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An Empirical Analysis of an Integrated Accounting Method to Assess the Non-Monetary and Monetary Value of Ecosystem Services

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Received: 16 August 2020; Accepted: 28 September 2020; Published: 9 October 2020

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Abstract: The process of ecosystem service value evaluation has developed from the use of a single economic value that only accounts for material products to an assessment of ecological value and the value of ecosystem services. However, due to the complexity of ecosystems and different understandings of ecosystem service values, different classification methods of ecosystem services and service values have been developed internationally, and this has resulted in a lack of clarity regarding the correlation between ecosystem service value and various ecosystems. The correspondence between the system and each value type is not clear; therefore, based on an analysis of the inadequacy of domestic and foreign ecosystem service classification systems and methods, this study constructed a new accounting framework for non-monetary ecosystem service functions based on emergy analysis and integrated monetary accounting methods. The practical application of the method was also researched. The research results re-classified the value of ecosystem services, established an accounting method for various ecosystem service values, clarified the principle of addition in accounting, and avoided double counting. In the empirical analysis, a large number of correlation coefficients, parameters, and index values found in the foreign literature were used, so, our method also has value for international use.

Keywords: ecosystem service value; non-monetary amount accounting; monetary amount accounting; emergy analysis method

1. Introduction

In recent years, various economic methods have been used to monetize the value of farmland ecological service systems, forest ecosystems, and wetland ecological service systems, and some progress has been made [1]. Several studies on the evolution of land use and the ability of landscapes to provide selected ecosystem services (ESs) have found that the assessed areas have the greatest capacity to provide ecological integrity, which decreases slightly due to category changes. In addition, it has been verified that ecological integrity and regulation services have similar development characteristics [2]. Researchers have applied the concept of project evaluation system (PES) to the monetary valuation of natural forest habitats and created the Natura 2000 European network. The results of such studies indicate that the method used to monetize forest biodiversity in protected areas is a promising tool for decision-making in countries where the results of habitat mapping are available [3]. Most of the evaluation methods are directly or indirectly based on the measurement of individual willingness to pay for ecosystem services. Global ecosystem service value evaluation is generally based on the global static total balance input and output model and the global static partial balance model [4]. However, due to the complexity of the ecosystem itself and the interdependence between various services, the classification of ecosystem services lacks precise standards [5]. Additionally, there are complex scale conversion issues in time and space, which makes the ecosystem difficult to evaluate. First, evaluating the value system services is prone to double calculation; second, because of the limitations of economic methods, different evaluation methods are often required for different evaluation objects and evaluation goals, and, thus, the evaluation results depend to a large extent on the methods selected, which results in a lack of comparability between the results [6]; and third, because ecosystems are different from economic systems, sometimes it is difficult to evaluate the value of natural systems using economic methods, especially when humans are involved and preferences for ecosystem services change over time and new information emerges [7]. Therefore, there are still many controversies in the field of value evaluation of ecosystem services. The focus of the debate is mainly on the necessity and effectiveness of the monetary evaluation of ecosystem services [8].

From an accounting perspective, traditional economic methods use economic value to measure ecosystem services, where economic value refers to the total willingness to pay for services or compensation for losses under strict economic conditions [9]. The two main methods that are used include the preference value evaluation method and the statement preference value evaluation method. Both are based on human preference or perceived value [10]. However, because ecosystems can provide services that are not perceived by humans, are difficult to define, or will be manifest in the future, the traditional economic value evaluation methods that are centered on human perception have limitations. Therefore, a method is needed to systematically and comprehensively calculate the value of ecosystem services from the perspective of ecosystem stakeholders.

The emergy analysis method can convert different grades and different types of substances or energy into a unified measurement scale through the emergy conversion rate [11], that is, solar energy value, so as to solve the problem of the lack of a common measurement scale in the current ecosystem service value accounting. This method helps to quantify the amount of environmental work that supports each flow or storage, and evaluate each resource from the perspective of its endowment value (contributor side), rather than basing the value on human preferences and market contingency. The early ecological methods for calculating the value of ecosystem services mainly used emergy analysis methods to calculate the emergy value of ecosystem services, and then converted it into an emergy monetary value to find the economic value. However, many studies are still limited due to improper use of the emergy conversion rate, which is not completely based on the supplier's perspective in its methodology, and it still uses the currency amount × emergy to currency ratio [12]. The core difference between monetary and non-monetary quantity ecosystem service value accounting is that the non-monetary quantity method and the monetary quantity method have different advantages in calculating the value of services from natural systems and the value based on human preference, thus, the most advantageous method needs to be used to calculate the value of the ecosystem. When the currency quantification method ($) and the emergy quantification method cannot reflect the market value after being converted to currency (Em$), the emergy analysis method can at least serve as a bridge between the monetary and non-monetary value accounting methods. The emergy method can be used to determine the "biosphere value" of ecological capital and service functions [13]. This value actually complements the existing monetary value assessment. In practice, a dual accounting method can be used, that is, energy is used to record environmental liabilities, and a monetized balance sheet is established to illustrate the economic situation and the environmental contribution to economic contribution [14]. It is possible to construct an ecosystem classification system that includes triple values by referring to the current literature research results, thereby reconstructing the non-monetary accounting analysis framework of ecosystem services, and partially integrating the accounting methods of monetary amounts. On this basis, based on this theoretical and methodological framework, according to the characteristics of different ecosystems, we provide non-monetary accounting methods for the value of ecosystem services and make relevant case studies. In the calculation of the value of ecosystem services, the calculation of more value indicators requires expert knowledge to judge, and the values of more parameters, coefficients, and indicators are also highly regional [15]. Therefore, empirical evaluation methods also play an important role in the evaluation of ecosystem services.

2. Methodologies and Calculation

2.1. Construction of Non-Monetary Ecosystem Service Value Accounting Framework

According to the research results of related literature [16], the value of ecosystem services is classified, and the classification results are shown in Table 1.

According to the new ecosystem service classification system, a non-monetary quantity ecosystem service value evaluation framework is constructed (see Figure 2 in reference [17]).

The new assessment framework refers to the results of the classification of ecosystems in the National Ecosystem Classification System Based on Remote Sensing Technology, and divides the value of ecosystem services into direct value, indirect value, and existence value. The three types of value are further divided into different sub-categories. The classification of direct value is based on *NPP* stock, soil stock, and water stock; indirect value is mainly based on the influence of different media, such as air, water, and soil. The tourism and leisure value and cultural and educational value in the existing value classification should be distinguished between local and non-local, so as to use an appropriate emergy currency ratio; the regulation of water storage and runoff mainly consider the circulation of water bodies, which can actually be regarded as the role of wetland ecosystem. Glacier/permanent snow is also equivalent to a body of water, but considering the particularity of its form, it is listed as a separate ecosystem, and its role in regulating runoff is emphasized. On this basis, the new framework also provides accounting principles for direct value, indirect value, and existence value. We established a basic accounting database and performed accounting.

2.2. Methods

2.2.1. Construction of Non-monetary Ecosystem Service Value Accounting Framework

According to the interface design of the integration of non-monetary quantity and monetary quantity, this paper adopts emergy analysis method as the non-monetary quantity accounting method. First, the emergy analysis method is used to calculate the emergy monetary value of the relevant service value indicators listed in Table 1. The specific accounting method is as follows:

(1) Increase *NPP*. Its calculation formula is:

$$E_{mnpp} = \max(R_i) \tag{1}$$

In Equation (1), R_i refers to all renewable emergy inputs in the area where the ecosystem is located (manual inputs may not be considered).

(2) Provision of agricultural products = agricultural product output × energy conversion factor × emergy conversion rate.

(3) Carbon fixation and oxygen release:

$$E_{mCS} = \frac{1}{2}\Delta B \times S \times UEV_{Bio} = \frac{1}{2} \times \frac{B}{T} \times S \times UEV_{Bio} = \frac{1}{2} \times \frac{B}{T} \times S \times \frac{E_{mNPP/S}}{NPP} \tag{2}$$

In Equation (2), E_{mCS}, ΔB, B, T, S, UEV_{Bio}, and NPP are the energy required for carbon sequestration (sej), the amount of farmland carbon sequestration (g·hm^{-2}·a^{-1}), biomass added value (g·hm^{-2}·a^{-1}), biomass stock (g), time (a), farmland area (hm^2), energy conversion rate (sej·g^{-1}), and primary productivity (g·hm^{-2}·a^{-1}).

Table 1. Classification system of ecosystem services.

First Level Index	Secondary Index	Forest	Wetland	Farmland	Grassland	Desert	Saline Land	Glacier /Permanent Snow	Tundra	Sparse Vegetation	Bare Ground and Lichen	Traffic Site	Live Site	Industrial Land
Direct value	Increase *NPP*	•	•		•	•	•		•	•				
	Provide agricultural products			•										
	Carbon fixation and oxygen release	•	•	•	•	•	•		•	•				
	Increase soil	•		•	•	•	•				•			
	Groundwater replenishment	•	•											
	Water conservation			•	•	•	•	•						
	Provide water		•											
	Provide water and electricity		•											
Indirect value	Purify the atmosphere	•		•	•		•							
	Purify water		•	•			•							
	Purify the soil	•		•	•		•							
	Reduce soil erosion	•	•					•				•	•	•
	Reduce erosion				•		•							

Table 1. *Cont.*

First Level Index	Secondary Index	Forest	Wetland	Farmland	Grassland	Desert	Saline Land	Glacier /Permanent Snow	Tundra	Sparse Vegetation	Bare Ground and Lichen	Traffic Site	Live Site	Industrial Land
	Purify human and animal waste			•										
	Purify livestock waste				•									
Existential value	Regulate the climate	•	•	•	•		•	•						
	Water storage capacity		•											
	Regulate runoff							•						
	Travel	•	•	•	•	•	•	•						
	Cultural education	•	•	•	•	•	•	•						
	Biodiversity	•	•	•	•	•	•	•						

Table note: In the table, "•" means that there are such services.

(4) Increase soil. The soil calculation formula is as follows:

$$E_{mSC} = E_{mRE} \times k_1 \times k_2 \tag{3}$$

In Equation (3), E_{mSC}, E_{mRE}, k_1, and k_2 are the energy value (sej) and the energy value (sej·a^{-1}), the proportion of farmland litter to the farmland biomass (%), and the carbon content of farmland litter as the proportion of litter (%).

Minerals come from renewable resources and soil-forming parent materials, and the calculation formula is:

$$E_{mM} = \sum_{i=1}^{n} \left[P_{ijM} \times BD_i \times D_i \times S \right) / T_j] \times UEV_{jM} \tag{4}$$

In Equation (4), E_{mM}, P_{ijM}, BD_i, D_i, S, T_j, UEV_{jM} are energy value (sej), mineral content percentage (%), soil bulk density (g·cm^{-3}), depth (cm), farmland area (hm^2), turnaround time (a), energy conversion rate of soil minerals (sej·g^{-1}), respectively.

(5) Conserve water. The formula for calculating the energy value (E_{mgr}, sej) of farmland conservation water sources is as follows:

$$E_{mgr} = P \times S \times \rho \times k \times UEV_{CW} \tag{5}$$

In Equation (5), P, S, ρ, k, UEV_{CW} are the annual precipitation of farmland (mm), farmland area (hm^2), water density (g·cm^{-3}), precipitation infiltration replenishment coefficient, and groundwater emergy conversion rate (sej·g^{-1}).

(6) Purify air pollutants. The calculation formula for the reduction of human health loss is as follows:

$$E_{mhh} = \sum M_i \times S \times DALY_i \times \tau_H \tag{6}$$

In Equation (6), E_{mhh} and M_i are energy value (*sej*) and air pollutant purification capacity (kg·hm^{-2}·a^{-1}); $DALY_i$ is the impact factor, *DALY* refers to the total life lost/year, τ_H is the total regional emergy/total population (sej·cap^{-1}). In the same way, the formula for calculating the loss of ecological resources is as follows:

$$E_{meq} = \sum M_i \times PDF_i \times E_{msp} \tag{7}$$

In Equation (7), E_{meq}, M_i, $PDF_{i,}$ and E_{msp} are energy value (sej), pollutant purification capacity (kg·hm^{-2}·a^{-1}), species potential extinction ratio (1), and emergy, respectively.

(7) Purify water and soil pollutants. The value of farmland purification of water and soil pollutants is to convert the purification ability in the formula for purifying air pollutants into the ability of farmland to purify the *i*-th heavy metal.

(8) Purifying human and livestock excrement can be regarded as a part of purifying water and soil.

(9) Adjust the climate. Using the carbon sequestration of the farmland ecosystem, the calculation formula is as follows:

$$E_{mCR_1} = \sum C_i \times S \times DALY_{ci} \times \tau_H \tag{8}$$

$$E_{mCR_2 =} \sum C_i \times PDF_i \times E_{msp} \tag{9}$$

In Equations (8) and (9), E_{mCR1} C_i, S, $DALY_{ci}$, τ_H, Em_{CR2}, PDF_i, E_{msp} are the energy value (sej) and the annual average fixed amount (kg·hm^{-2}, the area of farmland ecosystem (hm^2), the impact factor of the i-th carbon-containing greenhouse gas in the Eco-indicator 99 assessment framework, the regional total energy value/total population (sej·cap^{-1}), others are the same. The meaning of variables will not be repeated.

(10) Biodiversity is calculated as follows:

$$E_{bc} = N_1 \times S \times (GEB \times T) / T_0 \tag{10}$$

In Equation (10), E_{bc}, N_1, S, GEB, T, T_0 are emergy (sej), species density (number·hm^{-2}), farmland ecosystem area (hm^2), global emergy benchmark rate (sej), turnaround time (a), number of global species, respectively.

(11) The tourism and leisure value of farmland can be calculated as follows:

$$E_{mT} = I_T \times E_m R \tag{11}$$

In Equation (11), E_{mT}, I_T, $E_m R$ are corresponding emergy (sej), tourism income ($), and local emergy currency ratio (sej·$^{-1}$).

(12) The formula for calculating the cultural and educational service value of the farmland ecosystem is as follows:

$$E_{mw} = I_w \times E_m R \tag{12}$$

In Equation (12), E_{mw} and I_w are emergy (sej) and fixed asset investment in culture, entertainment, and sports ($).

2.2.2. Principles of Ecosystem Service Value Accounting

The following principles must be followed in the calculation of ecosystem service values.

(1) For direct value, when calculating the increase of *NPP* and carbon fixation and oxygen release index values, the maximum of the three must be taken; when calculating the increase of soil index values, take the sum of soil organic matter and mineral increase; finally, all the direct value index values are added as the total direct value of ecosystem services.

(2) For indirect service value, due to the different losses of human health and ecological resources caused by different atmospheric, water, soil pollutants, and human and animal excreta, the sum of the losses is taken as the indirect service value of the ecosystem.

(3) For the existence value, take the maximum value of both tourism value and cultural education value, plus the value of existence value indicators such as climate adjustment and water storage capacity as the total existence value.

(4) The total ecosystem service value is equal to the sum of the direct value, indirect value, and existence value of the ecosystem service.

3. Example Application Analysis and Discussion

3.1. Accounting of Farmland Ecosystem Services in Chongqing

We applied the ecosystem classification system, non-monetary accounting framework, and principles proposed by this research, and partially integrated monetary accounting methods, to calculate the value of farmland ecosystem services in Chongqing, China from 2007 to 2016. The calculation results verify the applicability and international generalizability of the method proposed in this study, reveal the regularity problems in the application of the method, and enrich and improve the service value accounting method system of different ecosystem types.

The application test used different types of land use data in Chongqing, China: China Chongqing Statistical Yearbook within the statistical year, Chongqing National Economic and Social Development Statistical Bulletin, actual monitoring data of cultivated land in Chongqing, and the values of parameters, coefficients, and indicators in related research documents. The emergy reference rate is 12×10^{24} (sej·a^{-1}), and the emergy conversion rate is quoted for the corresponding correction. For the selection of basic accounting data, emergy conversion rate, and related process parameters, see Tables 2–5. The final calculation results are shown in Tables 6–9.

Table 2. Description of data sources for this study.

Data Type		Data Source
Data on land use type in Chongqing region in 2007–2016		Chinese Academy of Sciences Resource and Environment Science Data Center
Physical and parameter data	Renewable resources: solar radiation, precipitation, annual mean wind speed, average altitude, etc.	Chongqing Statistical Yearbook 2017, Statistical Communiqué on Chongqing's National Economic and Social Development
	NPP data of farmland ecosystem	[18]
	Proportion of farmland ecosystem litter to farmland ecosystem biomass	[19]
	Mineral content	[20]
	Rainfall infiltration coefficient	[21]
	Absorptive capacity of forest Ecosystems to air pollutants	[22]
	Disability-adjusted life years and potentially disappeared fraction of species	[20]
	Potential erosion coefficient and actual erosion coefficient	[23]
	Vaporization	[24]
	Tourism income of forest ecosystem	Chongqing Statistical Yearbook 2007–2016
Unit emergy value (UEV)		Table

Table 3. Emergy analysis of farmland ecosystem service values in Chongqing in 2017.

Item		Raw Data	UEV (Sej·Unit^{-1})	Total Emergy (Sej·a^{-1})	Reference
Renewable resources	Sunlight	0.71×10^{19} J	1	0.71×10^{19}	[25]
	Geothermal energy	4.68×10^{14} J	4.90×10^{3}	2.29×10^{18}	[25]
	Wind energy	6.59×10^{15} J	7.90×10^{2}	5.21×10^{18}	[25]
	Rain chemical potential	8.35×10^{12} J	1.54×10^{4}	1.29×10^{16}	[25]
	Runoff potential energy	1.92×10^{16} J	1.28×10^{4}	2.46×10^{20}	[25]
	Runoff chemical potential energy	5.98×10^{12} J	2.13×10^{4}	1.27×10^{17}	[25]
Direct value	*NPP* increase	Updateable resource calculation results in this table	Updateable resource calculation results in this table	2.61×10^{20}	this research
	Agricultural products	Statistical Yearbook	Reference [25]	2.97×10^{20}	this research
	Carbon sequestration	1.06×10^{12}	2.57×10^{8}	1.19×10^{20}	this research
	Increase soil	Tables 2 and 3, Equation (4)	Tables 2 and 3, Equation (4)	5.94×10^{19}	this research
	Water conservation	4.39×10^{14}	2.23×10^{5}	9.79×10^{19}	[25]

Table 3. *Cont.*

Item		Raw Data	UEV ($Sej·Unit^{-1}$)	Total Emergy ($Sej·a^{-1}$)	Reference
Indirect value	Purify the atmosphere	Tables 4 and 5, Equations (7) and (8)	Tables 4 and 5, Equations (7) and (8)	1.07×10^{21}	this research
	Purify water and soil	Tables 4 and 5, Equations (7) and (8)	Tables 4 and 5, Equations (7) and (8)	6.63×10^{20}	this research
Existing value	Regulate the climate	Tables 4 and 5, Equations (9) and (10)	Tables 4 and 5, Equations (9) and (10)	1.72×10^{22}	[16]
	Tourism value	Table 6 and Equation (12) calculation	Table 6 and Equation (12) calculation	2.11×10^{22}	this research
	Cultural education and entertainment value	Investment in fixed assets and calculation in Table 6 and Equation (13)	Investment in fixed assets and calculation in Table 6 and Equation (13)	1.63×10^{22}	this research
	Biodiversity	Tables 2–4 and Equation (11)	Tables 2–4 and Equation (11)	1.33×10^{20}	this research

Table 4. Coefficients on accounting soil organic matter increase and groundwater recharge of forest ecosystem.

Forest Type	Biomass ($Mg·hm^{-2}·a^{-1}$)	Farmland Litter ($Mg·hm^{-2}·a^{-1}$)	K_1 (%)	K_2 (%)	Precipitation Infiltration Recharge Coefficient (k)
Food crops	5.59 ± 1.86	1.42	45.3	50	0.136
Small woodland	10.27 ± 1.94	2.88	59.4	50	0.141
Shrub and grass	3.99 ± 3.56	1.09	65.1	50	0.138

Table 5. Air and soil pollutants and their environmental impacts.

Pollution Type		Damage to Human Health	Disability Adjusted Life Years	Ecological Damage Category	Potentially Disappeared Fraction of Species ($\%·m^{-2}·a^{-1}$)
Air pollutant	SO_2	Respiratory diseases	5.46×10^{-5}	Acidification and eutrophication	1.04
	XF	Climate change	7.48×10^{-4}	Acidification and eutrophication	5.71
	NOx	Respiratory diseases	8.87×10^{-5}		
	CO	Respiratory effects	7.31×10^{-7}		
	O_3	Ozone layer depletion	1.53×10^{-3}		
	PM10	Respiratory diseases	3.75×10^{-4}		
	PM2.5	Respiratory diseases	7.00×10^{-4}		

Table 5. *Cont.*

Pollution Type		Damage to Human Health	Disability Adjusted Life Years	Ecological Damage Category	Potentially Disappeared Fraction of Species (%·m^{-2}·a^{-1})
Soil pollutant	Zn		-	Ecotoxicological effects	2.27×10^3
	Cu		-	Ecotoxicological effects	1.08×10^3
	Pb		-	Ecotoxicological effects	8.83
	Cr	Carcinogenic substance	2.71×10^{-1}	Ecotoxicological effects	2.87×10^3
	Ni	Carcinogenic substance	3.94×10^{-3}	Ecotoxicological effects	5.27×10^3
	Hg		-	Ecotoxicological effects	1.15×10^3
	As		-	Ecotoxicological effects	4.28×10^2

Table 6. Emergy currency ratios of countries that generate tourism revenue for Chongqing.

Country	Energy Monetary Ratio (Sej·$Yuan^{-1}$)
China	3.11×10^{12}
Japan	9.87×10^{11}
South Korea	1.94×10^{12}
United States	1.66×10^{12}
United Kingdom	2.25×10^{12}
France	2.42×10^{12}
Germany	4.32×10^{12}
Russia	4.86×10^{12}

Table 7. Changes in the values of farmland ecological services in Chongqing from 2007 to 2016 (yuan).

Year	2007	2008	2009	2010	2011
Literature results (10^{10} yuan)	9.7	9.5	10.5	10.3	9.95
Results of this article (10^{10} yuan)	19.58	21.35	22.07	22.83	23.57
Year	**2012**	**2013**	**2014**	**2015**	**2016**
Literature results (10^{10} yuan)	10.8	10.9	11.7	11.9	11.95
Results of this article (10^{10} yuan)	24.38	24.97	26.48	26.95	27.28

Table 8. Changes in the values of farmland ecological services in Chongqing from 2007 to 2016.

Type of Ecological Services Value		Value (10^{10} Yuan)		Change from 2007 to 2016	
		2007	2016	Quantity (10^{10} Yuan)	Rate (%)
Direct value	Increase *NPP*	3.09	4.26	1.17	37.86
	Carbon fixation and oxygen release	2.11	3.48	1.37	64.92
	Increase soil	0.45	0.86	0.41	91.11
	Agricultural products	3.27	4.85	1.58	48.32
	Water conservation	0.48	0.89	0.41	85.42
Indirect value	Purify the atmosphere	0.74	1.28	0.54	72.97
	Purify water and soil	1.54	1.68	0.14	9.09
Existential value	Regulate the climate	3.52	4.74	1.22	34.66
	Tourism value	2.93	3.27	1.34	45.73
	Biodiversity	0.45	0. 87	0.42	93.33
	Cultural education and entertainment	1.15	1.37	0.22	19.13
Total		19.58	27.28	7.7	39.32%

Table 9. Farmland ecological service value in Chongqing in 2007, 2012, and 2016.

Area	2007		2012		2016		Total Change Rate (%)	Per Capita Change Rate (%)
	Total Amount (10^{10} Yuan)	Per Capita (Yuan)	Total Amount (10^{10} Yuan)	Per Capita (Yuan)	Total Amount (10^{10} Yuan)	Per Capita (Yuan)		
Main city area	0.936	332.39	1.17	397.28	1.30	426.51	38.89	28.32
Western Chongqing	8.28	2940.34	10.31	3500.85	11.54	3786.09	39.37	28.76
Northeastern Chongqing	7.35	2610.09	9.14	3103.57	10.23	3356.30	39.18	28.59
Southeastern Chongqing	3.01	1068.89	3.75	1273.34	4.19	1374.67	39.2	28.61

3.2. Analysis of Accounting Results and Method Evaluation of Ecosystem Service Value

From the analysis of the calculation results, the value of farmland ecosystem services in Chongqing City has shown a linear and slow growth from 2007 to 2016. In 2007, the value of farmland ecosystem services in Chongqing was 19.58×10^{10} yuan, and in 2016 it was 27.28×10^{10} yuan. The total amount increased by 39% in nine years. From the perspective of changes in single index values, the index values of carbon fixation and oxygen release, agricultural product supply, soil increase, water conservation, air purification, and biodiversity have increased significantly. Biodiversity increased by 93.33%, and purified water and soil increased by 9.09%. This also reflects that in the farmland ecosystem, the range of changes of the indicators is inconsistent, the structure is not balanced, and the status and role of the indicators in the entire system are inconsistent. Chongqing's farmland ecological environment needs continuous improvement. From the perspective of spatial distribution, the value of farmland ecosystem services in various districts of Chongqing is inconsistent, reflecting the imbalance in the spatial distribution of the value of farmland ecosystem services in Chongqing. The growth of the value of ecological services in each area is relatively stable, with a growth rate of about 39%; the per capita growth rate is about 28.5%. It reflects the continuous improvement of the farmland ecological environment in Chongqing in the past ten years, and the system input and output have both increased steadily.

The calculation results obtained by using this research method are generally higher than those obtained by the original literature using traditional economic methods. This is in line with the fact that the emergy value of the ecosystem is much higher than that obtained by the original literature's theoretical analysis and expectations of market value. The change rule of each individual index value is slightly different from the results of the original literature.

In terms of the ecosystem service classification system, the classification system constructed by this research overcomes some of the problems existing in the actual operation of the traditional classification system. For example, simply adding up the value of all ecosystem services and calculating the value of supply products and *NPP* at the same time caused double calculation problems, the problem of limited ecosystem purification capacity in mediation services, and the problem of exaggerated calculation caused by the superposition of cultural service value; in the calculation, the support services are included in the total value, which causes the problem of exaggerated calculation.

Analyzed from the accounting principle, firstly, double calculation is avoided in the aspects of increasing *NPP* and carbon fixation and oxygen release; it is more objective and practical to increase the soil value to calculate the sum of soil organic matter and minerals. When calculating the value of indirect services, generally take the sum of the loss of air and water, soil pollutants, and human and animal excrement to human health and ecological resources. The calculation method refers to the calculation method of the value of air purification, and the calculation is simple and effective. When there is service value, the maximum value of tourism value and cultural education value is generally taken as the calculation total, to avoid exaggerating calculation.

Analyzed from the accounting method, this study also has a preset method lacking certain operability in the emergy calculation of ecosystem services, and it is concreted according to the actual system service; there are many parameters, coefficients, and indicators in the emergy analysis method. The value must be obtained with full reference to the research results in other research documents. For cultural and educational values and other indicators based on willingness to pay, there is still a lack of more general and effective accounting methods, which also affects the reliability of accounting results.

Through the case analysis and application test of the farmland ecosystem service value of this research method, the regional applicability and generalizability of a new classification system, accounting framework, accounting principles, and accounting methods are further verified, and the farmland ecology is enriched. We presented a system service value accounting method system and put forward theoretical presuppositions and method guidelines for the practical verification of other types of ecosystem service value accounting. Although this study has only done the application test of the service value accounting of the farmland ecological service system in Chongqing, China, and fully integrated the regional reality of Chongqing in the calculation of cultural tourism service value in the emergy analysis and calculation of the ecological service system, many parameters, coefficients, and indicator values draw on the latest research results of current global ecosystem service value accounting, so this research still has good international promotion and application value.

4. Conclusions

Using the ecosystem service classification system, ecosystem service non-monetary accounting analysis framework, and accounting analysis principles proposed in this study, and partially integrating monetary accounting methods, the application verification was carried out by taking the value accounting of the farmland ecosystem service system in Chongqing, China as an example. It was calculated that the total value of farmland ecosystem services in Chongqing, China in 2007 was 19.58×10^{10} yuan, of which the direct value was 9.4×10^{10} yuan, the indirect value was 2.28×10^{10} yuan, and the existing value was 8.05×10^{10} yuan. The total value of farmland ecosystem services in Chongqing, China in 2016 was 27.28×10^{10} yuan, of which the direct value was 14.34×10^{10} yuan, the indirect value was 2.96×10^{10} yuan, and the existing value was 10.25×10^{10} yuan. An increase of 39.32% was seen in 2016 over 2007. From 2007 to 2016, the value of farmland ecosystem services in Chongqing, China showed an increasing trend, with small fluctuations in individual years; the spatial distribution of the value of farmland ecosystem services in Chongqing, China remained basically stable, with small fluctuations in individual years.

Compared with the calculation results in the original literature, the calculation results obtained by this research method conform to the theoretical analysis expectation that the emergy value of the ecosystem is much higher than its market value.

From the perspective of the accounting process, this study has adopted and borrowed more parameters, coefficients, and index values in the international evaluation method, so it has a certain international promotion and reference value; at the same time, in the application of the monetary value accounting method, it combines research. The actual situation and experience of the region have obvious regional characteristics. Determining how to scientifically and effectively determine the non-monetary amount accounting and integrate the parameters, coefficients, and index values involved in the monetary amount accounting method, and organically combine the international universality and regional uniqueness of the selection of parameters, coefficients, and index values, and reveal the value of ecosystem services should be topics for further research. The general rules for the selection of parameters, coefficients, and index values in the accounting will be the key content of the future global ecosystem service value accounting theory and practice research.

The method proposed in this study provides a good method guide for the calculation of the value of farmland ecosystem services. However, due to the huge differences and complexity among various ecosystems, a new accounting framework, principles, and methods need to be further applied and tested and revealed in different types of ecosystem service value accounting. This is also what this research needs to carry out further in the future.

Author Contributions: Conceptualization, Y.L. and X.L.; methodology, Y.Y.; writing—original draft preparation, Y.Y.; writing—review and editing, Y.L.; funding acquisition, Y.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research is founded by the Sichuan Province Soft Science Research Project "Green Governance Path for Value Accounting and Conversion of Park City Ecological Service System" (2020RKX0421) and the Chengdu University of Technology special project to study Xi Jinping ecological civilization thought (2019).

Acknowledgments: This research has received strong support and help from Wang Minxi, Gao Yan and the author of the literature. Thank them for their helps.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Bojie, F.U. Development trends and priority areas of ecosystem research in China. *Geogr. Res.* **2010**, *29*, 383–396.
2. Pechanec, V.; Kilianova, H.; Tangwa, E.; Vondráková, A.; Machar, I. What is the Development Capacity for Provision of Ecosystem Services in the Czech Republic? *Sustainability* **2019**, *11*, 4273. [CrossRef]
3. Pechanec, V.; Machar, I.; Štěrbová, L.; Prokopova, M.; Kilianova, H.; Chobot, K.; Cudlín, P. Monetary Valuation of Natural Forest Habitats in Protected Areas. *Forests* **2017**, *8*, 427. [CrossRef]
4. Zhang, W.; Zhang, X. Capitalization of Ecological Resources: A Framework Explanation. *Reform* **2019**, *299*, 122–130.
5. Li, W.; Zhang, B.; Xie, G. Review and Prospect of China's Ecosystem Services Research. *J. Nat. Resour.* **2009**, *24*, 1–4.
6. Zhou, C.; Li, G. A Review of Researches on Evaluation Methods of Ecosystem Service Values-Concurrently Discussing the Progress of Conditional Value Theories. *Eco-Economics* **2018**, *34*, 207–212.
7. Chen, X.; Wang, L. Research progress on ecosystem service value assessment. *Urban. Intensive Land Use* **2018**, *6*, 114–119. [CrossRef]
8. Daily, G.C. (Ed.) *Nature's Service: Societal Dependence on Natural Ecosystems*; Island Press: Washington, DC, USA, 1997.
9. Xie, G.; Zhang, Y.; Lu, C.; Zheng, D.; Cheng, S. The value of natural grassland ecosystem services in China. *J. Nat. Resour.* **2001**, *16*, 47–52.
10. Freeman, A.M.; Herriges, J.A.; Kling, C.L. *The Measurement of Environmental and Resource Values*; RFF Press: Washington, DC, USA, 2014; pp. 1–459.
11. Kong, F.; Chen, Y.; Chen, Q. Analysis on the spatiotemporal characteristics and driving factors of ecological service value of farmland in Chongqing. *Chin. J. Eco-Agric. (Chin. Engl.)* **2019**, *27*, 1637–1648.
12. Liu, G.; Yang, Q. Non-monetary Accounting of Ecosystem Services Value: Theoretical Framework and Methodology. *China Environ. Manag.* **2018**, *10*, 10–19. [CrossRef]
13. Brown, M.T.; Ulgiati, S. *Environmental Accounting: Coupling Human and Natural Systems (Forthcoming)*; Springer: New York, NY, USA, 2018.
14. Zhu, D.; Du, T. Accounting Method and Results Analysis of China's Cultivated Land Resources Assets. *China Land Sci.* **2017**, *31*, 24–31.
15. Yang, Q.; Liu, G. Non-monetary Accounting of Forest Ecosystem Service Value: A Case Study of Beijing-Tianjin-Hebei Urban Agglomeration. *J. Appl. Ecol.* **2018**, *29*, 3747–3759.
16. Goedkoop, M.; Spriensma, R. *The Eco-Indicator 99 A Damage Oriented Method for Life Cycle Impact Assessment: Methodology Report*, 2nd ed.; PRé Consultants BV: Amersfoort, The Netherlands, 2000.
17. Odum, H.T. Tropical Forest Systems and the Human Economy. *Ecol. Stud.* **1995**, *1*, 343–396.
18. Che, Y. On the Ecological Value of Cultivated Land Resources and Its Realization. *Ecol. Econ.* **2004**, *S1*, 224–228.
19. Sun, Z.; Peng, S.; Li, X.; Guo, Z.; Piao, S. Changes in forest biomass over China during the 2000s and implications for management. *For. Ecol. Manag.* **2015**, *357*, 76–83. [CrossRef]

20. Liu, J.; Li, P. Emergy analysis for agroecosystem of Jiangsu province. *Syst. Sci. Compr. Stud. Agric.* **2005**, *21*, 29–36.
21. Chongqing Municipal Government. Chongqing's Economic and Social Operation [EB/OL]. Available online: http://data.tjj.cq.gov.cn/govindex.htm (accessed on 22 October 2019).
22. *Writing Team of China Biodiversity National Research Report. China Biodiversity National Research Report*; China Environmental Science Press: Beijing, China, 1998. (In Chinese)
23. Costanza, R.; De Groot, R.; Sutton, P.C. Changes in the global value of ecosystem services. *Glob. Environ. Chang.* **2014**, *26*, 152–158. [CrossRef]
24. Xie, G.; Xiao, Y.; Zhen, L.; Lu, C. Research on the Ecological Service Value of Grain Production in China. *Chin. J. Eco-Agric.* **2005**, *13*, 10–13.
25. Brown, M.T.; Ulgiati, S. Emergy assessment of global renewable sources. *Ecol. Model.* **2016**, *339*, 148–156. [CrossRef]

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