THE CHINESE ENVIRONMENTAL POLICY RESEARCH WORKING PAPER

Issue 23 Volume 5 No.8 October 2018

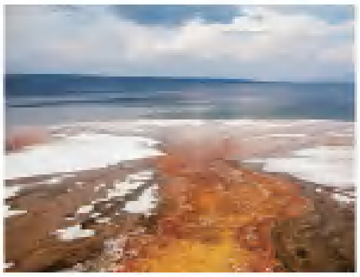
Chinese Academy of Environmental Planning
http://www.caep.org.cn

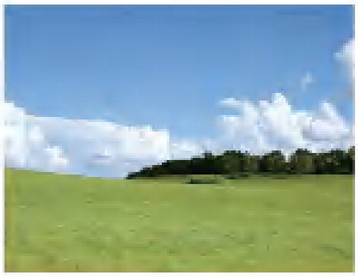
China's Gross Economic-Ecological Product Accounting Research Report 2016

Guoxia MA, Jinnan WANG, Fang YU, Weishan YANG, Fei PENG, Xiafei ZHOU, Ying ZHOU

Foreword »

Editor in Chief: Prof. WANG Jinnan





Since its opening-up and reform, China has been in the process of rapid economic development with its people enjoying an increasingly improved standard of life. Meanwhile accompanying this dramatic economic growth is the degradation of environment which has, to some extent, damaged the gains of the opening-up and reform and prevented the economy from a healthy and sustainable development. The Chinese government is increasingly aware of that without addressing the environmental issues it is facing now, will jeopardize its long term goal of the great rejuvenation of the Chinese nation. Given the magnitude and complexity of the environmental issues in China, there is no easy way in addressing them and the solution to them entails an equal priority being given to environmental protection, ecological conservation and economic development or even higher than the latter by mainstreaming the former into the overall socio-economic decision-making process. As a matter of fact, China has been in the struggle against environmental pollution since the very beginning of its economic take-off and trying to explore a pathway that could help address China's environmental issues in the way most suitable to China's specific circumstances.

In recent years, especially since the 12th Five-Year Plan period, the enhanced measures including legislation, policy, regulatory and economic means have been taken by the Chinese government in dealing with environmental problems, of which environmental policies have played an important role in this regard. Corresponding to this situation and in meeting the demand of governments at different levels for environmental policy tools, the environmental policy research projects on topics of a wide range have been conducted by some Chinese environmental research institutions including the Chinese Academy of Environmental Planning (CAEP).

CAEP founded in 2001, is a research advisory body supporting governments in the development of key environmental planning, national environmental policies, and major environmental engineering projects. In the past more than 10 years, CAEP has accomplished the development of the overall planning of national environmental protection for the 10th, 11th and 12th Five-Year Plan periods; water pollution prevention and control planning for key river basins; air pollution prevention and control planning for key regions; soil pollution prevention and control planning; and some regional environmental protection plans. In the same period of time, CAEP also actively engaged in research on such topics as green GDP, environmental taxation, emission trading, ecological compensation, green financing, etc. By so doing, CAEP has become an indispensable advisory body in the environmental decision-making in mainland China. According to *2013 Global Go To Think Tanks Report and Policy Advice* published by University of Pennsylvania, CAEP was ranked 31 in the field of environment in the world. Many of CAEP's research results and project outcomes regarding environmental policies have drawn great attention of decision makers and international institutions, and have been utilized to contribute to the formulation of national environmental policies concerned.

The Chinese Environmental Policy Research Working Paper (CEPRWP) is a new internal publication produced by CAEP for the purpose of facilitating the academic exchange with foreign colleagues in this field, in which the selected research papers on environmental policies from CAEP are set out on the irregular basis. It is expected that this publication will not only make CAEP's research results on environmental policies be known by foreign colleagues but also serve as a catalyst for creating opportunity of international cooperation in the field of environmental policies, and environmental economics in particular, with a view of both the academic research and practical policy needs.

In order to integrate resource consumption, environmental damage and ecological benefits into the evaluation system of social and economic development, and practice the green concept of "Lucid waters and lush mountains are invaluable assets", this research was based on the Green GDP and Gross Ecosystem Product accounting to develop comprehensive accounting indicators for Gross Economic-Ecological Product (GEEP). At the same time, the 2016 GEEP of 31 provinces in China is calculated. The results show that: 1) GEEP is a comprehensive ecological-economic accounting system based on weak sustainable development theory and welfare economics. GEEP follows the principle of GDP accounting and carries out value accounting for the final products of ecological and economic systems. Based on GDP, GEEP considers the ecological-environmental damage caused by human beings in economic product activities and the benefits of the ecological system to the economic system. 2) In 2016, China's GEEP was 126.6 trillion RMB, 1.6 times of GDP, among them, the cost of pollution damage was 2.1 trillion RMB, the ecological degradation cost was 0.69 trillion RMB, and the ecosystem regulating service was 51.4trillion RMB. 3) The regional Gini coefficient based on GEEP was 0.44, which was 0.07 smaller than the regional Gini coefficient calculated based on GDP in 2016, thus GEEP accounting would benefit to shrink regional disparity. 4) Compared GEEP ranking with GDP ranking among all provinces, the GEEP rankings of provinces such as Inner Mongolia, Heilongjiang, Yunnan, Qinghai and Tibet have risen by more than 10 places against their GDP ranking, with Beijing, Shanghai, Tianjin, Hebei and Shaanxi provinces their GEEP ranking compared with the GDP ranking has descending more than 10 places.

Contents

1. INTRODUCTION

As an important indicator for assessing the macro-economy, GDP is a general measure of the overall economic performance of a country. However, the current National Accounting System has certain limitations and it cannot measure whether the economy develops towards a sustainable path (Hartwick, 1990; Hamilton, 1995). There are several metrics has been proposed to replace GDP for measuring human well-being. The shortcomings of GDP including but not limited in four aspects: In first, it does not reflect the natural resource consumption and environmental costs burden by society as a whole for maintaining economic growth as what GPI (Genuine Progress Indicator) measured. Secondly, it does not imply the efficiency, cost-effectiveness, and quality of economic growth as what WVS (World Values Survey) and BLI (The Better Life Index) did. Thirdly, it does not fully reflect the contribution of ecosystems to human well-being. Fourthly, it does not indicate the total accumulation of social wealth and changes in social welfare (Shahani, 2009; Costanza, 2014). The growth of GDP has been an influential factor in evaluating the performances of local officials, which motivates the local government to pursue the pure growth of GDP at the price of natural resource depletion and environmental degradation. As a result, the energy-intensive and pollution-intensive economic growth mode has prevailed in China in the past 40 years.

The international study began to establish a green national economic accounting system in the 1970s, which was more rational by deducting the cost of natural resources consumption and pollution damage from the GDP accounting system, and more realistically measuring economic development results and national economic welfare. Green GDP and Genuine Savings have been regarded as indicators of sustainability to a nation or region, in order to make up the deficiencies in the traditional System of National Accounts (Pearce,1993; Hamilton,1994; Hamilton,1996). The United Nations Statistics Division issued and revised the Systematic Environmental and Economic Accounting System (SEEA) in 1993(United Nations,1993), 2003 (United Nations,2003) and 2012(United Nations,2012) respectively, providing a basic framework for the establishment of green national economic accounting to be adopted.

How to monetarize evaluation of depletion of natural resources and degradation of the ecological environment within a national accounting framework is one of the main difficulties to green national accounting. China sponsored the Green GDP and made < Chinese Environmental and Economic Accounting Report 2004> (Wang, 2009) to the public in 2006. The work reported that the cost to environmental pollution in 2004 was about 3.05% of GDP. The report has been warmly received and hailed by the international community, which is the first of its kind issued by the national government in the world. So far, Green GDP accounting from 2004 to 2015 has been completed by the Chinese Academy of Environmental Planning, which basically followed the SEEA with some adaption to China's specific circumstances and adding the accounting for China's ecological degradation costs since 2008. China economic-environmental accounting technical guideline was published and it promoted the study of China's green national economic accounting system (Wang, 2009,2013; Yu, 2009). The Green GDP accounting deducts the resource and environmental costs of economic system growth but does not account for all the ecological benefits provided by the ecosystem for the economic system. It cannot reflect the green concept of "Lucid waters and lush mountains are invaluable assets" provided by President Xi Jinping.

The ecosystem services are the direct and indirect benefits obtained by humans from their ecosystems (e.g., Costanza et al., 1997; de Groot et al., 2010; Obeng and Aguilar, 2018; S. Sannigrahi, 2018). The contribution of ecosystems to the world's economy and human well-being has been widely recognized in science and policy (G. Rodríguez-Loinaz et al.2015; MA, 2005; Ouyang,2016). However, improper information about ecosystem services, inadequate and inaccurate valuation of natural resources and ineffective conservation policy system are found to be the key challenges for developing a comprehensive ecosystem service valuation system (Turner and Daily, 2008; Tallis and Polasky, 2009; Matzdorf and Meyer, 2014). Chinese scholar Zhiyun Ouyang et al. proposed the concept of Gross Ecosystem Product (GEP), which fully accounted for the ecological benefits including ecosystem provisioning value, ecosystem regulating value, and ecosystem cultural value provided by the ecosystem annually. From the perspective of ecosystems, GEP accounts for the benefits provided by the ecosystem to the economic system alone, but there is still no full integration of the ecosystem and economic systems into the same accounting system. This has given rise to the degradation of non-marketed services as a result of actions taken to increase the supply of marketed ecosystem benefit (G. Rodríguez-Loinaz et al.2015). Safeguarding and enhancing the provision of non-marketed ecosystem benefit is crucial for both the human and economic perspectives.

In order to incorporate environmental damage, ecological degradation, and ecological benefits into the evaluation system of social and economic development, this paper builds a comprehensive Gross Economic-Ecological Product (GEEP) accounting framework based on Green GDP and GEP accounting. At the same time, the GEEP was accounted for 31 provinces, municipalities and autonomous regions of China in 2016 and the spatial distribution of GEEP was analyzed.

2. FRAMEWORK OF GEEP AND KEY INDEX

2.1 The framework of GEEP

The theoretical basis for GEEP is weak sustainable development and welfare economics theory. Weak sustainable development considers that capital stock can be replaced by different elements, allowing artificial capital to replace natural capital (Gao,2004), which means ecosystems and economic systems may replace each other and can be integrated into the same accounting system. Welfare economics realized that the purpose of economic activities is to increase the welfare of individuals in society. Individual welfare depends not only on the personal goods consumed by individuals and the government but also on the quantity and quality of goods and services in non-marketability of the ecosystem. Therefore, on the basis of the gross domestic product of the economic system, it is also necessary to consider the damage to the ecological environment caused by economic activities of human beings and the well-being of the ecosystem to the economic system.

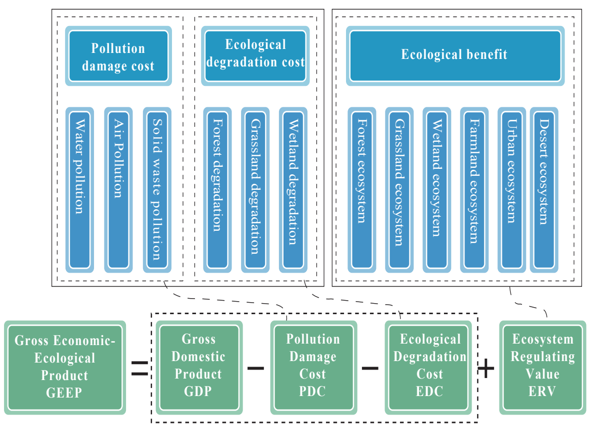
GEEP is based on the gross domestic product of the economic system, with considering the damage to the ecological environment caused by human beings in economic production activities and the well-being of the ecosystem to the economic system as well. So, it should be added the ecological welfare provided by the ecosystem to human beings on Green GDP accounting. Among them, the damage of the ecological environment is mainly expressed by the cost of ecosystem degradation induced by human activities and the cost of environmental pollution damage.

The ecosystem's well-being for human beings is expressed by GEP in which consists of three parts: ecosystem provisioning services, ecosystem regulating services and ecosystem cultural services. Since the value of ecosystem provisioning services and ecosystem cultural services have already been accounted in GDP system, deductions are required to avoid overlapping, that leads only the value of ecological regulating services of GEP conserved in GEEP system (Fig.1). The conceptual model of GEEP is shown in Eq 1.

$$
\begin{aligned}
&GEEP=GGDP+GEP-(GGDP\cap GEP)\\
&=(GDP-PDC-EDC)+(EPV+ERV+ECV)-(EPV+ECV)\\
&=(GDP-PDC-EDC)+ERV
\end{aligned}
$$

GGDP is Green Gross Domestic Product, GEP is Gross Ecosystem Product,   is the repeating part of GGDP and GEP, PDC is Pollution Damage Cost, EDC is Ecological Degradation Cost, EPV is Ecosystem Provisioning Value, ERV is Ecosystem Regulating Value, ECV is Ecosystem Cultural Value.

Fig.1 Gross Economic-Ecological Product (GEEP) accounting framework



2.2 The principle of GEEP

GEEP can be considered as a revision of GDP accounting system, and its accounting principles are basically consistent with GDP in terms of 1) Accounting time-span is one year; 2) Only accounts for the final product and which does not include intermediate products. For instance, the ecosystem regulating service is mainly accounted for the final services provided by the ecosystem to the economic system and should not include the intermediate process of some supporting services; 3) GEEP by the nature of its concept which is only flow amount rather than stock amount, the ecosystem regulating services, pollution damage costs and ecological degradation costs are only accounted when it occurred within one year. The value of ecological assets itself is not included in the GEEP accounting scope; 4) GEEP is a concept of monetized value. Many of the eco-environment products in GEEP have no direct market value, and it is necessary to use the alternative market method to evaluate its benefits human obtained from the ecosystem.

2.3 The index of GEEP and data sources

2.3.1 GGDP

GGDP is based on GDP and it deducts the cost of environmental pollution damage and ecological degradation caused by unreasonable consumption and production of human beings from GDP. Among them, the environmental pollution damage refers to the cost of environmental degradation caused by various pollutants discharged into the environment which is harmful to human health, agriculture, and the surrounding ecological environment. Ecological degradation refers to the loss of ecological service functions caused by the unreasonable use of the ecosystem.

(1) The cost of pollution damage

The cost of pollution damage mainly includes the cost of air pollution, water pollution, and the cost of the land occupation of solid waste. Among them, the cost of pollution damage caused by air pollution primarily includes four parts: human health damage caused by $PM_{2.5}$, crop production damage caused by acid rain and SO_2, damage due to outdoor building materials corrosion caused by acid rain and SO_2, and increased cost of cleaning caused by particulate matter. The cost of water pollution damage mainly includes human health loss by drinking unsanitary water, agricultural loss caused by sewage irrigation, additional treatment costs of industrial water, economic loss of urban life quality and water shortage caused by water pollution(tab.1). For the accounting method of each specific indicators of environmental damage costs, please refer to the book “China’s Environmental Economic Accounting Technical Guide” (Yu, 2009) published by our research group.

$$PDC=APDC+WPDC+SPDC$$

PDC is pollution damage cost, APDC is air pollution damage cost, WPDC is water pollution damage cost, and SPDC is solid pollution damage cost.

Tab.1 The methods of pollution damage cost

	Indexes	Physical value	Monetary Value
Air pollution	Human health damage	Exposure-response model	Adjusted human capital method
	Crop production damage	Exposure-response model	Market value method
	Outdoor building materials corrosion	Exposure-response model	Defensive expenditures method
	Increased cost of cleaning	Statistical survey method	Market value method
Water pollution	Human health damage	Exposure-response model	Adjusted human capital method
	Crop production damage	Statistical survey method	Market value method
	Additional treatment costs	Statistical survey method	Defensive expenditures method
	Economic loss of urban life quality	Statistical survey method	Defensive expenditures method
	Water shortage	Supply and demand balance method	Shadow price method
	Land occupation of solid waste	Statistical survey method	Opportunity cost approach

(2) The cost of ecological degradation

The cost of ecological degradation is accounted for the product of ecosystem regulating service and destruction rate of different ecosystems due to unreasonable use of forest, grassland, and wetland. The forest over-exploitation rate is adopted as the destruction rate of the forest ecosystem, which is the ratio of forest over-exploitation and forest accumulation. The wetland destruction rate is the proportion of the wetland severely threatened area to the total wetland area. The destruction rate of grassland is calculated according to the average livestock overload rate on the national key natural grassland from the 2017 National Grassland Monitoring Report.

$$EDC=ERV_f \times HR_f+ERV_g \times HR_g+ERV_w \times HR_w$$

$$HR_f=\frac{FO}{FGS}=\frac{DV\text{-}FCQ}{FGS}$$

$$HR_w=\frac{STA}{WA}$$

$$HR_g=\frac{1.0}{1.0+29.875*0.143^x}$$

EDC is ecological degradation cost, ERV_f, ERV_g, ERV_w are the ecosystem regulating the value of the forest, grassland, and wetland, HR_f is forest over-exploitation rate, FGS is forest growing stock, FO is forest over-exploitation, DV is deforestation volume, FCQ is forest cutting quota, HR_w is human destruction rate of wetland. STA is severe threat area of wetland, WA is wetland area. HRg is human destruction rate of grassland. x is a grassland overloading rate.

2.3.2 GEP

Ecosystems provide various ecological values which benefit for human economic activities, it includes three kinds of services: ecosystem provisioning service, ecosystem regulating service, and ecosystem cultural service. To avoid overlapping, GEEP only accounts for the value from the ecosystem regulating services provided by the ecosystem to the economic system, because ecosystem provisioning service and ecosystem cultural service has been included in GDP. Based on the summary of ecosystem service accounting indicators proposed from Costanza(1997), Millennium Ecosystem Assessment(2005), System of Environmental-Economic Accounting 2012-Experimental Ecosystem Accounting(United Nations,2014), Ouyang Zhiyun(2013), Specification for Assessment of Forest Ecosystem Services in China(China National Forestry Administration, 2008), and combined with data availability, we proposes that ecosystem regulating services mainly include climate regulation, water flow regulation, carbon fixation and oxygen release, water & air purification, soil conservation, wind and sand fixation, etc. About the accounting methods of these indexes(tab.2), please refer to the article published in China Environmental Science (Ma, 2017).

GEP= EPV+ERV+ ECV

ERV=ARV+WFRV+SSV+SFV+CFORV+WPV+APV+PDCV

EPV is ecosystem provisioning value, ERV is ecosystem regulating value, ECV is ecosystem cultural value, ARV is atmospheric regulating value, WFRV is water flow regulating value, SSV is soil stabilization value, SFV is sand fixation value, CFORV is carbon fixation and oxygen release value, WPV is water purification value, APV is air purification value, and PDCV is pest and disease control value.

Tab.2 The methods of GEP

	Indexes	Physical value	Monetary Value
	Provisioning service	Statistical survey method	Market value method
Regulating service	atmospheric regulation	Evapotranspiration model	Replace cost method
	carbon fixation	Carbon sequestration mechanism model	Replace cost method
	oxygen release	Oxygen release mechanism model	Replace cost method
	water purification	Water environmental capacity	Retreatment cost method
	air purification	Air environmental capacity	Retreatment cost method
	water flow regulating	Water balance method	Replace cost method
	pest and disease control	Statistical survey method	Replace cost method
	soil stabilization	RUSLE model	Replace cost method
	sand fixation	REWQ model	Recovery expense method
	Cultural service	Statistical survey method	Travel cost method

2.3.3 Data sources

The data for calculating ecosystem regulating service comes from <China Statistical Yearbook in 2017>, <China's Annals of Agricultural Statistics in 2017>, < Statistical Yearbook of Animal Husbandry in China in 2017>, < China Forestry Statistics Yearbook in 2017 >, < Compilation of Cost and Benefit of National Agricultural Products in 2017> and, < China Energy Statistics Yearbook in 2017>;.Remote sensing data include the land-use map in 2016 and DEM data provided by Resource Science Data Center of the Chinese Academy of Sciences, NDVI of MOD13A3 in 2016 and , NPP of MOD17A3; Soil type data from the Institute of Soil Science and the Chinese Academy of Sciences; Meteorological data come from the China Meteorological Data Network. Other data come from <2006 IPCC Guidelines for National Greenhouse Gas Inventories>, < Study on greenhouse gas inventory in China in 2008 >, <Specification for Assessment of Forest Ecosystem Services in China> and <Guideline for Chinese Environmental and Economic Accounting>.

The index of human destruction rate in the cost of ecological degradation mainly comes from Eighth National Forest Resources Inventory (2009-2013), Second National Wetland Resources Survey (2009-2013) and <The National Grassland Monitoring Report in 2017>. The accounting data of pollution damage costs mainly come from <China Statistical Yearbook 2017>, <China Environmental Statistics Annual Report 2016>, <China Urban Construction Statistical Yearbook 2016>, <Chinese Health Statistics Yearbook 2017>, < 2008 China health Service Investigation and Research Report>, <The China Environmental Status Bulletin 2016>. The environmental quality data and the environmental statistics data are provided by the China National Environmental Monitoring Center (CNEMC).

3. GEEP ACCOUNTING IN CHINA IN 2016

3.1 The results of GGDP

GGDP is the deduction of ecological degradation costs and pollution damage costs on the basis of GDP. In 2016, China's GGDP was 75.2 trillion RMB, accounting for 96.4% of GDP in the same year. In particular, the cost of pollution damage was 2117.5 billion RMB, and the cost of ecological degradation was 688 billion RMB. Among the cost of pollution damage in China, the cost of water pollution damage was 900.5 billion RMB, the cost of air pollution damage was 1172.4 billion RMB, and the land damage caused by solid waste occupation was 39.7 billion RMB. Air and water pollution damage costs were the main components, accounting for 55.1% and 42.3% of overall pollution costs respectively. In the ecological damage costs, the value of the forest, grassland, and wetland ecosystem degradation was 98.9billion RMB, 135.7billion RMB, and 454.1 billion RMB, accounting for 14.4%, 19.7%, and 65.9% of the total ecological degradation costs, respectively. The results of the Second National Wetland Resource Survey showed that although the wetland area in China has increased, the proportion of severely threatened wetland area has nearly doubled since the First National Wetland Resource Survey, which indicated serious damage on wetland ecosystem in China.

Eastern region of China contributed most GGDP. In 2016, the GGDP was 41.9 trillion RMB, and the central region accounted for 18.4 trillion RMB, and there were only 14.9 billion RMB from the western region, which accounted for 56%, 24%, and 20% respectively. The proportion of environmental damage and ecological degradation on GDP in the western region was higher than that in the central and eastern regions. The ecological environment degradation index in the western region was 5.2%, the central region was 3.6%, and the eastern region was 3.0% so that if the cost of ecological environment degradation was deducted from regional GDP, the economic development gap between the western region and the eastern region would be further widened.

3.2 The results of GEP

In 2016, China's total Gross Ecosystem Production (GEP) was 73.15 trillion RMB, which was 0.94 times GDP. The value of ecosystem provisioning services was 13.9 trillion RMB, the value of ecosystem regulating services was 51.4 trillion RMB, and the value of ecosystem cultural services was 7.8 trillion RMB, accounting for 19%, 70.3%, and 10.7% respectively. Within the ecosystem regulating services, climate regulating services contributed the largest value, accounting for 65.7%, followed by water flow regulation, accounting of 20.0%, solid carbon and oxygen release of 6.5%, and soil retention of 4.4%. Within the climate-regulating services, the value of wetland ecosystems was 29.5 trillion RMB, accounting for 45.4% of climate-regulating services. Followed by forests and grasslands, accounting for 25.6% and 17.6% respectively(tab.3).

The provinces with higher GEP were Inner

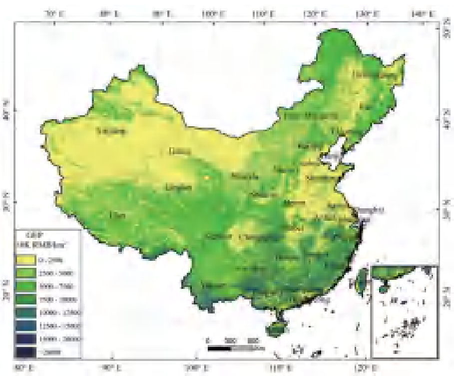
Mongolia in North China, Heilongjiang in Northeast China, Tibet in Qinghai-Tibet Plateau, Sichuan in Southwest China and Guangdong Province in South China. In addition, Yunnan in the southwest, Guangxi, and Jiangxi in southern China, Hunan and Hubei in central China, and Qinghai in the Qinghai-Tibet Plateau which was also with the relatively high value of GEP. Ningxia in the northwest, Beijing, Tianjin, and Shanxi in North China, Shanghai in East China, and Hainan in South China had relatively low GEP (Fig.2).

Tab.3 The indexes of GEP in chinese ecosystems in 2016 (billion RMB)

	Index	Forest	Grassland	Wetland	Farmland	City	Desert	Total
	Provisioning service	117.7	3033.4	5085.7	5661.7	-	-	13898.5
Regulating service	atmospheric regulation	8028.7	5261.9	20014.9	×	×	×	33305.6
	carbon fixation	38.9	22.9	1.8	×	×	×	63.6
	oxygen release	2012.5	1184.3	93.1	×	×	×	3290.0
	water purification	-	-	231.6	-	-	-	231.6
	air purification	20.2	10.2	2.5	20.0	4.0	4.5	61.3
	water flow regulating value	4317.7	1253.4	4820.3	-	-	-	10391.4
	pest and disease control	7.2	×	×	-	-	-	7.2
	soil stabilization	2070.8	476.9	61.7	560.2		√	3169.5
	sand fixation	11.8	185.9	8.4	10.0	1.3	315.1	532.3
	Cultural service	-	-	-	-	-	-	7815.9

Note: Cultural service cannot be decomposed to different ecosystem, and only have total. √ assessment, × no assessment, - Unsuitable for assessment.

Fig.2 The distribution of GEP in China in 2016 ($1\times 1km^2$)

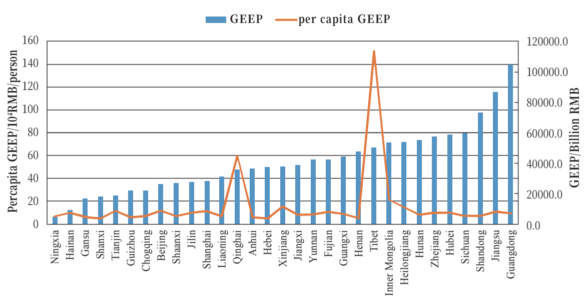


3.3 The results of GEEP

In 2016, China's GEEP was 126.64 trillion RMB, GEEP per unit area was 13.19 million RMB/km^2, and GEEP per capita was 92,000 RMB/person, which was 1.6 times of GDP per capita. Tibet, Qinghai, Inner Mongolia, Heilongjiang, and Xinjiang were the provinces with the highest GEEP per capita in China, and the GEEP per capita in these five provinces exceeded 141,657 RMB/person (Fig.3). The GEEP per capita in these five provinces was 2.9 times their GDP per capita, especially in Tibet and Qinghai where the per capita GEEP was about 14 times of the GDP per capita. Except for Heilongjiang, the other four provinces were in the western part of China. They belonged to areas with abundant population and sparse ecological functions, but the ecological environment was quite fragile and sensitive.

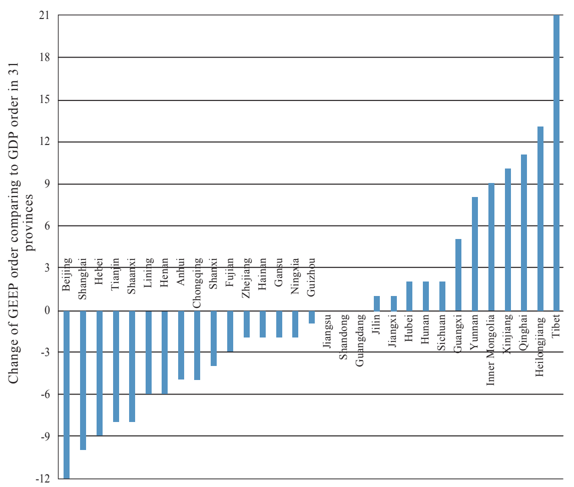
In 2016, the GDP of eastern, central and western region in China were 55.4%, 24.5% and 20.1%, respectively, while GEEP accounted for 40.7%, 26.5% and 32.8%. Based on the GDP and population of 31 provinces, the regional Gini coefficient was 0.51 in 2016, but regional Gini coefficient based on GEEP became 0.44, so the regional gap calculated by GEEP tends to shrink. China's "Nineteenth National Peoples' Congress Report" stated that the main contradictions in our society are the people's growing needs for a better life and the development of inadequate imbalances. The GEEP accounting framework system is conducive to resolve this contradiction between the growing needs of the people and the uneven development in China.

Fig.3 China's GEEP by provinces and per capita in 2016



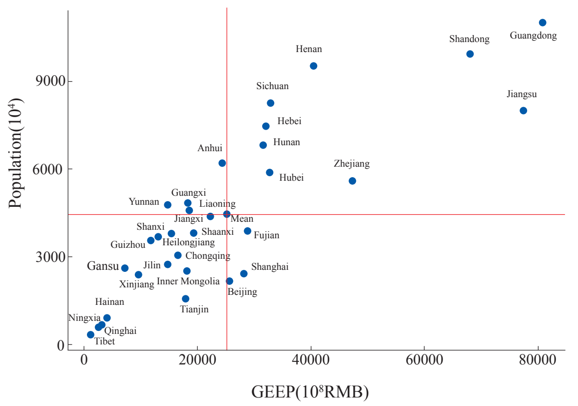
The GEEP rankings of China's 31 provinces had a large difference with the GDP ranking. Besides Guangdong, Jiangsu, and Shandong, the rankings of all other provinces had changed (Fig. 4). The provinces with a lower GEEP ranking than the GDP rankings were mainly Beijing, Shanghai, Hebei, Tianjin, Shaanxi, Henan. Beijing dropped from 12th in GDP ranking to 24th in GEEP ranking, Shanghai dropped from 11th in GDP to 22nd in GEEP, Tianjin dropped from 19th in GDP to 27th in GEEP, and Hebei ranked 8th in GDP places dropped to the 17th place in GEEP, and Shaanxi dropped from the 15th in GDP to the 23rd place in GEEP. Inner Mongolia, Heilongjiang, Yunnan, Qinghai and Tibet in GEEP ranking was much higher than its ranking in GDP. Inner Mongolia rose from the 18th in GDP ranking to the 9th in GEEP, Heilongjiang rose from 21st in GDP to 8th in GEEP, Yunnan rose from 22rd in GDP to 14th in GEEP, and Qinghai ranked 30th in GDP rose to the 19th place in GEEP, and Tibet rose from the 31st in GDP to the 10th in GEEP.

Fig.4 Changes of relative GDP by GEEP in 31 provinces ranking in 2016

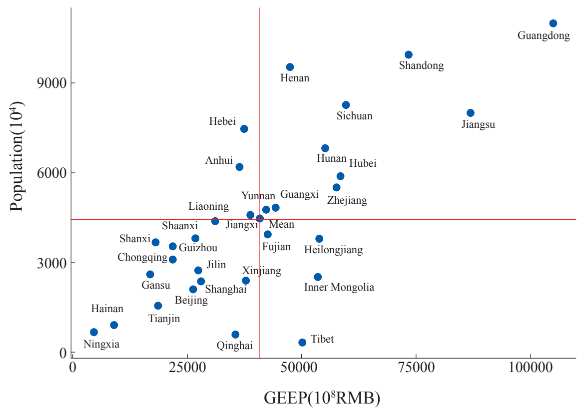


Set averages of the population, GDP, and GEEP of 31 provinces across the country for illustrating the distribution of scattering points for GDP, GEEP and relative populations (Fig.5, Fig.6). Except that Hebei changed from the first quadrant of Fig.5 to the second quadrant of Fig.6, the GEEP of other provinces in the first quadrant of Fig.5, was still higher than the national average. In Fig.5, GDP of Tibet, Heilongjiang, Inner Mongolia, Guangxi, and Yunnan are lower than the national GDP average, but their GEEP was higher than the national average in Fig.6. The GDP of Beijing and Shanghai exceeded the national average, but their GEEP was lower than the national average.

■ Fig.5 Distribution of population and GDP in four quadrants in 31 provinces in 2016



■ Fig.6 Distribution of population and GEEP in four quadrants in 31 provinces in 2016



4. RESULTS AND DISCUSSION

GEEP is an integrated economic-environment accounting system based on weak sustainable development theory and welfare economics. GEEP has similar accounting principle, methodological matrix and technical approach of GDP, and it considers both the value of the final products of ecological and economic systems and services provided by the ecosystem's flow amount. GEEP is calculated based on the GDP of the economic system, meanwhile considering the damage to the ecological environment caused by human beings in economic activities and the well-being contributed from ecosystems to the economic system as well. It is a comprehensive indicator of prosperity which corrects the one-sidedness that only considered the human economic contribution or ecological contribution on it.

GEEP in China was 126.64 trillion RMB, 1.6 times GDP in 2016. In which the cost of ecological degradation was 0.69 trillion RMB, the cost of pollution damage was 2.1 trillion RMB, and the ecosystem regulating services was 51.4 trillion RMB, accounting for 40.6% of GEEP. The regional Gini-coefficient based on GEEP calculation is 0.44, which was 0.07 smaller than its calculation based on GDP, indicating that the regional imbalance was narrowed in GEEP measuring system. The GEEP accounting framework system was evidence-proof for resolving the contradiction between the growing needs of the people and the development of inadequate imbalances.

The GEEP rankings of 31 provinces, in China, had a significant difference with their GDP ranking. Inner Mongolia, Heilongjiang, Yunnan, Qinghai, Tibet and other provinces with large ecological services value had increased by more than 10 ranks in GEEP ranking compared with the GDP ranking. The provinces with weak ecological services and serious environmental pollution such as Beijing, Shanghai, Tianjin, Hebei had decreased their GEEP rankings also more than 10 ranks compare with its GDP ranking. The results indicated that Northwest provinces have large potential of the overall human well-being rather than economic prosperous provinces located in east coast region.

GEEP is a relatively complex accounting system in which ecosystem regulating services, ecological degradation costs, and pollution damage costs unified under the same measurement system and included many accounting indicators, each of them involves both measurable physical quantity and monetized value, in the meanwhile accounting methods, are quite diverse causing various accounting results. China began to carry out ecosystem service accounting since the 1990s, however, due to the difference in accounting methods, key parameters, accounting scope, index system, and accounting contents, the results of ecosystem service value are quite different by different scholars. Therefore, it is necessary to develop a GEEP accounting technical guideline to standardize GEEP accounting methods, key parameters, accounting scope, and indicator systems to achieve the accounting system in standardization for accounting, assessing and monitoring reginal development performance.

Acknowledgments

This study was supported by the National Key Research and Development Program of China (No. 2016QY01W0200), and the National Natural Science Foundation of China (Grant No.41371533).

REFERENCE:

1 China National Forestry Administration, 2008. People's Republic of China forestry industry standard LY/T 1721-2008: specifications for assessment of forest Ecosystem Services In China. Beijing: China Standard Press (In Chinese)

2 Costanza R., 2014.Time to leave GDP behind. Nature 505(16):283-285

3 Costanza, R., dArge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., Oneill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., Van Den Belt, M., 1997. The value of the world's ecosystem services and natural capital. Nature 387 (6630), 253–260.

4 De Groot, R.S., Alkemade, R., Braat, L., Hein, L., Willemen, L., 2010. Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecol. Complex. 7 (3), 260–272.

5 Yu, F., Ma, G.X., Qi, J., 2012. China economic-environmental accounting research report 2007-2008. China Environmental Science Press (In Chinese)

6 Yu, F., Wang, J.N., Cao, D., 2009. China economic-environmental accounting technical guideline. China Environmental Science Press (In Chinese)

7 Gloria Rodríguez-Loinaz, Josu G. Alday, Miren Onaindia, 2015. Multiple ecosystem services landscape index: A tool for multifunctional landscapes conservation. Journal of Environmental Management. 147:152-163

8 Hamilton, K., 1994. Green adjustments to GDP. Resources Policy 20(3):155–168

9 Hamilton, K., 1995. Sustainable development, the Hartwick rule and optimal growth. Environ Resource Econ. 5:393–411

10 Hamilton, K., 1996. Pollution and pollution abatement in the national accounts. Rev Income Wealth. 42(1):13–33

11 Hartwick, J.M., 1990. Natural resources, national accounting and economic depreciation. J Public Econ. 43(3):291–304

12 Wang, J.N., Cao, D., Yu, F., 2009. Chinese Environmental and Economic Accounting Report 2004. China Environmental Science Press(in Chinese), Beijing

13 Wang, J.N., Yu, F., Cao, D., 2013. China economic-environmental accounting research report 2005-2006. Beijing: China Environmental Science Press (In Chinese)

14 Ma, G.X., Yu, F., Wang, J.N., Zhou, X.F., RMB, J., Mou, X. H., Zhou, Y., Yang, W.S., Peng, F., 2017. Measuring gross ecosystem product (GEP) of 2015 for terrestrial ecosystems in China. China Environmental Science (In Chinese). 37(4):1474-1482

15 Matzdorf, B., Meyer, C., 2014. The relevance of the ecosystem services framework for developed countries' environmental policies: a comparative case study of the US and EU. Land Use Pol. 38, 509–521.

16 Millennium Ecosystem Assessment, 2005. Ecosystems and human well-being: general synthesis. Island Press: Washington D.C.

17 Gao, M.X. 2004. Resources and environment statistics. Beijing: China Statistics Press(In Chinese)

18 Obeng, E.A., Aguilar, F.X., 2018. Value orientation and payment for ecosystem services: perceived detrimental consequences lead to willingness-to-pay for ecosystem services. J. Environ. Manag. 206 (Suppl. C), 458–471. https://doi.org/10.1016/j.jenvman.2017.10.059.

19 Pearce, D.W., Atkinson, G.D., 1993. Capital theory and the measurement of sustainable development: an indicator of "weak" sustainability. Ecol Econ. 8(2):103–108

20 Shahani, Deneulin S., Lila, 2009. An introduction to the human development and capability: approach(1. ed.). London: Earthscan Ltd

21 Sannigrahi, S., Bhatt S., Rahmat, S., Paul, S. K., Sen, S., 2018. Estimating global ecosystem service values and its response to land surface dynamics during 1995–2015. Journal of Environmental Management. 223:115–131

22 Tallis, H., Polasky, S., 2009. Mapping and valuing ecosystem services as an approach for conservation and natural-resource management. ýAnn. N. Y. Acad. Sci. 1162, 265–283. http://dx.doi.org/10.1111/j.1749-6632.2009.04152.x

23 Turner, R.K., Daily, G.C., 2008. The ecosystem services framework and natural capital conservation. Environ. Resour. Econ. 39 (1), 25–35. http://dx.doi.org/10.1007s10640-007-9176-6.

24 United Nations, 1993. Handbook of National Accounting: integrated environment and economic accounting 1993 (SEEA 1993). New York: United Nations

25 United Nations, 2003. Handbook of National Accounting: integrated environmental and economic accounting 2003 (SEEA 2003) . New York: United Nations

26 United Nations, 2012. System of environmental-economic accounting 2012: Central Framework - white cover publication. New York: United Nations

27 United Nations, 2014. The system of environmental-economic accounting 2012 experimental ecosystem accounting. New York: United Nations

28 Ouyang, Z.Y., Zhu, C.Q., Yang, G.B., Xu, W.H., Zheng, H., 2013. Gross ecosystem product: concept, accounting framework and case study. Acta Ecologica Sinica(In Chinese). 33(21) : 6747-6761

29 Ouyang, Z.Y., Zheng, H., Xiao,Y., Polasky, S., Liu, J.G., Xu, W.H., Wang, Q., Zhang, L., Xiao, Y., Rao, E. M., Jiang, L., Lu, F., Wang, X.K., Yang, G.B., Gong, S.H., Wu, B.F., Zeng, Y., Yang, W, Daily, G.C., 2016. Improvements in ecosystem services from investments in natural capital. Science. 352(6292):1455-1459

In order to improve our academic level and response with China's updated environmental policies, up to now, CAEP has built up 15 scientific platforms for research study.

Scientific Research Platforms

- Center for Total Quantity Control and Emission Trading
- Center for Ecological Environmental Compensation
- Center for Environmental Research on Beijing-Tianjin-Hebei Region
- Center for Heavy Metal Pollution Prevention
- Center for Climate Change and Environmental Policy
- Center for Environment and Health
- Center for Environmental Zoning
- Center for Ecological Environment in Yangtze River Economic Zone
- Center for Environmental PPP
- Center for Environmental Protection Tax
- Center for Investment Performance Management
- Center for Ecological Environment and Economic Accounting
- Center for Rural Environmental Protection
- Center for Regional Air Quality Simulation and Control
- Center for Environmental Auditing

Chinese Academy of Environmental Planning

8 Dayangfang, BeiYuan Road, Chaoyang District, Beijing 100012, China

Editor in chief: Prof. WANG Jinnan

President, Chinese Academy of Environmental Planning

Contact person: Mr. ZHANG Hongyu

Tel: 86-10-84917585

Fax: 86-10-84918581

E-mail: zhanghongyu@caep.org.cn

Web: www.caep.org.cn