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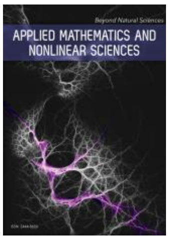

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Green GDP accounting system from the perspective of resources and environment and a case study of Chongqing

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Abstract

Green GDP represents the net positive effect of national economic growth. The positive effect of national economic growth will be enhanced if there is a higher percentage of green GDP in GDP. From the perspective of resources and environment, this paper introduces SEEA-2012 accounting system with indirect calculating methods of green GDP in China, within which the value of natural resource depletion, environmental pollution damage and environmental quality degradation are included. In order to reasonably select valid indicators and data so as to get accurate accounting results, different valuation methods and operational formulas in economics are adopted to construct a new accounting system model, and the green GDP of Chongqing City in 2018-2020 is accounted for. Results show that the green GDP of Chongqing in recent three years is 1,838.889 billion Yuan, 1,964.724 billion Yuan and 2,111.2 billion Yuan, respectively, and proportions of green GDP in traditional GDP are 90.30%, 91.01% and 89.44% respectively. By studying and analyzing the dependence of Chongqing on natural resources and the ecological environment in the process of economic development, this paper provides theoretical support for the sustainable development of the urban economy and environment, provides a reference basis for the local government to formulate economic development planning, and also provides a reference for the construction of green GDP accounting system in similar ecological areas.

Keywords: Green GDP; Accounting system model; Resource depletion; Ecological benefit; Chongqing city.
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1 Introduction

Gross domestic product (GDP) is an important indicator for the government to measure and diagnose the macroeconomic operation of the national economy. Green GDP is a new aggregate indicator adjusted from the original GDP indicators by taking into account resources and environmental factors [1]. Our economy has experienced rapid growth for 40 years. [2]. By pursuing the growth of GDP one-sidedly, China has paid a heavy price for its natural resources and ecological environment. Since the 1990s, our government and scholars have also conducted discussions and research on green GDP. Direct and indirect measurement methods are the main accounting methods. Direct measurement methods include the production method and expenditure method, while indirect measurement methods include methods such as SEEA-based equilibrium calculation method, social welfare measurement method, energy analysis method, and input-output analysis method. It adjusts traditional GDP indicators and integrates resources, environments, ecology, society, welfare, and other factors [3-7].

On the basis of large numbers of academic studies, SEPA and NBS jointly released China Green National Accounting Study Report 2004 in September 2006, which is the first published green GDP accounting report in China. The report shows that the rapid growth of GDP in China is at the cost of the loss of resources and environments, ringing the alarm bell of mindlessly pursuing inflated GDP [8-10]. This paper adopts the SEEA-2012 published by the UNSA to construct a new green GDP accounting system based on traditional national accounting systems from the perspective of resources and environments. The SEEA-based equilibrium calculation method and accounting are exemplified in this paper by utilizing Chongqing City as an example.

2 Indicator selection

The SEEA-2012 system has three main aspects: firstly, the accounting of the physical quantity of the natural environment. The loss of natural resources, environmental pollution, and the opening and closing of stocks are reflected in physical accounting. Secondly, the accounting of the value of natural environments. The actual expenditure for environmental protection is the only thing listed in the current national economic accounting accounts. Values of natural resource depletion, environmental pollution damage and environmental quality degradation, however, are not reflected [11]. Through market estimation methods, NPN methods, shadow price methods, and other methods, the value of natural environmental resources is monetized in accounting. Thirdly, to establish connections with national accounts. As a subsidiary environmental satellite account of the SNA, the SEEA-2012 Framework must incorporate the value of resource consumption and pollution damage into its accounting system with the help of the input-output table of the national accounts. To make the value calculation of resources and environment have realistic reference value, this paper comprehensively considers the characteristics of Chongqing City and the accessibility of data and selects indicator factors that have important influences on the development of Chongqing City. Relevant data of statistical data and accounting projects are from Chongqing Statistical Yearbook (2018-2020), Guideline for Chinese Environmental and Economic Accounting, and China Financial Yearbook (2018-2020).

3 Construction of the model of green GDP accounting system

3.1 Model of depletion value accounting of natural resources

Accounting for natural resources means measuring the amount of natural resources consumed due to economic activities in a period of a region [12]. Based on the SEEA asset classification, as well as characteristics of Chongqing, changes have been made to the classification of natural resources, including four major categories, namely, water resource, energy resource, forest resource and land resource (Note: the relevant indicators in the formula are expressed in capital letters, for example, the abbreviation of natural resources is NR).

$$C_{NR} = C_{WR} + C_{ER} + C_{FR} + C_{LR} \tag{1}$$

It is able to evaluate natural resources through methods such as market approach, net rent approach, and income capitalization approach. In this regard, this paper relies on specific types of natural resources for the appropriate valuation method.

3.1.1 Depletion value accounting of water resource

Industrial water, residential water, and urban public water are the main focus of the depletion value accounting of the water resources section. To value water resources using the market approach, it is necessary to categorize different types of water usage and match each type with corresponding prices.

$$C_{WR} = \sum_{i=1}^{n} Q_W \times P_W \tag{2}$$

In the formula, C_{WR} represents the depletion value of water resources (yuan/a); Q_W denotes the physical volume of water resources depleted in the current period (cubic meters); P_W is the unit market price of water resources during the accounting period (yuan); n refers to various types of water usage (industrial water, residential water and urban public water).

3.1.2 Depletion value accounting of energy resource

Accounting is done using the net rent approach in this section. The net price of natural resources refers to the balance of the market price of natural resource products minus the cost of natural resource development (that is, the cost of survey, development, exploitation, and reasonable operating profit) [13-15].

$$C_{ER} = \sum_{i=1}^{n} Q_E \times P_E \tag{3}$$

In the formula, C_{ER} represents the depletion value of energy resources (yuan/a); Q_E denotes the physical volume of energy resource depleted in the current period (tons); P_E is the net price of energy resources in the accounting period (yuan); n refers to various types of energies.

3.1.3 Depletion value accounting of forest resource

Depletion value accounting of forest resources plays an indispensable role in green national economic accounting [16]. Numerous factors need to be taken into account when creating a complete set of forest resource accounts in this context. Due to the set prices of forest land and forest trees in the market, it is appropriate to evaluate forest resources through the market approach.

1) Value of forest land

The accounting of stock and flow should be included based on the dynamic balance process of forest land value. Since this paper focuses on the value changes of forest land resources in Chongqing, it is sufficient to evaluate the newly added forest land area (that is, the flow change).

$$C_{FLR} = Q_{FL} \times P_{FL} \tag{4}$$

In the formula, C_{FLR} represents the depletion value of forest land resources (yuan/a); Q_{FL} forest land denotes the area of newly added forest land in the current period (mu); P_{FL} is the transferring price of forest land during the accounting period (yuan/mu/a).

2) Value of forest trees

The depletion value of forest trees due to tree logging in the current period is what forest tree value accounting refers to.

$$C_{FTR} = Q_{FT} \times P_{FT} \tag{5}$$

In the formula, C_{FTR} represents the depletion value of forest tree resources (yuan/a); Q_{FT} Denotes the area of forest trees harvested in the current period (cubic meters); P_{FT} is the comprehensive average wood price during the accounting period (yuan/cubic meter).

3.1.4 Depletion value accounting of land resource

Land resource falls into 8 categories, namely, farmland, forest land, residential land, industrial and mining land, transportation land, garden land, grassland, water area and undeveloped land [17-19]. In this section, two factors should be explained as follows. Firstly, since forest land is included in the category of forest resource, the depletion value of forest land is not taken into consideration when accounting for the depletion value of land resources. Secondly, due to factors such as the incomplete basic statistical data of several types of land use such as grassland, residential land, industrial and mining land, water area and undeveloped land, as well as the difficulty in evaluating the market value, the 6 items mentioned above are not included in this section of accounting. Therefore, for the depletion value accounting of C_{LR}, it is represented by that of the farmland recourse. The income capitalization approach is used for related accounting based on the actual situation.

$$C_{LR} = C_{FLR} = S \times \frac{P}{r} \tag{6}$$

In the formula, C_{LR} represents the depletion value of the land resource, that is, the depletion value of farmland resource (yuan/a); S denotes the depletion of farmland area in the current period (mu); P is the net income per unit area of farmland during the accounting period (yuan); r refers to the capitalization rate.

$$r = \frac{i}{a} \tag{7}$$

In the formula, r represents the land income capitalization rate; i denotes the one-year regular interest rate of the bank; a is the price index.

3.2 Model of the accounting of environmental degradation costs

The accounting of environmental degradation costs includes three steps: water pollution control costs, air pollution control costs, and solid waste pollution control costs.

$$C_E = C_{WPC} + C_{APC} + C_{SPC} \tag{8}$$

3.2.1 Accounting of water pollution control cost

Wastewater contains CODcr, BODs, ammonia nitrogen and other pollutants. This section is only targeted at the wastewater control cost in statistical data.

To this end, the replacement cost method is used to take into account the environmental degradation costs caused by municipal wastewater, including industrial wastewater and household wastewater, etc.

$$V_W = \sum_{i=1}^{n} Q_W \times P_W \tag{9}$$

In the formula, $V_{\mathrm{wastewater}}$ represents the wastewater pollution cost (yuan/a); $Q_{\mathrm{wastewater}}$ denotes the current wastewater discharge volume (tons); $P_{\mathrm{wastewater}}$ is the average control cost per unit area of wastewater during the accounting period (yuan); n refers to each types of wastewater (industrial wastewater, household wastewater, livestock and poultry breeding wastewater).

3.2.2 Accounting of air pollution control cost

The main air pollutants include sulfur dioxide, smoke, dust, and nitrogen dioxide [20]. The cost of air pollution is taken into account using the replacement cost method. Based on the national retail price index of rural commodities from 2018 to 2020, it tries to evaluate the average unit control cost of sulfur dioxide, smoke and nitrogen dioxide in each year.

$$V_G = \sum_{i=1}^{n} Q_G \times P_G \tag{10}$$

In the formula, V_G represents the waste gas pollution cost (yuan/a); Q_G denotes the current waste gas emissions (tons); P_G is the average unit control cost of waste gas during the accounting period (yuan); n refers each types of waste gas (sulfur dioxide, smoke dust, nitrogen dioxide).

3.2.3 Accounting of solid waste pollution control cost

In this regard, the replacement cost method is used to evaluate the costs of environmental quality degradation caused by local solid waste pollution.

$$V_S = \sum_{i=1}^{n} Q_S \times P_S \tag{11}$$

In the formula, V_S represents the pollution cost of solid waste (yuan/a); Q_S denotes the amount of solid waste generated in the current period (tons); P_S is the average unit control cost of solid waste during the accounting period (yuan); n refers to each type of solid waste (industrial solid waste, household solid waste).

3.3 Model of value accounting of ecological benefits improvement

In this section, mainly targets at the accounting of the improvement value of urban forest resources [21-22]. To this end, the LY/T1721-2008 assessment method issued by the State Forestry Administration in 2008 is performed to evaluate the ecological benefits brought by the soil conservation and biodiversity protection of the urban forest.

3.3.1 Accounting of soil conservation value

1) Soil consolidation value

The sediment accumulation in the reservoir caused by soil erosion may reduce the water storage capability. The opportunity cost approach can be used to evaluate forest soil consolidation by considering the cost of water storage.

$$U_S = A \times C_S \times \frac{X}{\rho} \tag{12}$$

In the formula, U_S represents the soil consolidation value of the forest (yuan/a); A denotes the newly added area of forest land in this period (hm^2); C_S is the cost of the average storage capacity (yuan/m^3); ρ is the forest soil volume weight (G/cm^3); X refers to the average reduction in soil loss of forest land [tons/(hm^2•a)] compared to non-forest land.

2) Fertility conservation value

Litter, animal matter, and soil microorganisms make up the nutrient cycle system of forest soil. Forest trees, by means of the nitrogen fixation function, play a role in maintaining long-term land productivity, as well as recycling nutrients to enhance the physical, chemical and biological properties of the soil in the forest ecosystem. Regarding the improvement of forest soil fertility, it specifically refers to the reduction of nutrient loss caused by soil erosion [23]. In this paper, it is mainly concerned with the loss of the three key mineral nutrients of nitrogen, phosphorus and potassium. In this section, the shadow price method is employed.

$$U_F = A \times X \times \left(\frac{N \times C_1}{R_1} + \frac{P \times C_1}{R_2} + \frac{K \times C_2}{R_3} \right) \tag{13}$$

In the formula, U_F represents the value of forest annual fertility conservation (yuan/a); A denotes the newly added area of forest land in this period (hm^2); X is the average reduction in soil loss of forest land than non-forest land [ton/(hm^2•a))]; N shows the average soil nitrogen content (%); P means the average soil phosphorus content (%); K refers to the average soil potassium content (%); C_1, C_2 represent the prices of phosphate diamine fertilizer and potassium chloride fertilizer, respectively (yuan/ton); R_1,R_2,R_3 respectively represent the nitrogen content of diamine phosphate fertilizer, the phosphorus content of diamine phosphate fertilizer, and the potassium content of potassium chloride (%).

3.3.2 Accounting of biological diversity conservation value

In the course of natural development, forest biodiversity plays an important role, and it also shows a close connection with the progress of human society and economy. All in all, forest biodiversity is of great significance to evaluate the species diversity.

The value of species diversity falls into the category of the non-use value of biodiversity. However, academic circles have still been exploring how to monetize non-use value. Professor Wang Bing thinks that Shannon-Wiener index, which measures species diversity in ecosystems, is more suitable for the current biodiversity accounting [24]. Therefore, this paper also applies the Shannon-Wiener index.

$$H' = -\sum_{i=1}^{S} p_i \log_{pi} \tag{14}$$

In the formula, H' represents the Shannon-Wiener index; p_i denotes the proportion of individuals in the whole, which also shows the abundance of species and the uniformity of species distribution.

The conservation of biodiversity in the newly increased forest area is mainly evaluated in this section due to the limitations of survey data and research technology.

$$U_B = S_B \times A \tag{15}$$

In the formula, U_B represents the total value of forest biodiversity conservation (yuan/a); S_B denotes the total value of forest biological species conservation [yuan/(hm²•a)]; A refers to the newly increased forest area (hm²)).

3.4 Model of green GDP accounting system

According to the definition of green GDP, this paper tries to adjust the GDP of Chongqing from three aspects, namely, natural resource depletion cost, environmental quality degradation cost, and ecological benefit improvement value, which leads to a model of green GDP accounting system as shown in Figure 1 for details.

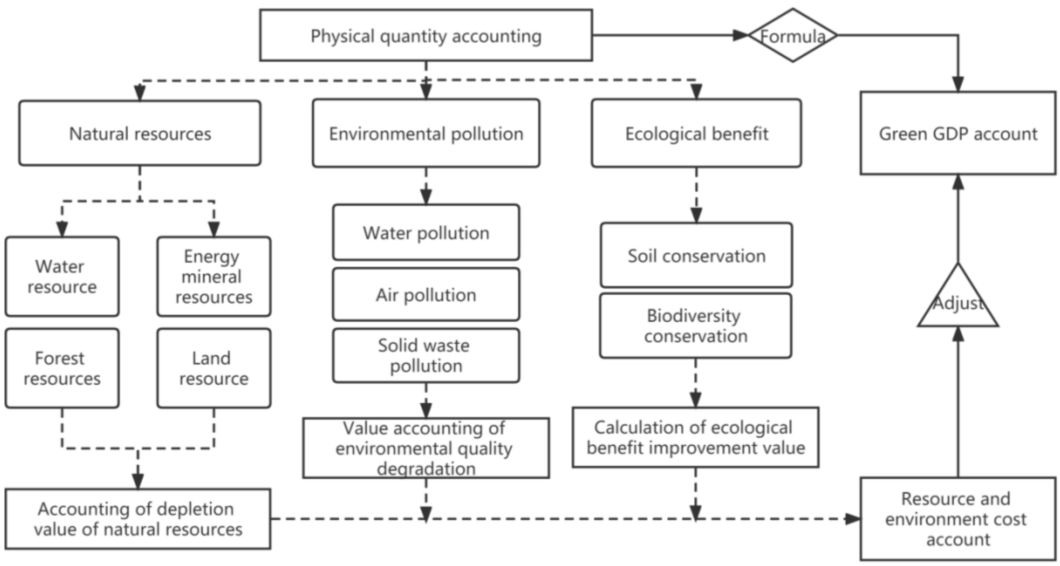

Figure 1. Framework of Green GDP accounting

The current green GDP accounting system it mainly takes the impact of national economic activities on the environment into consideration, including the depletion of natural resources and the degradation of environmental pollution. In this context, the green GDP adjusted for environmental pollution losses can be obtained by evaluating the physical volume, as well as the value of natural resource depletion and environmental pollution degradation, and then adjusting the regional GDP based on the environmental cost. Please see Table 1 for details.

Table 1. Model of Green GDP accounting system adjusted for resources and environment

No.	item	formula
①	GDP	①
②	Cost of natural resources depletion	②
③	Green GDP adjusted for resources	①−②
④	Cost of environmental degradation	④
⑤	Green GDP adjusted for environment	①−④
⑥	Value of ecological benefits improvement	⑥
⑦	Green GDP adjusted for ecological benefits	①+⑥
⑧	Green GDP adjusted for resources, environment, and ecological benefits	①−②−④+⑥

4 Case Study

4.1 Study Area

Chongqing covers an area of 82,400km², with the terrain descending from south to north along the Yangtze River Valley. The main rivers include the Yangtze River and Jialing River, etc. Chongqing belongs to the subtropical moist monsoon climate zone with abundant annual precipitation between 1000mm and 1300mm. Chongqing is located at the junction of the more developed eastern region and the resource-rich western region. It was listed as a municipality directly under the Central Government in 1997. It is the largest economic center in the upper reaches of the Yangtze River. Meanwhile, it is an important industrial and commercial town in southwest China and a hub of land and water transportation [25].

4.2 Study on green GDP accounting in Chongqing city

By combining with the situation of Chongqing city, costs of natural resource depletion value and environmental quality degradation, and value of ecological benefit improvement in the social economic production of Chongqing city in recent 3 years are calculated to truly reflect the proportion of resources and environment and social, economic development. Details are in Table 2.

Table 2. Costs of natural resource depletion value of Chongqing city between 2018 and 2020/ (10000 Yuan)

Items	2018	2019	2020
Natural resource depletion value	15337199.19	15951321.15	17163387.29
Water resources	1355718.15	1476613.51	1569690.61
Energy resources	14363534.13	14552447.66	15841654.07
Forest resources	-382876	-269523	-248412
Land resources	822.91	191782.98	454.61
Environmental quality degradation cost	5401662.59	4621725.46	8997227.95
Water pollution	182760	190128	196032
Air pollution	18632.70	18319.53	16566.36
Solid waste pollution	560269.89	731177.93	808729.59
Environmental protection expenditure	4626300	3677800	7972500
Natural disaster compensation	13700	4300	3400
Ecological benefit improvement value	995875.79	1157417.40	1222888.19
Newly increased value of soil conservation	511694.99	613733.33	662257.79
Newly increased value of biodiversity	484180.80	543684.07	560630.40

Note: positive values in table are depletion value, and negative values are newly increased value.

The green GDP accounting results of Chongqing from 2018 to 2020 are obtained by using the constructed green GDP accounting model and green GDP calculation formula, as shown in Table 3.

Table 3. The green GDP accounting results of Chongqing from 2018 to 2020

Items	Year		
	2018	**2019**	**2020**
GDP	203631900	215888000	236057700
minus:			
Resource depletion value	15337199.19	15951321.15	17163387.29
Environmental degradation cost	5401662.59	4621725.46	8997227.95
plus:			
Ecological benefit value	995875.79	1157417.40	1222888.19
Green GDP	183888914	196472370.8	211119973

Results found that in recent years, Chongqing city has actively developed green economy. However, in the city's social and economic development, its industry, especially the 2nd industry, still plays an important role. Natural resources depletion in Chongqing is mainly from the exploitation and utilization of energy resources (Figure 2-a and Figure 2-b). According to the comprehensive calculation and analysis of single environmental factors, the cost of Atmospheric pollution control and natural disaster compensation is only an extremely small percentage in the accounts of environmental quality degradation value (Figure 2-c and Figure 2-d), and ecological benefit value is progressively increasing (Figure 2-e), indicating that Chongqing government has offered much policy encourage and economic support in forest ecological resource protection as well as forestry economy industrial structure adjustment.

By accounting for the cost of natural resource depletion value and environmental quality degradation value as well as ecological benefit improvement value, then incorporating them into the current GDP, and making some adjustments, we can obtain the green GDP of Chongqing from 2018 to 2020, which is 1,838.889 billion yuan, 1,964.724 billion yuan, 2,111.2 billion yuan (Figure 2-f) respectively.

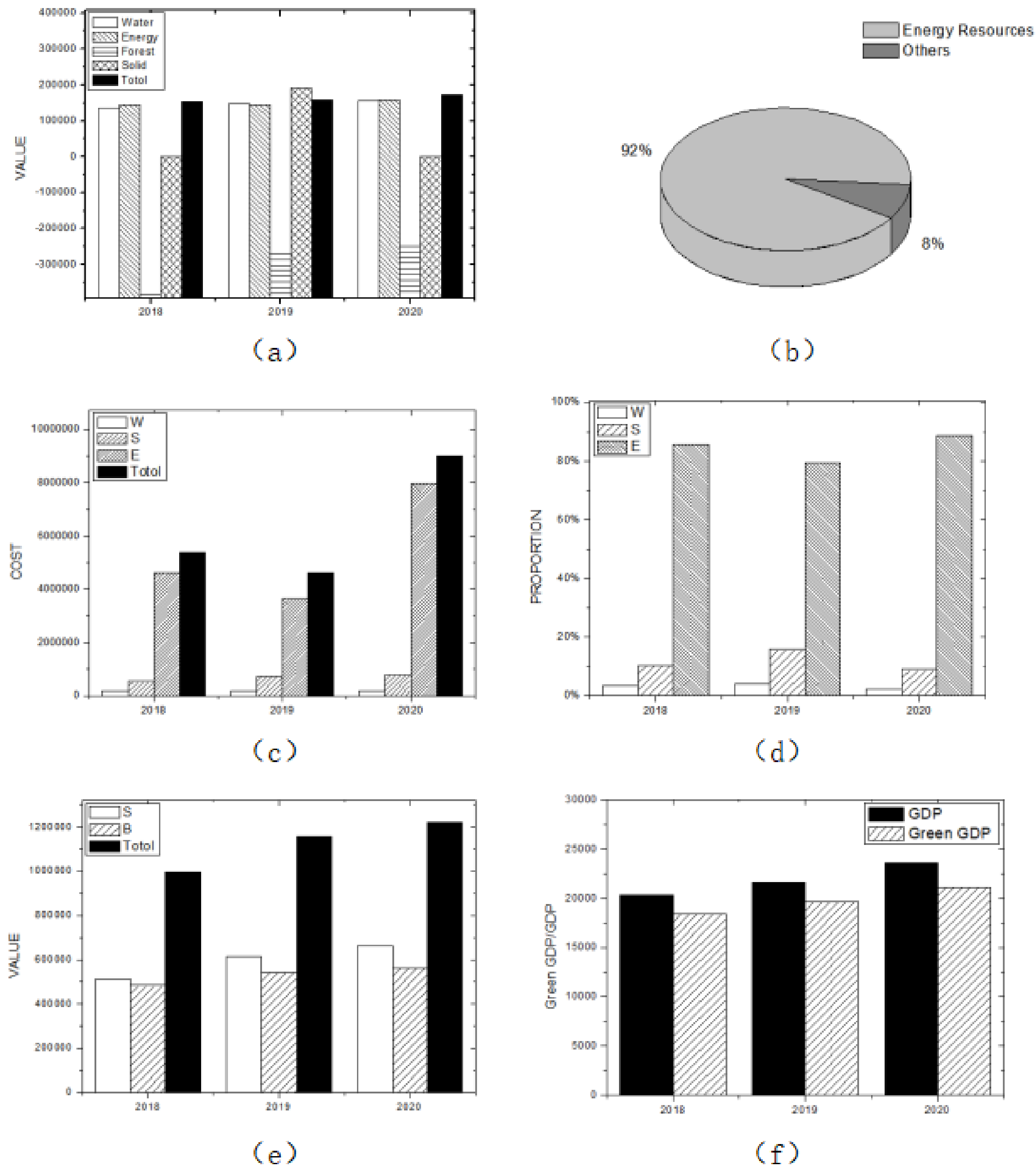

Figure 2. Constitute of resources and environments

5 Conclusion

Based on the research and development of green GDP at home and abroad, this paper constitutes the green GDP accounting system of Chongqing by combining the local ecological planning design, subject requirements and collected data. The cost of natural resource depletion, of which the main contribution factor is energy resources, trends to increase continuously.in the corresponding period, the cost of environmental quality degradation value trends to decrease first and then increase, of which the main governance cost is environmental protection expenditure. The value of ecological benefits is also rising. The factors contributing to soil conservation and biodiversity value are similar. From 2018 to 2020, both green GDP and GDP in Chongqing show an obvious rising trend, and the proportion of green GDP fluctuates with an overall downward trend, which decreases from 90.30% in 2018 to 89.44% in 2020.

According to accounting results, both green GDP and GDP are increasing each year. One of the most important components of increasing green GDP production value is the external cost obtained after the natural resource and environment improvement, as well as the increasing value of ecological benefit improvement. Thus, we know that Chongqing attaches great importance to the protection and improvement of land and forest resources in the last 3 years. From 2018 to 2020, the proportion of green GDP to traditional GDP in Chongqing was 90.30%, 91.01%, and 89.44%, respectively, showing a trend of rising first and then falling. The cost of resource consumption reduction is greater than that of environmental pollution, indicating that Chongqing is a consumptive economic system and that its economic development relies less on the resource and environment than those resource-oriented areas.

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