounting Model[5] has a more comprehensive scope of accounting, and its methods and formulas are more in line with the current research content. This model comprehensively addresses the valuation issues of forest and woodland, making it more reasonable and applicable. Its accounting of forest ecological benefits is more detailed, with more complete indicators, making it more conducive to assessing the sustainable development potential of a region. Ultimately, this paper selects Zhang Ling's GGDP Forest Resource Accounting Model as the foundational model, and modifies and supplements data accordingly, to estimate the GGDP of forests on a global scale[5].

2.3. Establishment of GGDP Accounting Model Based on Maximum Sustainable Development Principle

2.3.1. Factor Selection and Model Construction

The model presented in this paper is a modification based on Zhang Ling's GGDP accounting model focusing on forest resources. Taking into account factors such as computational redundancy, parameter homogeneity, and practical considerations, certain parameters and indicators have been adjusted to streamline and enhance the efficiency of the model. Despite these modifications, the model maintains a high degree of equivalence in estimating GGDP values and their impacts. Hence, it can be preliminarily concluded that the model established in this paper possesses a certain level of reference value and feasibility.

The model consists of four main components: the evaluation factor of water conservation benefit, the evaluation factor of water quality improvement benefit, the evaluation factor of carbon oxygen balance benefit , and the evaluation factor of air purification benefit. The primary functions of forests include climate regulation, water source purification, air purification, and ecological balance maintenance. Since climate factors are not quantifiable, the four categories of evaluation factors established in this model correspond to the assessment and estimation of forest functions other than climate regulation. This also demonstrates the comprehensiveness, applicability, and feasibility of the model.

Factors selected which is considered the functionality of the forest:

(1) The evaluation factor of water conservation benefit (Z):

$$Z = R \times W \quad (1)$$

$$R = \sum_{i=1}^{n} (P_i - E_i) \times S_i \times 10 \quad (2)$$

$$P_i = Q \times r_i \quad (3)$$

In the equations, where Z represents the economic value of forest water storage, R represents the annual water storage of forests, W represents the price of water, Q represents the annual precipitation in the region, P_i represents the total annual precipitation of the class i of forest, E_i represents the total annual preliminarily of the class i type of forest, S_i represents the area of the class i of forest, and r_i represents the coverage rate of the class i type of forest.

The model also includes the soil and water conservation benefit evaluation factor q. However, due to its homogeneity with the evaluation factors of water conservation benefits, the small short-term impact of soil erosion on forest ecological benefits, the large gap in soil composition content worldwide and the lack of relatively complete statistical data, this model ignores the impact of the evaluation factors of water and soil conservation benefits.

$$q = \sum_{i=1}^{n} \left[(D_{i0} - D_i) \times S_i \times \frac{1}{100} \right] \quad (4)$$

In the equation, represents the soil erosion modulus.

(2) The evaluation factor of water quality improvement benefit (V):

$$V = \sum_{i=1}^{n} R_i \times S_i \times \Delta P \quad (5)$$

The evaluation factor of carbon oxygen balance benefit (V_1):

This model retains the evaluation factor V_1 of carbon-oxygen balance and divides it into the benefit V11 of carbon dioxide fixation and the benefit V22 of oxygen generation:

(A) The benefit of carbon dioxide fixation(V_{11}):

According to the data released by China's Henan Provincial Forestry Bureau, 1.63 t was used to calculate the amount of carbon dioxide required by a forest to produce one ton of dry matter.

$$V_{11} = \sum_{i=1}^{n} M_i * d_i * k * 0.2729 * C_i \quad (6)$$

In the equations, where M_i represents the current stock volume of the class i type of forest, d_i represents the average net dry weight of wood in the class i type of forest, k represents the amount of carbon dioxide required to produce one ton of dry matter in forests, and C_i

represents the afforestation cost of the class *i* type of forest.

The EPA has studied the costs of carbon sequestration in cold temperate, temperate, and tropical forests and determined that the typical cost of sequestration for afforestation is less than$30/t(C).

(B) The benefit of oxygen generation (V_{12}):

According to the data published by the Forestry Bureau of Henan Province of China,1.19 t was used in this article to represent the amount of oxygen released by a forest to produce 1t of dry matter. According to related industrial oxygen enterprises published data, take $128.89/t to represent the market unit price of liquid oxygen.

$$V_{12} = \sum_{i=1}^{n} M_i * d_i * P * k \tag{7}$$

In the equation, where P represents the unit price of industrial oxygen production.

According to the above analysis， the total benefit of the forest in terms of carbon and oxygen balance should be the sum of the benefit of absorbing carbon dioxide and releasing oxygen:

$$V_1 = V_{11} + V_{12} \tag{8}$$

(3) The evaluation factor of air purification benefit (V_2):

The benefits of forest air purification are mainly reflected in the absorption of sulfur dioxide. The evaluation of sulfur dioxide purification effect of forests is mainly measured in terms of the engineering cost of reducing sulfur dioxide. According to public data, the average price of manual processing is calculated, which is expressed by $0.44/kg in this article.

$$V_2 = p \sum_{i=1}^{n} I_i * S_i \tag{9}$$

In the equation, where p represents the cost of sulfur dioxide reduction projects, and I_i represents the absorption capacity of sulfur dioxide by the class *i* type of forest.

According to the above model，the GGDP of global forest resources is preliminarily estimated as follows:

Take the evaluation factor of water conservation benefit as an example: Precipitation Q is the global average annual precipitation -- 870 (mm). Coverage r is 1. Area S is 4.06 billion (ha) according to the data published by the United Nations. The evapotranspiration ratio of precipitation in most regions of the world ranges from 0.4 to 0.9, so we take the average evapotranspiration ratio -- 0.65. Considering that the average water price for grain and forage irrigation is generally lower than $0.05/cubic meter according to UN statistics, the water price in this paper is $O.05/cubic meter.

If you do the same thing with the rest of the factors, we get V_G.

According to the law of natural economic development, the development of social economy is accompanied by the input of resources and the change of environment. Therefore, the economic development is inevitably accompanied by the reduction of the economic and ecological value of forest resources, among which the ecological value occupies the vast majority of the value of forest resources. In 2022, the world's gross domestic product reached10i.5593 trillion dollars. According to the calculation of the model, the sum of the ecological value and social value of global forest resources is 14.71 times of the economic value.

According to the formula: GGDP forest resource accounting is equal to traditional GDP minus forest resource waste minus environmental pollution; further calculation is equal to GD minus forest resource ecological value loss minus forest resource social value loss. The available global GGDP value is 95.7663 trillion dollars.

$$\frac{GGDP}{GDP} = \frac{95.7663(\text{Trillion dollars})}{101.5593(\text{Trillion dollars})} = 94.2559\%$$

example verification:

The GGDP of Heilongjiang Province calculated by Zhang Ling in the Research on forest resource accounting of green GDP is as follows[5]:

$$\text{GGDP} = 4235.4 - 7.768 \times 9.02 = 416533.264$$

（million yuan)

$$\frac{\text{GGDP}}{\text{GDP}} = \frac{4165.33264}{4235.4} = 98.35\%$$

The above example verify that the GGDP value calculated by this model is within a reasonable range, which can be said to indicate that this model has certain applicability and feasibility.

2.3.2. Calculation of Maximum Sustainable Development

Since this model takes the principle of maximum sustainable development as the main basis to measure whether the economy can develop healthily and calculate GGDP based on it, how to design the maximum sustainable development scheme is the primary problem in the application process of this model. For example, in the utilization and production of forest resources, the growth cycle of forest should be considered to set the optimal rotation period, so as to ensure the sustainable utilization of forest resources.

As shown in Fig.2 and Fig.3, according to the research results of the application of the Faustmann model by Sun JosephChang[8], the LEV of a forest (it is the present value of profits from planting and harvesting wood for an unlimited cutting cycle at the beginning of the cutting cycle) reaches its maximum value during the rotation period of 10 to 11 years. As shown in the figure below, when the base forest area was 64 acres and 66 acres, the LEV size reached its maximum when the rotation period was between 10 and 11 years.

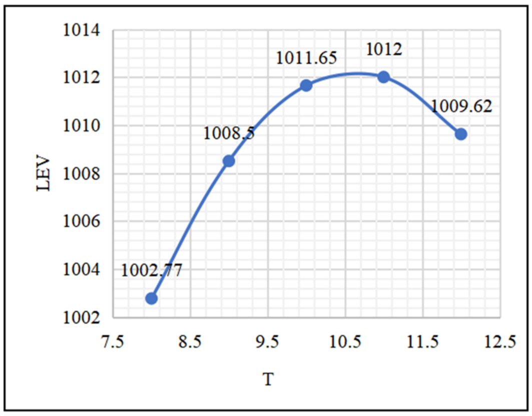

Fig.2. When the area is 64 acres, the LEV change curve under different rotation periods

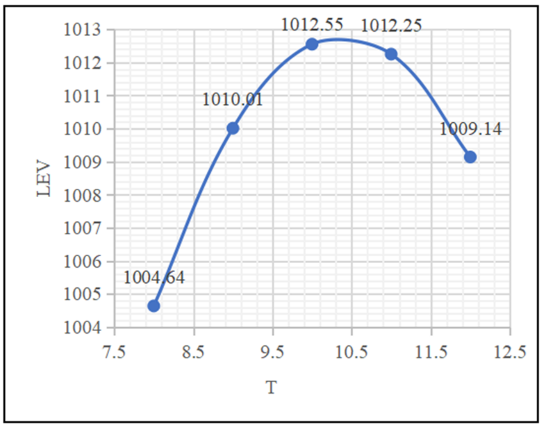

Fig.3. When the area is 64 acres, the LEV change curve under different rotation periods

In fact, according to the research of Sun Joseph Chang, no matter what the base area is, LEV can always reach its maximum value when T is 10-11 years. At this point, if T is the growth cycle of the forest, it also proves the rationality of considering the maximization principle of sustainable development.

According to the research of Zhang Huietal[9], the growth cycle of forest is 10-15 years. So 10 years is not only the best rotation period with the highest LEV, but also the growth cycle of forest. The rationality of the model has been proved by fully considering the principle of maximizing economic benefits and sustainable development.

In fact, the growth cycle of trees varies from five to eight years, but considering the carbon sequestration factor, which is when the forest reaches its maximum carbon sequestration capacity, the growth cycle of the forest is 10-15 years.

3. China's GGDP accounting

3.1. GGDP accounting of China's forest resources

China's forest resources are rich and diverse. In order to facilitate the study, the forest species in China are divided into four types: coniferous forest, tropical rainforest, deciduous broad-leaved forest and evergreen broad-leaved forest. According to the statistics of China Forestry Yearbook, the average annual precipitation of coniferous forest is 800mm/a, tropical rainforest is 2000mm/a, deciduous broad-leaved forest is 800mm/a, and evergreen broad-leaved forest is 1000mm/a, Some other data used are listed in the table below:

According to the above data, other data in Table 1, and the model established in 2.3, it can be obtained that.

Table 1 Partial data list of China GGDP forest resource accounting

data item	coniferous forest	tropical rainforest	deciduous broad-leaved forest	evergreen broad-leaved forest
P_i	800	2000	800	1000
E_i	400	2600	350	600
r_i	0.27	0.45	0.16	0.11
D_i	1000	200	200	350

$$\begin{cases} Z = R \times W \\ R = k\sum_{i=1}^{4}(P_i - E_i) \times S_i \\ P_i = Q \times r_i \end{cases}$$

In the formula. k is the unit conversion coefficient, and the calculated water conservation benefit is \$250 billion. By the same token, China's annual GGDP is \$17.9 trillion.

3.2. China Daihai Basin GGDP accounting examples

For the calculation of total GGDP, this paper is based on the research foundation of Li Jinlei et al.[10], combined with the model established in this article, taking Daihai Area as an example for calculation. At this time, GGDP consists of GDP and EDC(environmental degradation and ecological damage cost).

Environmental degradation mainly considers the three major factors of water， air and soil pollution. Water pollution cost and soil pollution cost are calculated using the evaluation factor Z of water conservation efficiency and the evaluation factor V of water quality improvement; air pollution cost is calculated using the evaluation factor V of carbon and oxygen balance efficiency and the evaluation factor V, of air purification efficiency. It should be noted that factors such as Z and V here are different from those in 3.3, which only considers the accounting situation of the part of forest resources occupied in GGDP, while here refers to the total amount of GGDP involving the whole local industry.

Taking Daihai River Basin as an example, the cost of environmental degradation and ecological damage in 2019 obtained by consulting the data and calculating above is:

$EDC = Z + V + V_1 + V_2 = 2116.38$ (ten thousand dollars)

After consulting the local GDP data and according to the research of Li Jinlei et al.[10] , the discounted GDP of 2019 is:

$GDP_T = 52740.13$(ten thousand dollars)

As a result, the total local GGDP for 2019 is:

$GGDP = 50623.75$(ten thousand dollars)

According to other data, GGDP change table of Daihai Basin can be obtained by using the same calculation process.

Table 2 Annual variation of GGDP in Daihai Basin

Year	1989	1996	2004	2011	2019
GDP_T	4770.68	12960.22	31911.50	94204.10	52740.13
EDC	2071.93	2363.06	1935.31	2677.18	2116.38
GGDP	2698.75	10597.16	30556.19	91526.92	50623.75

According to Table 2, the curve war drawn and fitted to obtain the timing curve of the three changes as Fig.4 shows:

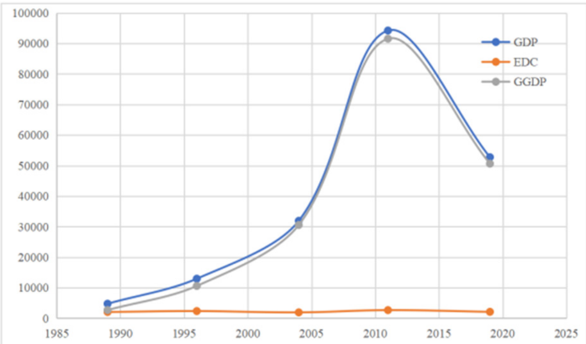

Fig.4 Time sequence curve of GDPT, EDC, GGDP

4. Summary and Outlook

On the whole, China's level of sustainable development continues to improve. However, in the process of economic development, there is excessive consumption of natural resources, so that the potential of comprehensive sustainable development is decreasing. This shows the importance of shifting economic indicators and industrial restructuring, which will transform China towards green, high-quality development and enhance China's sustainable development capacity. Promoting the transformation of GDP accounting system to GGDP accounting system is an effective countermeasure to cope with the neglect of ecological environment due to economic development.

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