Valuation of Ecosystem Services: Research Progress and Prospects

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Abstract The ecosystem services are material base and natural capital for sustainable development of human being. Valuation of ecosystem services is favorable for people realizing the importance of natural ecosystem to human being, and considering its long-term influence on sustainable development of human society when making decisions. Besides, it is an attempt of ecology, geography and other natural sciences to influence social decision process by economic methods. *The Value of the World's Ecosystem Services and Natural Capital*, written by Robert Costanza *et al.*, in 1997, is generally regarded as a masterpiece for the research of valuing ecosystem services. However, the classifying standard of ecosystem services, the method of various services summation and the purpose for static global value, had confronted many criticisms. Still to now, accurately valuing ecosystem services is not easy, because of the complexity of natural ecosystem, the weak capability of economic system to pricing ecosystem services and the lack of more study in this field. Based on the criticisms summarizing and comprehensive analysis, further study suggestions of ecosystem services valuation is presented: multi-scale integrated and community participation applied in evaluation, dynamic changes of material value and intangible value of ecosystem services, investigation and simulation studies of the marginal value when ecosystem services changed, associated with related areas like ecological compensation research, and research on the market-oriented evaluation of ecosystem's intangible values.

Key words Ecosystem services, Value evaluation, Research progress, Research prospects

1 Research progress

1.1 International research progress The services of ecological systems and the natural capital stocks that produce them are critical to the functioning of the Earth's life-support system[1]. Natural capital, artificial capital, human capital and social capital constitute together the capital foundation of welfare of human society[2]. Valuation of ecosystem and its service functions is favorable for clearly understanding the importance of support, adjustment, product and culture provided by ecosystem. The valuation of ecosystem services can be traced back to the second half of the 19th century. In the 1970s, Holder and Ehrlich *et al.*[3] pointed out that the loss of bio-diversity directly influences ecosystem services. By then, the concept of ecosystem services was clearly established. In 1997, research achievements of Daily and Costanza lifted the study in this field to a new height. *Nature's Service Societal Dependence on Natural Ecosystem* written by Daily *et al.* not only summarizes concept of ecosystem services, but also takes special research on value of various ecosystem services[1]. *The Value of the World's Ecosystem Services and Natural Capital*[2], written by Costanza *et al.* and published in Nature, makes the principle and method of valuation of ecosystem services more definite. This research achievement rapidly evoked great reaction in the world. Ecological Economics collected relevant ecosystem services and valuation research achievements in the form of forum or workshop. In 2002, the United Nations organized the Millennium Ecosystem Assessment, which further deepens researches on ecosystem services[4]. MA's research promotes change of academic research of ecosystem services to practical research. However, due to much more attention paid to supply and demand of service and product, the research fails to go deep into valuation period of ecosystem services.

1.2 Domestic research progress In China, the research on ecosystem services started in the 1980s, for example, Zhang Jiabin *et al.* adopted Shadow Project method and Substituted Expense method to valuate ecosystem of forest resource in Yunnan regions[5]. Since the middle and later period of the 1990s, relevant research achievements successively spring up. At theoretical level, Ouyang Zhiyun introduced concept of ecosystem services and elaborated the concept connotation and valuation method[6]. Zhao Jingzhu *et al.* compared quantitative evaluation and value evaluation methods for ecosystem services[7]. Zhang Zhiqiang *et al.* elaborated the significance of research on valuation of ecosystem service and natural capital to the establishment of "integrated ecological, environmental and economic accounting system"[8]. On the basis of valuation model of Costanza, Xie Gaodi put forward "Form for equivalent value factor of ecosystem services"[9]. Li Wenhua[10], and Li Jinchang[11-12] *et al.*[11-12] further studied ecosystem service functions and value structure from the perspective of ecology and environmental economics. Most empirical cases of domestic ecosystem service value at early stage are oriented towards forest ecosystem, such as Hou Yuanzhao[13], Jiang Yanling[14], and Xue Dayuan[15-16] valuated functions of forest ecosystem services of the whole country or some impor-

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tant forest regions. Around 2000, research achievements of the nation-wide or regional ecosystem appear one another. For example, Ouyang Zhiyun[17], Chen Zhongxin[18], Zhao Tongqian[19], Pan Yaozhong[20], and He Hao[21] made preliminary estimation for value of functions of land ecosystem services in China. Since methods and calculation procedures are different, the results are also significant different. Xie Gaodi[9] and Lu Chunxia[22] assessed separately economic value of China's natural grassland, Qinghai-tibet Plateau and colony ecosystem. Xu Qiao[23], Xiao Yu[24], Wu Lingling[25], and Yang Qingwei[26] evaluated service value of typical ecosystems, such as urban, wetland, estuary and coastal zone. Cai Bangcheng[27] and Wang Zongming[28] respectively studied changes of service value of Jiangsu Kunshan urban ecosystem and Sanjiang Plain regional ecosystem. At present, Chinese scholars begin to systematically sum up and review past researches. Li Wenhua *et al.* published *The Theory, Method and Application of Valuation of Ecosystem Service Functions*[29]. In 2009, he wrote the article *Review and Prospects of Researches on Ecosystem Services in China*, which summarizes achievements and existing problems and pointed out that it is required to change the current approximate calculation to deeper level researches.

2 Research disputes

The Value of the World's Ecosystem Services and Natural Capital, written by Costanza *et al.* in 1997, made the research on ecosystem service value rise to a new peak. Their achievement is not only helpful for calculating total amount of global natural ecological capital, but also provides a basic research frame for evaluation of ecosystem services. In the paper, Costanza *et al.* also stated that the purpose of writing the article is mainly to attract attention of academic circle to this field, as a result, to make the ecosystem service research more deep and mature. From then on, academic circle begins to debate on evaluation of ecosystem service functions. The focus is mainly on following points.

2.1 Characterization of ecosystem service functions Research achievements made by Costanza *et al.* in 1997 divide the global ecosystem into 15 biomes according to land cover, divide functions of ecosystem services into 17 main types, estimate values of service functions of each biome, and add up to the total value of global ecosystem. The implied assumption is that every ecological unit is independent in space and every ecological service is irrelevant, which are opposed by some scholars. Because there is no serious limit of every ecosystem in space, the ecosystem is always connected with surrounding environment[31]. Ecosystem is a non-linear, diverse and dynamically changing complicated system, and an integration of internal structure and external functions[32]. Artificial division of functions of ecosystem services is random, and dynamic along with change of social preference. Therefore, functions and services of ecosystem are not corresponding one to one. In addition, research achievements of Costanza *et al.* are extrapolated from typical values of many sample cases, which will lead to inconsistency of calculated total value with actual value of functions of global ecosystem services.

2.2 To be valuated or not? Costanza *et al.* believe that improvement or deterioration of functions of ecosystem services will definitely influence sustainability of human welfare, so it is required to take account of its importance in decision making[2]. Nevertheless, due to loss of market or low price at current stage, it fails to reflect actual social value of most ecosystem service functions. Therefore, it is imperative to carry out research of valuation. They also contend that it is more important to arouse attention of the public to protection of natural ecosystem. Besides, valuation is not necessarily monetary, but compared to a certain objective, is people's weighing on importance of matter and their choice. Even if it is doubt about valuation of ecosystem service functions, it is still a kind of weigh and choice. Thus, it constitutes a kind of value cognition[33]. Contrary to opinions of Costanza[31], some scholars think that natural ecosystem plays an inestimable role of spiritual and moral principle and support, and it is unnecessary to measure the total value.

2.3 Total global value and regional marginal value As stated by Costanza *et al.*, it is difficult to accurately measure total value of the function of natural ecosystem and it is more realistic to evaluate marginal value of ecosystem change. In reality, however, it is the calculation of total static value based on regional balance. Along with environmental deterioration and population growth, functions of ecosystem services will gradually rare. Consequently, its social value will be greater and greater, so it will be much more significant to predict trends of value of ecosystem service functions[34]. Furthermore, most decisions on ecosystem management are based on understanding of local communities and government. Therefore, evaluation of local ecosystem service functions has greater warning significance and decision guidance significance than evaluation of global ecosystem[35].

2.4 Calculation of marginal value Since most social actions and decisions are based on economic analysis of "cost – benefit", it will be more significant to evaluate marginal value influenced by changes of ecosystem service functions than to evaluate its static value. The determination of marginal value not only needs actual value of ecosystem services, but also needs quantification of people's satisfaction at changes in ecosystem service functions. Most scholars agree that it is possible to obtain value of non-commercial articles through surveying willingness to make payment[36], to bring decisions closer to actual social public preference[37-38]; however, there is still no ideal methods for solving the problems of how to make interested people realize the irreplaceability of ecosystem service functions and non-linear relation of ecosystem structure, and reflect the real willingness of payment, and how to guarantee decisions reflecting preference or willingness of the majority.

2.5 Science of value coefficient Costanza indicated that most values of ecosystem service functions are generated from survey of willingness to pay. However, since the previous work is expanded on the basis of few sample data collected, the val-

ue coefficient of every ecosystem type is not universal and can not reflect actual value of global ecosystem services[39]. In fact, for the same type ecosystem, social willingness to pay for functions of ecosystem services will be greatly different because there are differences in economic development level, residents' income, value cognition and consumption preference between different countries and regions. Therefore, the determination of values of ecosystem services must consider various factors, including time, region, environment and object. Only from this, can results be objective and actual. Besides, researches of Costanza *et al.* are mainly based on survey on payment willingness of residents in developed countries. If using this criterion in the world wide range, it is easy to result in too high evaluation value. Therefore, many scholars think it is not believable for the value close to double GNP of global ecological capital[40-41]. Some scholars think that research of Costanza is not scientific because of too high pricing of wetland and too low pricing of cultivated land[42].

3 Difficult points in research

Valuation of ecosystem services is favorable for people realizing the extreme importance of natural ecosystem to human being, and considering its long-term influence on sustainable development of human society when making decisions. In addition, it is an attempt of ecology, geography and other natural sciences to influence social decision process by economic methods. Even though there are various valuation methods, such as Surrogate Market Approach, Simulation Market Method, and Contingent Valuation Method, etc, it is difficult to accurately measure total value of the function of natural ecosystem. In fact, by now, the dispute over the above researches has not stopped. The reasons can be summarized as follows: complexity of ecosystem itself, uncertainty of reflection of ecosystem service functions from economic system, as well as limitation on period of valuation researches.

3.1 Complexity of ecosystem Complexity of ecosystem includes dynamic heterogeneity of time and space and non-linearity of ecological process and diversity of ecological functions. Space heterogeneity of ecosystem service value comes from heterogeneity of distribution pattern of biological productivity and biological diversity[43]. Besides, since value of some ecological service functions may be generated within the region and be realized outside the region through energy and material flow, it is extremely important to make clear regional difference and space circulation of ecological service functions[44-45]. Valuation of ecosystem services should also pay attention to ecosystem's dynamic change of time. Long-term change of ecosystem is often hidden in " intangible now"[46], so the research of ecosystem by measure of specific time can not reveal trend of long-term dynamic change, and thus the valuation must be based on research of ecosystem by different time measure. Outside a specific ecosystem, there will always be a series of factors influencing functions of ecosystem. And due to constant change of external driving factors, simple expansion of time and space measure will lead to hysteresis effect in understanding of ecological process[47]. The time and space heterogeneity of ecosystem determines that the valuation of ecosystem service functions must clearly recognize timeliness and space of ecosystem process. For this, the research on integration of multiple space and time scales becomes particularly important[48]. The complexity of ecosystem also depends on its composition structure, diversity of acting mechanism and non-linearity of ecological process. The action and feedback within the ecosystem and between different types of environment are mainly shown in complex relationship of non-linearity and unbalance[49].

3.2 Difficult to catch ecosystem service information The difficulty in accurately valuating ecosystem services is also manifested in that economic system often fails to accurately catch and adapt to complex information change of ecosystem service functions. Most ecosystem service functions have the nature of natural public goods or quasi public goods. For individual members, people would like to act as hitchhikers, rather than dealers. As a result, even if social groups have the willingness and ability of supply and demand, the product and service provided by ecosystem will not be shown by economic rareness[50]. Besides, complex non-linearity of ecosystem will make the valuation expression much more difficult[51]. Acts of government, such as adjustment of property system and transfer payment, will to a certain extent realize static value of ecological service functions, but the evaluation of marginal value will be more difficult. Extensive survey on payment willingness and making decisions accordingly may solve such problem. In the context of reasonable system, decision-makers, local common people and scientists form real cognition of natural ecosystem through mutual exchange, and can obtain real value of regional ecosystem service functions.

4 Research prospects

The research on valuation of ecosystem services is not started till the late of the 20th century, so it needs further deepening. At present, the valuation of regional ecosystem service functions is mainly oriented towards those types of ecosystems with single function. Most researches adopt method of first classification and then calculation; few researches touch on valuation of compound ecological functions of many ecological types. Most researches focus on fixed space or instantaneous time, and few are continuous researches on dynamic change of marginal value of ecosystem in different regions and time sequence.

According to the above analysis and summary, it is believed that valuation of ecosystem services should be started from following five aspects.

4.1 Multi-scale comprehensive research and evaluation with dynamic participation Based on dynamic time and space heterogeneity of ecosystem, combined observation and research of biological productivity and diversity by multiple time and space scales and integration of multiple sciences are evaluation of ecosystem service values. Exchange and integration of multiple value concepts and dynamic feedback process of

"evaluation – adjustment – reevaluation" are social basis for obtaining real values of ecosystem services.

4.2 Separation of material value and nonmaterial service value People's production activities in farming, forestry, husbandry and fishing have nearly extended to all global regions and ecological types. In the context of gradual establishment of agricultural and sideline product market and trading system, material value of foods and raw materials of ecosystems have been realized through market trading, and directly converted into economic welfare of producers. Therefore, it is easy to obtain results according to statistical analysis. In the condition of stable utilization technology, material value of ecosystem is in general inversely proportional to nonmaterial service value. In the past, researches neither distinguish these two points, nor touch on growth and decline relationship of time and space.

4.3 Survey and simulation research of marginal value Marginal value of ecosystem services is the change of social payment resulted from change of quantity and quality of ecosystem services. The research on marginal value needs continuous tracing of social payment willingness on the basis of constant change of ecosystem itself. In fact, on the basis of theoretical analysis of ecological economics, according to typical survey data of payment groups' income level, consumption habit and rareness of ecosystem services, it is able to carry out dynamic simulation of marginal value. At present, relevant researches basically remain blank.

4.4 Comparison with relevant fields or combined researches The most direct application of valuation of ecosystem services is to provide practical compensation standard for ecological compensation policies. Both ecosystem service valuation and ecological footprint research take regional biological productivity (*i.e.* land) as starting point of researches. They have common features and also have differences, so it is required to carry out combined or comprehensive research. With monetary valuation of ecosystem services, the contribution of ecological system and economic system to social welfare can be calculated together, and finally it is able to obtain real capital accounting result.

4.5 Market-oriented trend of nonmaterial service values With rise of social payment willingness and decline of transaction costs such as transportation and communication, those nonmaterial ecological services with higher recreational or aesthetic value have been manifested in various forms like ecological tourism. Therefore, it is urgent to follow up this trend and study factors influencing realization of the trend.

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Province, such as low efficiency of moisture production, low use rate of irrigation water and serious waste of water. Therefore, based on the regional characteristics of Hebei Province (such as water resource shortage and serious overexploitation of groundwater), we seriously implement the Hebei Provincial Party Committee and Provincial Government's strategic plan on the transformation of economic development pattern; on the basis of giving full play to the role of the scientific and technological innovation in promoting technical progress in traditional industries and cultivating strategic emerging industries, carefully study issues concerning efficient water use in agriculture first started by Hebei Provincial Department of Science and Technology in March 2010.

We try to predict the efficient water use in crop farming, in order to alleviate the grim situation of groundwater overexploitation in Hebei Province, and promote the sustainable use of water resources in Hebei Province, achieving the goal of efficient water use in crop farming, stable production and high yield during the future period 2011 -2020 in Hebei Province.

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