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Economic Values of Biodiversity in China

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1. Introduction

As part of its Country Study on Biological Diversity[1], China conducted an assessment of economic values of its biodiversity[2]. The assessment includes direct use values, indirect values, option values, existence values, economic loss of biodiversity destruction, and baseline values of endangered species, following the UNEP Guidelines for Country Studies on Biological Diversity.

Considering the enormous historical, contemporary and future economic value of biodiversity, economic valuation provides a common view and valuation tool for the public, engineers, scientists, administrators and decision-makers. The natural attribute of biodiversity is, however, far from the social attributes of market and commodities. It is difficult to conduct accurate economic valuation, but only possible to make a generic assessment.

2. Direct use values

2.1 Basis for valuation

The socio-economic value of the direct use of biodiversity consists of two parts, direct material use, and direct non-material use. To evaluate the direct material use of biodiversity, it is usually necessary to take into consideration the way resources are used and the benefit therefrom, measured by marketable value of the resource products, or simply-processed products, or, in the absence of market pricing, calculated in the light of the cost of its substitute. Only by deducting the intermediate consumption for producing the resource products, can the intrinsic value of the resources be better identified.

2.2 Direct use value of products and processed goods

Table 1 provides the direct use value of products and processed goods.

Table 1 China's output of biological products and goods in 1993

Category	Value ((billion yuan)	Value added ((billion yuan)	Percentage of GDP
i. Forestry	46.28	33.57	1.5
Bamboo products	30.26	20.50	0.9
Forest products	12.51	9.56	0.4
Annual mean net forest reserves	3.51	3.51	0.2
2. Farm production	534.59	358.21	15.9
Crop cultivation	518.31	347.30	15.4
Wild plant collection	16.28	10.91	0.5
3. Animal husbandry	268.68	137.01	6.1

[1] China (1998). China Biodiversity Country Study (in Chinese), State Environmental Protection Administration, Beijing, 430 pp.

[2] China (1998). China's Biodiversity: A Country Study - Executive summary, Organized by State Environmental Protection Administration of China, http://chinagate.cn/english/2036.htm

4. Fisheries	78.36	51.80	2.3
5. Industry	1397.54	438.78	19.4
Light industrial products based on agricultural produce	1379.54	431.78	19.1
Other industrial goods based on agricultural produce	18	7	0.3
6. Total	2,325.45	1019.37	45.2
Agricultural, forestry, animal husbandry and fisheries	927.91	580.59	25.8
Industrial products based on agricultural produce	1397.54	438.78	19.4

Note: The monetary value of all the products is based on the 1990 fixed price. Data sources: the State Statistical Bureau, the Ministry of Agriculture, the Ministry of Forestry, the State Oceanic Administration.

Forestry

In 1993, the value of China's total forest output was 46, 277 million yuan (on the basis of the 1990 fixed price, similarly hereinafter). By deducting the intermediate consumption from this, the value was 33,571 million yuan, or 1.5% of GDP.

Agriculture

The value of China's agricultural crop output in 1993 accounted for 97% of farm production and totaled 518 billion yuan. A further 3% came from collecting wild plants, equaling 16 billion yuan, indicating that China's farm production depends mainly on cultivation. After deducting the intermediate consumption from this, China's total farm produce created 358 billion yuan, or 15.9% of GDP.

Animal husbandry

The value of China's animal husbandry output was 268.68 billion yuan in 1993, of which 72% came from livestock and poultry meat, and year-end growth of livestock and poultry, and only 0.1% from hunted wild animals, indicating that the importance of hunted wild animals in terms of total animal production is believed to be declining. After deduction of the intermediate consumption, the 1993 animal husbandry figure amounted to 137.01 billion yuan, or about 6.1% of GDP

Fisheries

China's fishery output value in 1993 was 78 36 billion yuan in 1993 and about 12.18 billion yuan or 18.4% higher than the previous year. After deduction of the intermediate consumption, the fishery added 51.80 billion yuan, or about 2.3% to GDP.

Medicine

China's biological resource is a pharmaceutical treasure for Chinese traditional medicine to make use of. The latest survey identified a total of 12, 807 species of Chinese medicinal materials, of which between 600 and 700 are in common use including over 70 animal species, most are wild. In order to conserve wild medical resources and to meet the demand for medical supplies, attempts have been made to domesticate wild medicinal plants and animals. This has to some extent relieved the demand for some medicinal materials. The value in 1992 of the total output of the Chinese traditional drug industry was 11.65 billion yuan, of which 11.48 billion yuan came from Chinese patent drugs, 0.17 billion yuan from

Chinese medicinal concoctions and pills. The net output rate of this industry is 38.6%. The production of wild plant medicinal materials is identified by the wild plant collection column in the agriculture statistics, that of domesticated medicinal crops in the farmed agriculture and forestry column statistics; that of animal medicinal material, including the hunting of wild animals and the rearing of animals, is contained in the animal husbandry statistics; and that of patent drugs in the industry statistics. As a consequence, medicinal products do not appear in Table 1 as an independent item.

Industry

Biological resources account for a large proportion of the raw materials for production in China. Statistics show that, since 1978, agriculture-based light industrial products had been kept at around 68%-70% of the total output value, and in 1993, this dropped to 65.9%, amounting to 1,379.54 billion yuan. Deduction of the intermediary consumption resulted in a net output value of 431.78 billion yuan, or 19.1% of GDP. Other agriculture-based industrial products such as processed timber good created an output value of 18 billion yuan (figure for 1993), and a net output value of 7 billion yuan when the intermediate consumption is deducted. The sum of these two shows that, in 1993, the total value of industrial output using biological resource product as raw materials was 1,397.54 billion yuan or 438. 78 billion yuan after deducting the intermediate consumption, contributing 19.4% to GDP.

Consumptive use value

In 1993, the State Statistics Bureau found in a sample survey of 67, 570 households and 310,194 people that, in terms of personal annual consumption, an average of 279.51 was spent on biological resources-based products, 89.02% for food, 0.21% for clothing, 10. 09% for fuel such as firewood and straw, and 0. 38 % for health care using Chinese medicinal herbs. Calculated on the basis that the rural population of China is 851 million, the self- sufficiency consumption of biological products by the rural population in terms of personal consumption in 1993 could have been 200 billion yuan. If the intermediate consumption is deducted at the same rate of 37 % for general agriculture, forestry, animal husbandry and fisheries, the net value of the biological resources consumed by the rural population is estimated to be 126 billion yuan.

It can be inferred from the above data that the supply of biological resources from agriculture, animal husbandry and fisheries in China depends mainly on artificial cultivation, which yields far more than caught or collected natural biological resources, suggesting that the country has already broken away from direct dependence on natural materials.

2.3 Service value

The value of biodiversity in terms of tourism, science and culture and as animal power is estimated.

Tourism and sightseeing value

Biodiversity may provide various services in terms of tourism and sightseeing, such as ecological tours in forest parks, scenic resorts, natural features and other natural landscape visits to zoos, botanic gardens, natural history museums, aquaria and other biodiversity gardens as well as animals and plants-related sports and sightseeing. The value of China's tourist services related to biodiversity is identified in Table 2.

Table 2. Biodiversity tourism and sightseeing services in 1993

Item	Quantity (places)	Areas or operating areas (km^2)	Number of tourists (million)
Forest parks	630	50000	47
Scenic spots	477	85000	300
Nature reserves	717	660,710	3-4
Zoos and animal exhibits	171	-	170
Botanic gardens and tree parks	116	-	30-40
Natural history museums and the nature section of comprehensive museums	17	-	4-5

According to a survey carried out by the Urban Sampling Survey Force of the State Statistics Bureau in 1993 and by the Urban Social Economy Survey Force of the State Statistics Bureau in 1994, about 48.3% of urban residents showed an interest in natural landscapes and 46% travelled for the purposes of sightseeing and vacationing in 1993. These data are quite close to the percentage (43. 1%) of foreign visitors coming to China who travelled just for sightseeing and on vacation. In 1993, the number of Chinese citizens visiting natural landscapes was 189 million and the number of foreign visitors was 17.9 million.

The value of biodiversity in terms of tourism and sightseeing should be the people's willingness to pay for the services it provides:

Willingness to pay = Travelling expenses + Consumer surplus

Supposing that when tourists, whether domestic or foreign, come to enjoy the services China's biodiversity and biological resources provide, the total benefit obtained is the same. This benefit equals to the travelling expenses of foreign tourists in China, and thus the consumer surplus of foreign tourists is nil, while the consumer surplus of domestic tourists is the difference between the total benefit and their actual travelling expenses. Suppose, again, that foreign tourists coming to China for the purposes of sightseeing and vacation travel just to enjoy the services that landscapes provide whereas foreign travelers visiting relatives and friends, on commercial and official business and for other aims are those who come with a defined purpose. Statistics show that in 1994, the weighted average international travelling expenses for a foreign tourist coming to China was 209 US dollars. Supposing that 20.2% of the foreign tourists go to other countries in addition to China, the weighted international travelling expenses for each foreign tourist who came to China as his or her only destination was 188 US dollars. If some flexible expenses are excluded from the calculation, the total tour expenses might average 873 US dollars for overnighting foreign tourists and 208 US dollars for day trippers.

The number of natural landscape oriented domestic tourists was estimated at 189 million, of whom 55 million were day-trippers and 134 million stayed several days. Of the domestic tourists, short and medium-range travelers constituted the highest proportion, with an average visitor line of 3. 9 days, half that of the foreign tourists'. Thus, when calculations are made comparing foreign and local tourists, the number of natural landscape oriented multi-day domestic tourists is 67 million, overnighting foreign tourists is 17.45 million and one-day foreign tourists is 0.45 million visitor units.

Based on the above assumptions, statistics and calculations, the total benefit that might be obtained from the tourist and sightseeing services that China's biodiversity could provide is 85 billion US dollars, or 710 billion yuan (calculated with the 1995 exchange rate of 1 US dollar = 8.3 yuan).

Value for science and culture

The use value of biodiversity in science can be measured in two ways, subjective and objective, that is, society' s willingness to pay for the possible services biodiversity may provide to science and the benefit obtained from the scientific utilization of biodiversity.

Investment. Willingness to pay can be roughly expressed in the form of society's investment in the study and conservation of biodiversity. Incomplete statistics show that in China, mainly in the past decade, a direct investment of 26.2 billion yuan (excluding investment for economic development) has been made in the study and conservation of biodiversity, which includes in situ conservation of species (nature reserves, scenic spots and forest parks), ex situ conservation (zoos, botanic gardens and germplasm banks), sustainable utilization of biodiversity (forest resources, grassland resources, aquacultural resources and wilderness), research and monitoring (investigating and inventorying, research and monitoring of biodiversity) and international co-operation in science and technology. Such annual investment has, in recent years, reached 2. 68 billion yuan (Table 3)

Table 3 China's investment in the study and conservation of biodiversity

Category	Accumulative investment (billion yuan)	Annual investment in recent years (billion yuan)
In situ conservation	2.50	0.38
Ex Situ conservation	7.40	0.57
Sustainable utilization	15	1.60
Research and monitoring	1.30	0. 13
Total	26.20	2.68

Magazines. In 1993, China published 7,011 magazines and journals, about 8.09% more than the previous year and with a total of 2. 35 billion copies, 6. 42 billion printed pieces and a sale value of 2.72 billion yuan. A sample of 3,895 journals shows that 9.4% were of an academic and popular science nature containing papers related to a biodiversity theme such as biological resources, ecosystems, biotechnology and environmental protection. It can be calculated that, in 1993, China had 660 journals and magazines carrying biodiversity-related articles and papers, with a total of 55.36 million copies, 170 million printed pieces and a sale value of 84 million yuan.

Books . In 1993, China published 96, 761 books (of. which 66. 313 were new), 5% more than in lie previous year (14% more new books), with a total of 5. 934 billion copies, 28. 23 billon printed pieces and a sale value of 13.67 billion yuan. Statistics on the 89,615 volumes published in 1991 show that 2. 9% were books concerned with the biological, agricultural, and environmental sciences, medicine and health care and general natural science related to biodiversity. If no big changes have taken place in the structure and focus of published books, the number published in 1993 on biodiversity could have reach 2,600 with a total of 23 million copies and a sale value of 110 million yuan.

Films. In 1993, China produced 148 volumes (252 reels) of popular science films and 160 volumes (300 reels) of documentaries. Of these, 37 volumes (65 reels) of popular science films and 17 volumes (32 reels) of documentaries were concerned with species germplasm resources, the ecological environment and nature reserves. The total production cost of these amounted to 4 million yuan.

It can be calculated, therefore, that the value of biodiversity services to science in 1993 was more than 2.68 billion yuan and to culture (publications and films) around 200 million yuan.

Value of animal power

At the end of 1993, draught animals still in use provided a total power amounting to 11.2% of the total mechanical power of China's rural areas, that is, about 35. 58 billion watts, creating a value of 120 billion yuan or a net service value of 70 billion yuan (after deducting the intermediate consumption) adding 3.4% to the total national income.

3. Indirect use values

3.1 Basis for evaluation

The indirect value of biodiversity is expressed mainly in the form of its ecological functions, which display themselves in the following ways. (1) Biodiversity provides the abundant species and genetic resources needed for ecosystem succession and biological evolution. (2) Biodiversity plays a part in forming and sustaining the structures and functions of ecosystems. (3) The service functions of ecosystems are sustained by biodiversity. This report, by focusing on service functions, addressed the ecological functions of China's terrestrial ecosystems in the production of organic matter, fixation of CO_2, release of O_2, degradation of major pollutants, as well as the conservation of water resources and soils and then apply a market value method, substitute market method, conservation cost method and rehabilitation cost method on such data to make an economic evaluation.

3.2 Production of organic matter

Plants (producers), with the aid of solar energy, synthesize organic matter from inorganic compounds such as CO_2 and H_2O. This is a critical function of an ecosystem, because it sustains the whole life system and the food basis for both consumers (man and animals) and reducers (micro-organisms). Primary productivity and biomass are the two key indexes reflecting the production of organic matter. By making integrated analyses of the various results of investigations and surveys on primary productivity and biomass of different ecosystems and forest wood, the annual primary productivity and the total biomass of China's terrestrial ecosystems have been calculated to be 6.71 billion t/a and 12.84 billion t, respectively. (Table 4)

Table 4 The total biomass and productivity of various terrestrial ecosystems in China

Ecosystem	Area (million hm^2)	Biomass (million t)	Productivity (million t/a)
Forestlands	128.63	9067.69	1268.01
Economic forests	13.74	325.73	190.99
Grasslands	400.00	2266.52	3875.94
Farm crops	95.65	891.78	1054.00
Deserts	128.24	46.17	35.91
Wetlands	11.00	110.00	192.50
Others	182.74	133.16	93.20
Total	960.00	12841.05	6710.55

Owing to the variety of China's geographical environment and climate, primary productivity and biomass varies from ecosystem, to ecosystem showing significant discrepancies in spatial distribution. Take forest as an example, the range of its total biomass varies from 40 t/hm^2 to 750 t/hm^2 and net primary productivity varied from 1 $t/(hm^2a)$ to 35 $t/(hm^2a)$. The total biomass and the primary productivity of different climatic zones showed an increasing trend from the temperate to tropical zones. The total biomass of primary mountainous rain forests, with the most complex ecosystem and most diversified species in China, could be as high as 600-750 t/hm^2a, and for the humid sub-alpine coniferous forest of southwest China, the total biomass could also reach to 250-300 t/hm^2. The forest primary productivity of hot and humid tropical areas is much higher than those of alpine and sub-alpine coniferous forests of arid and semiarid areas. For example, the net productivity of coastal mangrove forest at Hehuang, Hainan Province, could be as high as 35.47 t/hm^2a, while it could be as low as 1.04 t/hm^2a for the Dragon Spruce forest of Baiyinaobao, Inner Mongolia Autonomous Region.

Only a small proportion of the organic matter produced by ecosystems, usually less than 10%, is used by man as food and the daily necessities that are essential for human survival. This is what is called direct use value. The remaining larger proportion, though not used directly by man, supports the whole ecosystem, providing food and habitats for all animals and heterotrophic micro-organisms, of which the economic value can be calculated in accordance with the economic value of direct use of China's biodiversity. The organic matter production of China's terrestrial ecosystems is estimated to be 23,300 billion yuan.

3.3 Maintenance of $CO_2$and O_2 balance in the atmosphere

Ecosystems exchange CO_2 and O_2 with the atmosphere by means of photosynthesis and respiration, thus playing an irreplaceable role in maintaining the dynamic balance of these gases in the atmosphere. In evaluating the ecosystem's function of fixing CO_2 and releasing O_2, the total amounts of CO_2 fixed and O_2 released are calculated in line with the reaction equations of plants photosynthesis and respiration with the value for organic matter production of the terrestrial ecosystem of China as a basis.

CO_2 fixation and its value

With the organic matter production of the terrestrial ecosystem of China as a basis and in line with the equation of plants photosynthesis and respiration, the total amount of CO_2 fixed by the terrestrial ecosystem is calculated to be 10.87 billion tons per annum and hence the total stock of CO_2 in the system is 20.80 billion t.

Attempts have been made to use the afforestation-cost method and the carbon taxation method to evaluate the indirect economic value of China's terrestrial ecosystem from CO_2 fixation. The results show that on the basis of the averaged afforestation cost of 240.03 yuan/m^3 of wood, or 260.90 yuan/t of carbon (the average cost of afforestation for Chinese firs, Masson pines and Paulownias in China), the total economic value of CO_2 fixed by the terrestrial ecosystem of China may be 2,840 billion yuan per year (Table 5). When evaluated with the carbon taxation method using the rate of 0.15 US dollar per kilogram of carbon proposed by the Swedish Government, the fixed CO_2 tax rate could then be converted to be 40.94 USD/t of CO_2. Thus the total economic value of CO_2 fixed by China's terrestrial ecosystem could be calculated as 445 billion USD or 3,690 billion yuan per year. The mean value resulting from the two methods is 3,270 billion yuan per year.

Table 5. CO_2 consolidation rates of various terrestrial ecosystems in China and their values

Ecosystem	CO_2 storage (million t)	CO_2 fixation (million t/a)	Afforestation cost method		Carbon taxation method	
			CO_2 storage (billion yuan)	CO_2 fixation (billion yuan/a)	CO_2 storage (billion USD)	CO_2 fixation (billion USD)
Forests	14,689.66	2,054.18	3,832.53	535.94	2,203.45	84.10
Planted forests	527.68	309.40	137.67	80.72	79.15	12.67
Grasslands	3,671.76	6,279.02	957.96	1,638.20	550.76	257.06
Farm crops	1,444.68	1,707.48	376.92	445.48	216.70	69.90
Deserts	74 80	58. 17	19.52	15.18	11.22	2.38
Wetlands	178.20	311.85	46.49	81.36	26.73	12.77
Others	215.72	150.98	56.28	39.39	32.36	6.18
Total	20,802.50	10,871.08	5,427.37	2,836.26	3,120.38	445.06

O_2 release and its value

On the basis of the total biomass of the terrestrial ecosystem of China, the total amount of O_2 released by the terrestrial ecosystem is calculated to be 8.05 billion t. The afforestation-cost method and the industrial O_2 shadow price method were taken for the calculation of the economic value of O_2 released. The results show that on the basis of an averaged afforestation cost of 240.03 yuan/m^3 of Chinese fir, Masson pines and Paulownias in China, and the value of 352.93 yuan per tonne of O_2, the total economic value of O_2 released by the terrestrial ecosystem of China may reach 2,840 billion yuan (Table 6). When evaluated by the industrial O_2 shadow price method with the present price of 0.45 yuan/kg of O_2, the total economic value of O_2 released by the terrestrial ecosystem of China may be calculated to be 3,382 billion yuan. The average of the two calculations is 3,110 billion yuan.

Table 6. O_2 release rates of various terrestrial ecosystems of China and their economic values

Ecosystem	O_2 released (million t/a)	Afforestation-cost method (billion yuan/a)	Industrial O_2 shadow price method (billion yuan/a)
Forests	1,521.61	537.02	639.07
Planted forests	229.19	80.89	96.26
Grasslands	4,651.13	1,641.52	1,953.47
Farm crops	1,264.80	446.39	513.22
Deserts	43.09	15.21	18.10
Wetlands	231.00	81.53	97.02
Others	111.84	39.47	46.97

Total	8,052.57	2,841.99	3,382.08

3.4. Cycling and storing of nutrients

Nutrients are recycled in ecosystems through complex food chains. This is one of the key chains in the global biochemistry cycle. The functions of China's ecosystem in nutrient cycling have been evaluated on the basis of the biomass and the productivity of China's terrestrial ecosystem. The annual intake and the total storage of the three key nutrients, nitrogen (N), phosphorous (P) and potassium (K) of China's terrestrial ecosystems have been estimated to be 76.78, 1.69 and 48.68 million t, and 86.84, 8.52 and 49.09 million t, respectively (Table 7). On the basis that the average price of fertilizers in China is 2,549 yuan per tonne (China Rural Statistics Yearbook 1989—1990), China's terrestrial ecosystems can fix N, P, and K at amounts with a total .value of 324 billion yuan per year.

Table 7. The storage and consolidation of nutrients in various terrestrial ecosystems of China (millions)

Ecosystem	N		P		K	
	Storage (m.t)	Fixation (m.t/a)	Storage (m.t)	Fixation (m.t/a)	Storage (m.t)	Fixation (m.t/a)
Forests	37.90	5.30	8.07	1.13	16.41	2.30
Planted forests	4.33	2.54	0.03	0.02	2.90	1.70
Grasslands	30.12	51.51	0.21	0.35	20.19	34.53
Farm crops	11.85	14.01	0.08	0.09	7.95	7.95
Deserts	0.61	0.48	0.004	0.003	0.41	0.32
Wetlands	1.46	2.56	0.01	0.02	0.98	1.71
Others	0.56	0.39	0.12	0.08	0.24	0.17
Total	86.84	76.78	8.52	1.69	49.09	48.68

3.5. Conservation of soil and water

Biodiversity protects the soil and its productivity through interrelated ecological processes, such as reducing soil erosion, preserving soil fertility and alleviating silt sedimentation. In this study, forests and grasslands are taken as examples to evaluate the effect of the ecosystem on soil and water conservation and its potential economic value. First, the amount of soil eroded from bare land is used as a basis to estimate the amount of soil loss reduced by forest and grasses every year and then the economic value is evaluated of the effect of the forest and grassland on controlling the loss of surface soil, loss of soil fertility and soil deposition.

(1) Estimation of the reduced amount of soil erosion

The amount of potential soil loss from erosion refers to the maximum amount of soil loss from erosion on land without any vegetation cover. The amount of soil loss from land with or without forests varies sharply. Based on research findings on soil erosion in China, on non-forested land the erosion depth on average is in the range of 15-35 mm/a and the erosion modulus 150-350m^3/(ha.a). The lower limit of 150m^3/(ha.a) (192 t/ha.a), the upper limit of 350m^3/(ha.a) [447.7 t/(ha.a)] and the mean value 250m^3/(ha.a) [319.8 t/ha.a] of the erosion modulus have been as the bases for the estimation. The results of the estimation show that, the total annual amount of potential soil loss from erosion of existing forestland and grassland in China is in the range of 100 billion t to 336 billion t. Thanks to the cover of forests and grasses, the oil erosion modulus drops significantly to 0.84 billion t. From the above data, it can he calculated that the forests and grasslands in China can reduce soil loss by a minimum of 99.4 billion t, a maximum of 235 billion t, and an average of 168 billion t.

(2) Estimation of the area and value of saved wasteland

The reduction of wasteland area is estimated on the basis of the amount of soil loss from erosion and the general thickness of the soil plow layer. The average thickness, 0.5 meter, of soil plow layer in China is first used as the thickness of the soil layer saved by forests and grasses on wasteland. Then, based on the minimum soil loss reduced by forests and grasses (99.44 billion t/a, about 76.49 billion m^3) and the average thickness of the soil layer (0.5 m), it is estimated that the forests and grasses can save approximately 15.30 million m^3 of new wasteland every year.

The economic value of the land saved can be calculated by the opportunity cost method. The forest production opportunity cost is used for forests, and the animal husbandry production opportunity cost for grasslands. According to the China Statistics Yearbook, during the period from 1985 to 1990, forests and animal husbandry created, on average, yearly profits of 263.58 yuan/ha and 245.50 yuan/ha respectively. If the average annual profits are used as the opportunity costs of the wastelands saved by forests and grasses, then, the economic value of the land saved each year can be 3.89 billion yuan.

(3). Reduction in soil fertility loss

Soil erosion causes a tremendous loss of soil nutrients, mainly soil organic matter, total N, total P and total K. The major forest soils and steppe soils in China and the amount of soil loss and the minimum amount of these nutrient losses reduced by annually forests and grasses in China can be calculated with results showing that, 3.95 billion t of organic matter, 0.644 billion t of N, 0.14 billion t of P and 1. 74 billion t of K can be saved every year. Hence, the economic value of the saved soil organic matter can be calculated as 202.53 billion yuan per annum and the soil N, P. K saved as 6, 420 billion yuan, the later by multiplying the total amount of N, P. K saved (2.52 billion t) by the average price of chemical fertilizers (2,549 yuan per ton).

(4) Economic value of reducing soil lost to erosion by forests and grasslands

The soil loss from erosion of forests and grasslands in China totals 99.44 billion tonnes per annum. According to the silt movement patterns in the major river basins of China, generally, 24% of the soil lost from erosion is deposited in reservoirs, rivers and lakes directly causing decrease in their storage capacity and an increase in the chance of droughts or floods- Another 33% is retained and the other 37% goes into the sea. In this study, only the first portion is taken into account, that is, the economic value of a reduction of 23.87 billion t of silt deposition per annum.

Deposition of silt from soil erosion in reservoirs, rivers and lakes generally reduces the storage capacity of surface available water and whose economic loss can be calculated in terms of storage cost. The 23.87 billion t of reduced silt deposition equals 18.31 billion m^3 of storage capacity. Based on related researches, in China, 1 m^3 of storage capacity costs 0.67 yuan. Hence, the economic value of reduced silt deposition by forests and grasslands can be 12.27 billion yuan/a.

To sum up the above analyses, China's forest and grassland-based terrestrial ecosystems can reduce soil erosion by 6,642 billion yuan in terms of economic value (Table 8).

Table 8. The reduction in total economic loss caused by soil-erosion due to the existence of forests and grasslands in China

Type of loss	Reduction loss	Pricing standard		Total economic loss reduced (billion yuan/a)
		Forests	Grasslands	
Land	$15.30X10^6$ ha	263.58 yuan /ha	245.50 yuan/ha	3.89
Organic matter	$3.95X10^9$ t	51.3 yuan/t	51.3 yuan/t	202.53
N, P, K	$2.52X10^9$ t	2,549 yuan/t	2,549 yuan/t	6,423 48
Siltation	$18.31x10^9$ m^3	0.67 yuan /m^3	0.67 yuan /m^3	12 27
Total				6,642.17

3.6 An economic evaluation of water resource conservation

By taking the forest ecosystem as the main subject for analysis, this section uses the water-balance method to calculate the water conservation rate of the forest, and the shadow reservoir project method to evaluate the indirect economic value of the role biodiversity plays in water resource conservation.

The total amount of annual rainfall in the forest regions of China is 1,205.57 billion t (the annual precipitation in Taiwan is 2,429 mm, and with a forest area of 1.57 million ha, its rainfall is calculated to be 48.74 billion t). Considering forest transpiration and runoff, the total amount of rainfall water conserved by forests in mainland China is calculated to be 404.9 billion t.

Forests function like a reservoir, retaining water. The annual economic value of forests in conserving water resources could be calculated as 271.28 billion yuan on the basis that the cost of the water capacity of a shadow reservoir project is set at 0.67 yuan (1990 fixed price) per cubic meter.

7 The environmental purifying effect of biodiversity and its economic value

This section deals only with the function of biodiversity on the absorption of SO_2 and retention of dust, without considering others.

(1) The function and economic value of biodiversity on the absorption of SO_2

The SO_2 absorption capacity of broad-leaf forests is 88.65 kg/ha, and that of coniferous forests is an average of 215.6 kg/ha, that is 411.6 kg/ha for Cypress, 117.6 kg/ha for Chinese fir and 117.6 kg/ha for pines. China has 54.83 million ha of broad-leaf forest and 52.41 million ha of coniferous forests (Collection of China Land Resources Data), which can absorb 4.86 billion kilogram and 11.30 billion kilogram of SO_2, respectively, totaling 16.16 million tons per annum. The investment in reducing SO_2 emission is estimated to be 50,000 yuan per 100 tons and the average operation cost of such facilities is 10,000 yuan per 100 ton. Without the forests absorbing SO_2, the cost of clearing the SO_2 would be 9.70 billion yuan.

(2) The function and economic value of biodiversity on the retention of dust

The dust-retention capacity of coniferous forests is 33.2 t/ha while that of broad-leaf forests is 10.11 t/ha, which means that they can retain 1740 million t and 554 million t of dust, respectively, totaling 2,294 million t. As the cost of dust reduction is 170 yuan/t, the indirect economic value of forest-retaining dust can reach as much as 390 billion yuan.

4. Option values

4. 1 Economic value of potential optional use

The willingness to pay method is adopted to evaluate the potential optional use value of China's biodiversity. In view of the complexity of this subject, the general lack of public awareness and knowledge and a lack of experience on this subject in China, this section will only present a simple enquiry form for specialists to assess insurance payment willingness.

As an insurance industry to cover biodiversity and wilderness has not been formally developed and differs greatly from agricultural type insurance schemes, the only thing that can be done is to design a specialist enquiry form from the point of view of economic value of biodiversity by making reference to the basic practices of artificially-cultured biota and incorporating them into the features of biodiversity, as follows.

Energy form of insurance payment willingness for China's biodiversity option values

Key order		Optional value qualitative	Insurance period description (a)	Insurance amount (10^4 yuan)	State paid premium (10^4 yuan/a)	People-paid premium (yuan/a)
Order	Option					

Note: (1) In the Insurance period column, there are short-(less than 100 years), medium-(between 100 and 500 years) and long-term (over 500 years) schemes. (2) In the state paid premium column, there are 3 categories: 10 million, 10 million-100 million and >100 million yuan/a. (3) In the people-paid premium column there are 4 categories: <0.1, 0.1-1.0, 1 0-10.0, > 10.0 yuan/person/a).

Prom Table 9, it -is clear that:

(1) In terms of range distribution, the difference varies widely from to 10^3 to 10^{18} yuan that is about 15 levels of magnitude. It is obviously advisable, therefore to take a median instead of a mean value in handling willingness to pay data.

(2) In terms of intermediate-value, each suborder varies between 10^8-10^{10}, with a difference of only two levels of magnitude, which is rather narrow in comparison with the range difference. This suggests that the simple enquiry form is of some representiveness if it is reasonably designed and the enquirers are honest specialists in this field.

(3) The total accumulative insurance amount of all the 10 orders and 65 sub-orders ranges from $3.14X10^6$-$4.0X10^{18}$ yuan, of which the mid-value is $89.3X10^9$.

Table 9. The statistics of a willingness to pay enquiry for insurance of the potential optional value of China's biodiversity

Key order			Range (yuan)	Median-value (yuan)
Order	Option	Classification		
Mammalia	A	1-7	10^5-10^{18}	10^8-10^{10}
	B	8-11	10^5-10^{12}	10^8-10^{10}
	C	12-14	10^4-10^{12}	10^8-10^9
Aves	A	15-20	10^4-10^{18}	10^8-10^9
	B	21-26	10^4-10^{12}	10^8-10^9
	C	27-32	10^4-10^{11}	10^8-10^9
Reptilia	A	33	10^4-10^{11}	10^8
	B	34	10^4-10^{12}	10^9
	C	35	10^4-10^{12}	10^9
Pisces	A	36	10^4-10^{12}	10^9
	B	37	10^4-10^{18}	10^9
	C	38	10^4-10^{12}	10^9
Invertebrata	A	39	10^4-10^{11}	10^9
	B	40	10^4-10^{11}	10^9
	C	41-46	10^4-10^{12}	10^8-10^9
Insecta	A	47	10^4-10^{11}	10^8
	B	48	10^3-10^{12}	10^8
	C	49-52	10^3-10^{18}	10^8
Bryophyta	A	53	10^4-10^{12}	10^8
	B	54	10^4-10^{12}	10^8
	C	55	10^4-10^{11}	10^8
Pteridophuta	A	56	10^4-10^{11}	10^8
	B	57	10^4-10^{11}	10^8
	C	58	10^5-10^{11}	10^8
Gymnospermae	A	59-60	10^5-10^{11}	10^9
	B	61	10^5-10^{11}	10^8
	C	62	10^5-10^{11}	10^9
Angiospermae	Aa	63	10^5-10^{11}	10^9
	B	64	10^5-10^{12}	10^9
	C	65	10^5-10^{12}	10^{10}
Total			10^3-10^{18}	10^8-10^{10}
Cumulative sum			3.14X10^6-4X10^{18}	89.3X10^9

Note: A - Value of highly endangered and rare species; B - Value of scientific significance; C - Value of economic significance

4.2 Economic estimate of potential conservation value

Potentially optional species account for only a small proportion of the total species, with the majority comprising those not selected for their potential conservation value and even species either not yet discovered or registered. The total number of the world's species might well be between 5 million to 30 million, whereas those known are only 1.5 million or so. China's species account for only for one-tenth of the world total. As science and technology are developing fast, breakthroughs may be made to eventually make use of much of the total potential conservation value.

In the light of development of the national economy, the more the economy develops, the higher will become the State's and people's willingness to pay and the higher the potential conservation value will be.

Based on the afore-mentioned hypothesis, the potential conservation value should be higher than the potential optional value. A conservative estimate can be made as follows by adopting the rate of 0.6:

Potential conservation value =0.6 x 89.3 x 10^9 /(1-0.6) = 134 x 10^9 yuan

5. Existence value of biodiversity

5.1 Basis for valuation

At the environmental protection publicity day held in Changzhou, Jiangsu Province, on 8 June 1995, a survey was made of "Donation Payment Willingness for Conservation of the Existence Value of China's Biodiversity" (it was actually an overall examination of payment willingness and capacity). A form was distributed before the meeting and at which the Chairman put forward practical and realistic requirements and a rapporteur gave some explanations. The form was filled in before the environmental report was reported upon, and then another form with the same content was distributed for completion after the report. The structure of the form was as follows.

Survey Form on the Donation Payment Willingness for Conservation of the Existence Value of China's Biodiversity (8 June 1995)

	Item	State payment/a (100 million yuan)	people payment per capita/a (yuan)
Pre-report	Protect the total existence value of biodiversity		
	Protect endangered and rare species only		
Post-report	Protect the total existence value of biodiversity		
	Protect endangered and rare species only		

5.2. Result of the evaluation

The amount of the donation payment for the protection of China's biodiversity was raised from the pre-report level of 6.6 billion yuan to a post-report value of 13 billion yuan. The amount the State should invest for protection of the whole existence value of biodiversity was raised from the pre-report level of 0.6 billion yuan to 1.0 billion yuan and the donation by the people from 5 yuan to 10 yuan/(capita.a). The amount the State should invest for protection of the existence value of endangered and rare species was raised from the pre-report level of 0.2 billion yuan to a post-report value of 0.4 billion yuan, and the people's donation from 2 yuan to 4 yuan/(capita.a). The post-report willingness to pay was much higher than the pre-report, indicating the value of publicity and education in changing the government's and the people's attitudes towards biodiversity conservation.

6. Economic loss of biodiversity destruction

6.1 Calculating the economic loss in monetary terms of environmental pollution in China

Table 10 shows that the total loss from pollution is 38.16 billion yuan, of which a loss of 12.17 billion yuan is related to biodiversity, that is, about 31.9% of the total loss.

Table 10. The economic loss to various environmental factors by pollution

Factors	Loss item	Value (billion yuan)	Percentage (%)
Air pollution	Human health	3.76	9.9
	Crops	2.02	5.3
	Grazing animals	0.001	-
	Materials and buildings	4.61	12.1
	Domestic cleaning	2.00	5.2
	Sub-total	12.40	32.5
Water pollution	Human health	8.32	21.8
	Crops	0.24	0.6
	Livestock and poultry	0.12	0.3
	Fisheries	0.26	0.7
	Industry	6.73	17.6
	Sub-total	15.67	41.0
Pesticide pollution	Crops	9.52	25.0
Solid waste	Land	0.57	1.5
Total		38.16	100.00
Proportion related to biodiversity		12.17	31.9

6.2 Calculating the economic loss in monetary terms from damage to the ecology of China

Calculating economic loss on the basis of the type of ecological damage

Economic losses from ecological damage in 11 provinces (or regions), such as Guangdong and Hainan, can be calculated on the basis of the type of damage. The results of such an analysis are listed in Table 11.

Table 11. The economic losses in 11 provinces (or regions) from various types of ecological damage

Item	Type	Index	Amount (billion yuan)	Percentage (%)
Damage to vegetation	Damage to forests	Direct loss	9.75	28.66
	Damage to forests	Indirect loss	2.42	7.12
	Damage to grasslands	Desertification	3.59	10.56
	Damage to grasslands	Degradation	1.56	4.58
Damage to land	Loss from land alienation		9.81	28.85
	Loss from land salinization		0.95	2. 79
	Loss from irrational cultivation		4.80	14.12
Loss from damage of water resources			0.23	0.66
Loss from various natural catastrophes			0.9	2.65
Total			34.01	100.00

(2) Economic loss from ecological damage in 11 typical provinces (or regions)

The economic losses from ecological damage in the 11 provinces (or regions) are listed in Table 12 in relation to their socio-economic status.

Table 12. The economic losses from ecological damage in 11 provinces (or regions), as compared with their socio-economic status

Province (region)	Loss (billion yuan)	Loss/km (1,000 yuan)	Loss per capita (yuan)	Rate against national income (%)	Year
Guang-dong	3.17	17.83	55	5.62	1986
Hainan	0. 32	9.47	53	6.0	1986
Yunnan	2.36	6.17	68	15.19	1986
Sichuan	10. 22	18.02	100	19.37	1985
Jiangxi	2. 14	12.85	61	11.33	1985
Shaanxi	1.58	7.70	52	8.97	1985
Shan-dong	2.96	19.31	38	5.36	1985
Xinjiang	8.95	5.34	657	86.38	1985
Gansu	1.08	2.38	51	10.62	1985
Qinghai	1.08	1.50	266	43.50	1985
Ningxia	0.15	2.78	36	6.77	1985

(3) Calculating economic toss to the country from ecological damage

Based on the analysis of the 11 provinces (or regions), three methods were used to calculate the economic loss to the country from ecological damage, taking into consideration the ecological environmental and socio-economic characters of different parts of the country (except Taiwan). In the following analysis, the province was taken as the unit for calculation. Other parameters involved are values of total social output, national income, population, rural population, values of total agricultural output, and land area for the year 1986. The loss figure obtained by the method of a weighted mean is 96.59 billion yuan; by the expert sorting method it is 78.86 billion yuan, and by the two-factor correlation sorting method it is 73.99 billion yuan. The average of these three results is 83.15 billion yuan.

6.3 Calculating the present value of economic loss caused by environmental pollution and ecological damage

Based on the above calculations, the environmental pollution-related biodiversity economic loss is 12.17 billion yuan and the ecological damage-related economic loss is 83.15 billion yuan. This means that the affected ecology causes seven times as much biodiversity economic loss as environmental pollution does. The total economic loss is 95.32 billion yuan, accounting for 9.84% of China's GNP in 1986.

6.4 Calculating the present value of economic loss caused by environmental pollution and ecological damage in recent years

This is, however, only a reflection of the situation prior to 1986. During the period from 1986—1994, the average annual national economic growth rate was higher than 10%. However, China is a developing country, its economic structure is strongly reliant on natural resources and, while developing its economy, land degradation, desertification and acid precipitation problems have been getting more serious, and the rate of pollution and ecological damage have shown no significant improvement. According to the statistics data and the comments collected from consultants, the economic loss caused by ecological damage and environmental pollution in China in recent years could be calculated to be approximately 14% of GNP. This rate is basically within the commonly-expected world range of 8%-15%.

Thus, the 1994 figure for economic loss caused by environmental pollution and ecological damage could be calculated to be as much as 613 billion yuan.

7. Baseline values of endangered species

7.1. The significance of setting a protection benchmark value

It is important to study and calculate a species benchmark value, particularly for endangered and rare species, because it:

(1) helps decision-making and administrative departments make investment decisions;

(2) facilitates the formulation of relevant regulations, rules and standards for protection of such endangered and rare species;

(3) facilitates the regulation of protection, restoration and rational utilization of endangered and rare species by means of an economic lever;

(4) facilitates the comparison of the cost benchmark value (C) with the benefit (B) to quantitatively evaluate the B/C ratio and net benefit (NMV=B-C) and;

(5) reinforces publicity and education on the protection of endangered and rare species with a quantitative basis.

7.2 The meaning of a species protection benchmark value

The species protection benchmark value refers to the minimum requirement needed to protect its existence value, that is, the protection benchmark value of a certain species can be interpreted as the lowest cost value for it to sustain a normal population or a gradually increasing one.

The protection of species, each considered as a kind of "biological product", has its cost value (C) consisting of direct (C1) and indirect (social and opportunity) costs (C2). i.e. C =C1+ C2, where: C1 includes inputs of fixed assets, operating staff expenses, special allocations and the direct loss in business suffered by local industries for protecting the species; and C2 the loss in net land profit caused by occupation of the local land resources by the protected species.

7.3 Equations for calculating the protection cost value of endangered and rare species

$L = C \times G_1/k + C \times (G - G_1)$

$C = C1 + C2 = \sum[(A_i + D_i)/Q_i]/N + \alpha \times B \times F$

where: L - the protection benchmark value of a protected animal species (10^3 yuan/head); C - amount of investment averaged on the basis of per head per annum of protected animal species [10^3 yuan/(head.a)]; C1 and C2—direct cost and indirect cost [10^3 yuan/(head.a)]; G - the average life span of a protected animal species (years); G_1 - period of adulthood (years); k - return rate in propagation of a protected animal species (%); A_i - sum of various expenses involved in protecting a species over a certain year (10^3 yuan); D_i - loss in industrial value as a result of protecting a species for a certain year (10^3 yuan); Q_i—population number of a protected animal species in a year (head); N - number of years for accounting (year); α - loss rate in annual net benefit from the occupied land (%); B - annual net benefit from the lands occupied by a protected animal species [10^3 yuan/(km^2a)); F - averaged land area occupied by a single individual of a protected species.

7.4 Calculation of the protection benchmark values for some endangered and rare species

For this calculation, a large herbivorous mammal (*Elephas maximus*), a mammal sitting on top of an ecosystem food-chain (*Panthera tigris altaica*), a reptile (*Ailuropoda melanoleuca*), a relic species from ancient times (*Alligator sinensis*), and a rare bird (*Nipponica nippon*) are taken as samples to calculate the direct arid indirect costs as well as their totals for every protected animal every year and the cost of protecting it throughout its lifetime. These results are used to identify the protection benchmark value. All results are shown in Table 13.

Table 13. Protection benchmark values for some endangered and rare species

Species	Protection	Average cost value form (10^3 yuan/individual/a)			Lifespan (year)	Protection cost of each Individual (10^6 yuan/head)
		Direct	Indirect	Total		
Elephas maximus	in situ	17.40	28.60	46.00	50	13.64
Panthera tigris altaica	in situ	-	2,970	2,970	20	59.40
Panthera tigris altaica	ex situ	57.40	-	57.40	20	1.49
Ailuropoda melanoleuca	in situ	37.40	281.40	318.80	20	>>6.00
Alligator sinensis	in situ	0.23	7.92	8.20	20	0.30
Nipponica Nippon	in situ	34.50	84	118.50	10	1.81

8. Results

Preliminary estimates of the direct, indirect and potential economic value of China's biodiversity are included in Table 14.

Table 14. Summary of economic values of China's biodiversity

Category of values	Values (Yuan, trillion)
Direct use values	**1.8**
Net value of materials and processed products	1.02
Direct services value	0.78
Indirect use values	**37.31**
Organic matter	23.3
CO_2 fixation	3.27
O_2 release	3.11
Cycling and retention of nutrients	0.32
Soil conservation	6.64
Water conservation	0.27
Purification of pollutants	0.40

Potential use values	**0.22**
Option values	0.09
Existence values	0.13

To sum up, China analyzed the anticipated benefits to be gained if the input into biodiversity conservation were realized, China would have created 123.4 billion yuan in the form of ecological benefits and 55.6 billion yuan in terms of economic benefits, which suggests that such benefits, especially the significant ecological benefits, far outweigh the investments. The study divided the value of biodiversity into three types.

The first refers to direct use value, which was 1,800 billion yuan, including:

(1) direct material value, e.g. market value of product or simply-processed bioresource products, encompassing those from forestry, agriculture, animal husbandry, fisheries, medicine, and industry (using biological raw materials) and bioresources consumed, which was estimated at 1,020 billion yuan net per annum

(2) non-material value which covers, for example, tourism, science and animal power but often lacks a direct set market value and uses a substitute cost instead of a direct calculation, which was estimated at 780 billion yuan.

The second is indirect use value. Starting from the service function of the terrestrial ecosystem, the study addresses the ecological functions of China's terrestrial ecosystem in terms of biomes production, O2 release, CO2 fixation and cycling of nutrient elements, degradation of major pollutants and conservation of water and soil, and then evaluates its economic value by using market value method, substitute market method, protection cost method and rehabilitation cost method. The final calculation of annual indirect use value (ecological function value) of China's biodiversity in recent years is 37,310 billion yuan.

The third is termed as potential use value, consisting of potential option value and potential existence value. For the former, the insurance payment willingness method is adopted to evaluate China's major animal and plant communities and species in the form of expert-consultation insurance payments, and for which a mid-value of 90 billion yuan has been obtained. For the latter, coefficient method is used, on the basis of the former, to estimate potential existence value of the species that have not yet been identified. This turns out to be 130 billion yuan. The former plus the latter can be calculated to be 220 billion yuan.

The study calculated that the annual economic loss caused by environmental pollution and the undermining of ecology in China in recent years is 610 billion yuan (1 USD=8.3 yuan RMB in 1995).

9. Accounting system of green GDP

China explored establishment of accounting system of green GDP[3]. In March 2004, State Environment Protection Administration and State Statistics Bureau established work group to jointly carry out the research of green GDP, and organized the International Workshop on the Establishment of System of Green National Accounts in June 2005. The framework of system of green national accounts based on environment was initially established, and efforts were made to explore the ways to incorporate forest resources into the system of green national accounts. While further experiment and experience is needed to implement green GDP accounts, it remains long-term and challenging to incorporate the market and non-market value of biodiversity into the relevant plans, policies, planning and other relevant fields.

[3] China (2005). China's Third National Report on Implementation of the Convention on Biological Diversity, State Environmental Protection Administration, 15 September 2005, 232 pp.