Value of ecosystem services in China

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Abstract The function and services are the important components of the life-support system in the planet, as well as the basic elements for sustainable development of environment and society. It is a must to evaluate it for incorporating it with the social-economic system. It is also an important approach to draw the public attention on the environmental and ecosystem conservation. In this study, the ecosystem function and services in China were estimated by employing the classification and economic parameters from Costanza et al. The type and area of terrestrial ecosystems were extracted from Vegetation Map of China (1:4 000 000), and then the distribution map of ecosystem

services of China was drawn. According to our calculation, the total value of ecosystem services in China is 77 834.48×10^8 RMB yuan per annum. The value for terrestrial ecosystem is 56 098.46×10^8 yuan per annum, and that for marine ecosystem is 21 736.02×10^8 yuan per annum. The value of ecosystem services in China is 1.73 times bigger than GDP in 1994. The value for forest ecosystem services is 15 433.98×10^8 yuan per annum, which is 27.51% of the total annual ecosystem services in China. Although wetland is little in area, its ecosystem service value is huge, which is 26 736.9×10^8 yuan per annum. The value for grassland ecosystem is 8 697.68×10^8 yuan per annum. Coastal ecosystem service is 12 223.04×10^8 yuan per annum. Overall, the ecosystem service in China contributes 2.71% to that of our planet. The estimation method employed in this study was a conservative one, and should be improved in the future studies.

Keywords: ecosystem, function, service.

1 Aim and method of the research

Biosphere and ecosystems are life-support systems of the earth as well as the material base for existence and reproduction of human beings and other organisms. During the process of use and transformation of nature, usually, we emphasize only the direct consumer value or market value of natural resources, but neglect the ecological services as well as their value of biosphere and ecosystems. There were too many bitter lessons in the exploitation of natural resources and practice of social development. Irrational utilization and exploitation would finally cause destructive disasters for a society or nationality.

Sustainable development or not for our planet is a hot spot greatly concerned by the public, governments, social organizations, and scientists in different countries. The final solution of this problem depends on human race's reasonable recognition to the value of ecosystem services. Its essence is the integration of ecological conservation and economic development. An appropriate economic value for ecological services and ecological functions may receive human race's general recognition, rational management and utilization through the formulation of a certain input and output in economic systems of markets, thus a basis of sustainable utilization and development could be established. Therefore, the value of ecological services would be a very significant component in the socio-economic system in the 21st century. The incorporation of the value of ecosystem services into the socio-economic system is a great reformation for the system. From the goal of sustainable development of society, economy and environment, the research and assessment of the value of ecosystem services is becoming the focus of international attention. Using economic lever to regulate the interaction between human beings and environment could be an important measure for sustainable development of the earth.

China is a large country in the aspect of economy in the world and also one of the country with megabiodiversity on the earth. The assessment of China's value of biodiversity and ecosystem services is of great significance. The methodology and theory of the assessment are developing continuously, the accurate achievement of that assessment depends on the basic ecological study and observation to deeply understand the various ecological processes of ecosystems on the earth. Although the current ecological study and observation are far not enough for the requirement of the assessment for China's condition, the effort for the assessment should not be abandoned. The current way of doing such an assessment developed by Costanza et al. and others[1, 2] is to generalize the value of ecological functions and their services of various ecosystems in different regions from the published scientific literature.

The study of this paper is proceeded according to the international research results and method to assess the value of ecosystem services in China. This study is based on the vegetation map of China (scale 1: 4 000 000)[3]. We combined the vegetation types of China with 10 terrestrial ecosystem types: tropical/subtropical forest, temperate/boreal forest, grasslands, mangroves, swamps/wetlands, lakes /rivers, desert, tundra, glacier/rock, and croplands; and the oceans were divided into open oceans and coastal zones. The value of terrestrial ecosystem services was computed and graphed by Ecological Information System (EIS) developed in the Institute of Botany, the Chinese Academy of Sciences.

The computation for the value of oceanic ecosystem services was based on statistical data [4].

For the sake of convenience to compare with the value of global ecosystem services, we have used the system of ecosystem services proposed by Costanza et al.[1], which contains 16 types of ecosystems and 17 services of ecosystem functions (see table 1). The unit value per hm per year of the ecosystem types was also derived from Costanza's study[1]. Although some data from that study may have deviation, for example, the estimation for the value of cropland seems too low, while that for the wetland may be too high, we still use Costanza's parameters[1)] for China's estimation, thus the result could be in comparison with the estimation of the world's ecosystem services.

Table 1 Ecosystem services and functions used in this study[11]

No.	Ecosystem service	Ecosystem function	Example
1	Gas regulation	regulating atmospheric chemical composition	CO_2/O_2 balance,O_3 for UVB protection, and SO_x levels
2	climate regulation	regulating temperature, precipitation, and other biologically mediated climatic processes	greenhouse gas regulation, DMS production affecting cloud formation
3	disturbance regulation	capacitance, damping and integrity of ecosystem response to environmental fluctuations	storm protection, flood control, drought recovery and other aspects of habitat response to environmental variability mainly controlled by vegetation structure
4	water regulation	regulating hydrological flows	storage and retention of water
5	water supply		provisioning of water by watersheds, reservoirs and aquifers
6	erosion control and sediment retention	retention of soil within an ecosystem	prevention of loss of soil by wind, runoff, or other removal processes, storage of stilt in lakes and wetlands
7	soil formation	soil formation processes	weathering of rock and the accumulation of organic material
8	nutrient cycling	storage, internal cycling, processing and acquisition of nutrients	nitrogen fixation, N, P and other elements or nutrient cycles
9	waste treatment	recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds.	waste treatment, pollution control, detoxification
10	pollination	movement of floral gametes	provisioning of pollinators for the reproduction of plant populations
11	biological control	trophic-dynamic regulations of populations	keystone predator control of prey species, reduction of herbivory by top predators
12	refugia	habitat for resident and transient populations	nurseries, habitat for migratory species, regional habitats for locally harvested species, or overwintering grounds
13	food production	the portion of gross primary production extractable as food	production of fish, game, crops, nuts, fruits by hunting, gathering, subsistence farming or fishing
14	raw materials	the portion of gross primary production extractable as raw materials	the production of lumber, fuel or fodder
15	genetic resources	sources of unique biological materials and products	medicine, products for material science, genes for resistance to pathogens and pests, ornamental species (pets and horticultural varieties of plants)
16	recreation	providing opportunities for recreational activities	eco-tourism, sport fishing, and other outdoor recreational activities
17	culture	providing opportunities for non-commercial uses	aesthetic, artistic, educational, spiritual, and/or scientific values of ecosystems

1) As to the data source and calculating methods for the value of ecosystem services for various ecosystems, please consult *Nature*'s website at www.nature.com.

Costanza's calculating method could be illustrated by the evaluation on the function of gas regulation of grasslands[1] as follows:

i) CO_2. Using the estimation of C losses associated with agricultural use from grassland soils across the Great Plains of USA. C losses ranged from 0.8 to 2 kg/m^2 [5]. An average value of 1 kg/m^2 multiplied by the cost USD 0.02 of CO_2 emissions [6] results in the total cost of releasing this C to be USD 200/hm^2. Assuming that this amount was released during a 50-year period, a discount rate of 5% was used.

ii) N_2O. Cultivation of grasslands led to the significant increase of the emission of N_2O (a greenhouse gas) in the short-grass steppe of NE Colorado[7]. The annual cost of nitrous oxide emissions was estimated based upon the difference in emissions between grasslands and adjacent wheat fields (0.191 kg/hm^2 • a) and the cost per unit of N emitted as nitrous oxide was USD 2.94 /kg[6].

iii) CH_4. Cultivation reduces by half the uptake of CH_4 by grassland soils [7]. The same approach as for nitrous oxide was used: the difference in CH_4 uptake between grasslands and adjacent wheat fields (0.474 kg/hm^2 • a) multiplied by the cost per unit of CH_4 (USD 0.11 /kg) to calculate the cost of CH_4 emissions.

The sum of items i), ii) and iii) was approximately USD 7 /hm^2 •a, that was the value per unit of the function of gas regulation by ecosystem services of grasslands. After multiplying that number by the area of global or China's grasslands, the estimation of total value of ecosystem services was obtained.

2 Results and discussion

A distribution map for the value of ecosystem services in China (see Plate I) is obtained by computing the area of vegetation types from the Vegetation Map of China (1: 4 000 000) with their value per unit from Costanza's parameters. The values of various ecosystem services in China are listed in table 2.

Table 2 Value of Ecosystem Services in China

Ecosystem type	Area/km^2	Value per unit area / USD • hm^{-2} • a^{-1} a)	Total value×10^8 /USD • a^{-1}	Total value×10^8 /yuan • a^{-1}
Terrestrial	9 600 000	678	6 508.92	56 098.46
Forest	1 291 177	1 387	1 790.75	15 433.98
Tropical/subtropical	821 595	2 007	1 648.94	14 211.73
Temperate/ Taiga	469582	302	141.81	1 222.25
Grassland	4 349 844	232	1 009.16	8 697.68
Mangroves	575	9 990	5.74	49.51
Wetlands	158 597	19 580	3 105.33	26 763.90
Lakes/rivers	50 843	8 498	432.06	3 723.83
Desert	1 499 473			
Tundra	4 120			
Ice/rock	442 461			
Cropland	1 802 910	92	165.87	1 429.56
Marine	4 730 000	533	2 521.96	21 736.02
Open ocean	4 380 000	252	1 103.76	9 512.98
Coastal	350 000	4 052	1 418.20	12 223.04
Total	14330 000	630	9 030.88	77 834.48

a) The right-aligned data are from Costanza et al.[11], and the left-aligned are calculated by the authors.

The total area of China is 14.33 million km^2 and the total value of ecosystem services for the country is 77 834.48×10^8 yuan/a (in RMB of 1994)[8]. This estimation contains 56 098.46×10^8 yuan/a for 9.60-million-km^2 terrestrial ecosystem processes and 21 736.02×10^8 yuan/a from 4.73-million-km^2 marine processes. China's GDP in 1994 was 45 006×10^8 yuan (2 252.7×10^8 yuan in 1970). The annual value of ecosystem services in China was about 1.73 times the value of GDP (about 34 times more than that in 1970); the value of terrestrial ecosystem services was even about 1.25 times of the GDP. Thus the ecosystem of

China provides a tremendous value by ecological products and ecological functions every year, even the minimum estimation of that value goes beyond the scope of the value produced by human beings during the same period. The total forest area of China is 1.29 million km^2, which covers 13.45% of the nation's terrestrial area, and its value of ecosystem services is 15 433.98×10^8 yuan/a and accounts for 27.51% of the total value of terrestrial ecosystem services in China; this value is mostly due to the tropical and subtropical forest ecosystems. The area of wetlands in China is in small amount, which is only 158.597×10^3 km^2 and 1.65% of the total land territory of China. However, its value of ecosystem services, 26 763.9×10^8 yuan/a, exceeds others, accounting for 47.74% of the total value of terrestrial ecosystem services of China. The value of the coastal ecosystem services exceeds 100 000×10^8 yuan/a. All these ecosystems have relatively rich biodiversity, it is incorporated with the assessment of the value of ecosystem services.

The comparison of the value of ecosystem services between China and the world is shown in table 3. It shows that the ratio of value for ecosystem services of China to the world is quite close to that of areas, but China is less; the value of terrestrial ecosystem services is even less than the global one. That is because China's population size is too large and with a very long history of cultivation, thus the national ecosystem was disturbed significantly in China. The ratio of value of ecosystem services to national economic production is also shown in table 3; the global one is 1.82 and China's one is 1.73, the two are quite close.

Table 3 Ecosystem service value comparison of China with the globe

		Area×10^4 /km^2	Ecosystem service ×10^9/USD • a^{-1}	ESV per unit/ USD •hm^{-2} •a^{-1}	GNP×10^9 /USD • a^{-1} a)	ESV/GNP a)
Terrestrial	Globe (G)	15 323	12 319	804		
	China (C)	960	650.89	678.01		
	C / G (%)	6.27	5.28			
Marine	Globe (G)	36 302	20 949	577		
	China (C)	473	252.20	533.19		
	C / G (%)	1.30	1.20			
Total	Globe (G)	51 625	33 268	644	18 300	1.82
	China (C)	1 433	903.09	630.21	522.19	1.73
	C / G (%)	2.78	2.71		2.85	

a) It is GDP or ESV/GDP for China.

Table 4 presents the result of analysis on the pattern of spatial distribution of ecosystem services in China according to provinces and regions. It shows that: i) the southern provinces provide larger values of ecosystem services than the northern ones, which agrees with the latitudinal distribution gradient of biodiversity; ii) because of the very high values of ecosystem services in wetlands, the northern provinces with more wetlands therefore provides larger value of ecosystem services, such as Heilongjiang Province; iii) some remote provinces, such as Xinjiang and Inner Mongolia, still keep some less distributed ecosystems and have higher values of ecosystem services; iv) the provinces in lower reach of the Yellow River often have less values of ecosystem services owing to the intensive cultivation and damaged functions of natural ecosystems and reduced ecosystem services, that was the negative impact of the human activities to the value of ecosystem services.

The assessment of value of ecosystem services according to their functions in China is shown in table 5. It is also compared with the global one. From the comparison (see tables 3 and 5), it is known that the ratio of China's area to the one of the earth is 2.78%, that of the value is 2.75%; but the ratio for various ecosystem services is quite different, some of them exceed their global conterparts, but some are less. The contribution of China's ecosystem services to the earth in aspects of pollination, water supply, disturbance regulation, refugia, erosion control and sediment retention, biological control, genetic resources, raw materials, food production, waste treatment, soil formation, climate regulation, and recreation exceed the average level of the globe; but those in the aspects of gas regulation, water regulation, nutrient cycling and culture are less. The value of cultural function of ecosystems does not include the contribution of the artificial landscape; the assessment method we used may underestimate the cultural value of China's ecosystems. The other studies on the value of ecosystems that might be

Table 4 Ecosystem service values of each province, municipality and autonomous region

No.	Province or autonomous region	ESV per unit/ yuan • hm^{-2}	Total ESV $\times 10^8$/yuan • a^{-1}	Rank for total ESV	No.	Province or autonomous region	ESV per unit/ yuan • hm^{-2} • a^{-1}	Total ESV $\times 10^8$/yuan • a^{-1}	Rank for total ESV
1	Heilonjiang	17 399	7 867.002	2	17	Guangxi	4 499	1 063.525	11
2	Taiwan	10 349	357.971	21	18	Anhui	4 153	595.982	18
3	Yunnan	8 766	3 364.312	7	19	Gansu	3 665	1 526.187	9
4	Hainan	8 484	265.155	24	20	Guizhou	3 619	652.144	16
5	Hunan	8 167	1 739.548	8	21	Xizang	3 602	4 424.567	4
6	Jiangxi	8 105	1 358.573	10	22	Beijing[a)]	2 251	37.158	29
7	Fujian	7 668	950.572	14	23	Ningxia	2 239	118.298	28
8	Sichuan (including Chongqing[a)])	7 286	4 217.448	5	24	Shaanxi	2 105	443.782	20
9	Xinjiang	6 773	11 154.950	1	25	Shandong	1 840	290.900	22
10	Inner Mongilia	6 262	7 225.534	3	26	Shanxi	1 717	275.353	23
11	Zhejiang	6 079	605.206	17	27	Henan	1 535	261.363	25
12	Guangdong	5 437	959.755	13	28	Tianjin[a)]	1 509	17.759	30
13	Jilin	5 195	1 007.943	12	29	Liaoning	1 456	214.972	27
14	Jiangsu	4 766	466.441	19	30	Hebei	1 356	256.035	26
15	Hubei	4 733	887.207	15					
16	Qinghai	4 730	3 456.403	6	31	Shanghai[a)]	793	4.348	31

a) Municipality directly under the Central Government.

Table 5 Ecosystem functions and services in China and in the globe

	Ecosystem service	Ecosystem service value $\times 10^8$/USD • a^{-1}		
		China	globe	China/globe (%)
1	gas regulation	237.18	13 410	1.77
2	climate regulation	224.54	6 840	3.28
3	disturbance regulation	1184.05	17 790	6.66
4	water regulation	297.40	11 150	2.67
5	water supply	1319.54	16 920	7.80
6	erosion control and sediment retention	324.44	5 760	5.63
7	soil formation	18.13	530	3.42
8	nutrient cycling	2561.30	170 750	1.50
9	waste treatment	791.54	22 770	3.48
10	pollination	133.99	1 170	11.45
11	biological control	178.65	4 170	4.28
12	refugia	72.52	1 240	5.85
13	food production	503.12	13 860	3.63
14	raw materials	279.81	7 210	3.88
15	genetic resources	33.69	790	4.26
16	recreation	234.53	8 150	2.88
17	culture	636.45	30 150	2.11
		9 030.88	332 680	2.71

referred to is a report entitled "Teaming with life: investing in science to understand and use America's living capital", which is transmitted to President W. J. Clinton by President's Committee of Advisors on Science and Technology (PCAST) [9]. The report stated the great contribution of American biodiversity and ecosystems, including the formation of arable soil worth USD62 billion, biocontrol of crop and forest pests worth USD17 billion, bioremediation worth USD22.5 billion, nitrogen fixation by micro-organisms in natural ecosystems worth USD8 billion, forest and ocean ecosystems assisting in mitigating the green house effect by sequestering CO_2 worth USD6 billion, and waste disposal-breakdown of organic matter by decomposers worth USD62 billion per year in the US.

3 Conclusions

This study applied the advanced method and concurrent results of international research to estimate the value of ecosystem services and obtained the distribution map of it in China. These estimates are conservative and minimum ones, and must be confirmed or corrected by further research.

According to the study, the total value of China's ecosystem services is 77 834.48×10^8 yuan per year, with 56 098.46×10^8 yuan from the terrestrial ecosystems, and 21 736.02×10^8 yuan from marine ecosystems. The ecosystems of China provide a tremendous value by ecological products and ecological functions every year, even the minimum estimate of that value goes beyond the scope of the value produced by human beings during the same period.

As we strengthen invest in eco-environmental engineering projects, the budget of the research on biodiversity and ecosystem should be increased with priority.

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