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Ecosystem services research in China: Progress and perspective

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ABSTRACT

This paper provides a comprehensive review of ecosystem services and their economic valuation in China. The main objective of this review is to introduce the findings of the various valuation studies, and explore the challenges that emerged in these studies. This paper shows that ecosystem services research in China went through four stages covering all the main ecosystem types and multi-scales. These studies have raised public awareness of the value of ecological and bio-resource issues, and promoted the establishment of eco-compensation mechanisms in China. However, there are still many controversies and challenges that have emerged from current ecosystem services research. We propose that future ecosystem services research focuses on i) the corresponding definition and classification systems for all ecosystems; ii) the observation and establishment of the relationship between ecosystem structures and corresponding functions; iii) the improvement and normalization of valuation methods; and iv) the exploration and analysis of the spatial and temporal variations of ecosystem services. Furthermore, it is important to improve the accessibility of ecosystem services valuation in environmental decision-making.

1. Introduction

The ecosystem, an organized and functional unit of the natural world, provides a variety of services and goods for maintaining human livelihood (Millenium Ecosystem Assessment, 2003). With the rapid increase in human population and the excess utilization of natural resources, the demands for ecosystem services often surpass their provisioning capacity (Vitousek et al., 1997; Bennett et al., 2005), and therefore humans frequently enhance the production of some services at the expense of the others (Jackson et al., 2001). Nevertheless, if there is insufficient understanding and care taken of these ecosystem services, the anthropogenic transformation could seriously aggravate the degradation of ecosystems (Bennett et al., 2005).

The objective of the ecosystem services approach is to explain the effects of the human policies on both the ecosystem functions and human welfare by integrating ecology and economics (Costanza et al., 1997; Daily, 1997). In the past 30 years or so, the valuation of environmental services and changes has become one of the most significant and fastest developing areas in environmental and ecological economics (Turner et al., 2003), and the number of papers addressing ecosystems services is rising exponentially (Fisher et al., 2009). Encouragingly, a better and more comprehensive information base has been built from these studies for policy formulation and decision-making process (Turner et al., 2003).

This paper gives a comprehensive review of ecosystem services research in China, where a wide range of valuation studies have been introduced. The findings and shortcomings of the studies are then discussed. Some agenda and actions are proposed that, in view of these limitations, need to be undertaken for the future research on ecosystem services in China.

The rest of the paper is organized as follows. First, the evolution of the research on ecosystem services in China is introduced. This comprises four stages: the primitive perceptual recognition phase, the short-term ecological study phase, the long-term ecological observation phase, and the ecosystem services valuation phase. Second, about 230 case studies of ecosystem service valuation are reviewed, and their major findings and debates are discussed. Finally, future paths for ecosystem services study in China are proposed.

2. The Four Stages of Ecosystem Services Research in China

2.1. The Primitive Perceptual Recognition Phase

In the early stages of China's ecology history, the ancient Chinese people recognized and recorded the benefits afforded by the natural environment. For example, about 6000–7000 years ago, rice was planted in the Yangtze River Valley and millet in the Yellow River Basin (Li and Zhao, 2004). Prior to Pre-Qin times, there was a simple recognition of the water and soil conservation properties of the forest ecosystem, and this had gradually deepened over the subsequent millennia (Guan, 2004). Furthermore, the ancient Chinese planted trees on both sides of rivers to mitigate the erosion of the riverbeds and along roads to beautify the environment. They also planted the

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so-called *Fengshui wood* to preserve the memory of the past relatives. Moreover, a great number of Chinese ancient literatures, such as *Spring–Autumn of Lü*[1], *Nongzheng Quanshu*[2], *Qi Min Yao Shu*,[3] for instance, recorded a primitive recognition of ecosystem services. Although this recognition and practices regarding ecosystem services at this stage are very primitive (or perceptual), and different from 'scientific research', they lay a solid foundation for the ecosystem services research in China.

2.2. The Short-term Ecological Study Phase

There has been a long history of observing the interactions between forest and water in China. As early as the 1920s, Chinese scientists were studying the impact of the forests on the runoff and sediment generation in Laoshan Mountain in Shandong Province and Wutai Mountain in Shanxi Province (Li et al., 2001). In 1962, the impact of the forest on annual runoff in the Yangtze River Basin was observed. The results showed that the watershed with a high forest cover produced more stream runoff than watersheds with low forest covers and those in non-forest areas (Pan, 1989). The relation between the cutting and the water and soil conservation of *alpine dark coniferous* in the west Sichuan province was also studied (Ma, 1963). To facility these studies, several forest ecosystem experimental stations were established from the late 1950s to early 1960s (Zhang et al., 2004), that contributed to the early ideas about forest and water relations in China.

Farmland shelterbelts began to be constructed on the northeastern plain of China as early as the 1950s, and some shelterbelts have a history of half a century (Cao, 1983). In particular, the speed of their construction was greatly accelerated during the first-stage and second-stage construction of the Project of Sanbei Protective Plantations, started in 1978 (Zhu, 1985). Studies of the windbreak benefits of farmland shelterbelts were carried out in the early 1950s (Hu et al., 1990). These early studies, however, mainly focused on the determination of distribution condition of wind speed, temperature, humidity, and soil improvement, as well as crop yield and quality (Yuan, 1955; Tang, 1965), not practicable for a perfect farmland shelterbelt net today (Zhao, 2002).

2.3. The Long-term Ecological Observation Phase

After the Cultural Revolution, the ideas and methods of many long-term ecological research stations and networks, such as Terrestrial Ecosystem Monitoring Sites (TEMS) and United States Long Term Ecological Research Network (USLTER), were introduced into the Chinese long-term forest ecosystem research with emphasis on nutrient and energy flow at the ecosystem level. The Changbai Mountain forest ecosystem station, the world famous forest ecosystem research base with its well-preserved typical mountain forest ecosystem in Eastern Asia, was established and joined the MAB (Man and Biosphere) program in 1979. The Chinese Ecosystem Research Network (CERN), one of the founding members of the International Long Term Ecosystem Research Network (ILTER), and Global Terrestrial Observation System (GTOS), was established in 1988 under the auspices of the Chinese government and the World Bank Loan. CERN consists of 36 field research stations for various ecosystems, including agriculture, forest, grassland and water, five disciplinary centers and one synthesis center. Moreover, another large ecological research network, the Chinese Forest Ecosystem Research Network (CFERN), administered by the Science and Technology Department of State Forestry Administration of China, was established in the late 1950s. CFERN constitutes 15 sites at present, and six of them are at the states-level (Li and Gan, 2006). The distribution of CERN and CRERN Observation Stations is shown in Fig. 1. These long-term observation sites have accumulated a great amount of crucial data for scientific research on the complicated interrelationships between organisms and their environments, and provided scientific information for the ecosystem services study in China.

2.4. The Ecosystem Service Valuation Phase

Ecosystem services research has become an important area of investigation over the past decade (Fisher et al., 2009). In the early 1980s, some Chinese researchers tried to evaluate the economic benefits of forest ecosystem services (Liao et al., 1983). In 1999, Ouyang et al. estimated the Chinese terrestrial ecosystem services and their indirect economic values based on ecological function analysis. The results showed that the indirect economic values of organic matter production, CO_2 fixation, O_2 release, nutrient recycling, soil protection, water holding capacity and environmental purification added up to 30.49 trillion yuan yr^{-1}. At county-level, Guo et al. (2001) estimated the annual economic value of some ecosystem services by forest ecosystems in the Xingshan County of Hubei Province of China, using both simulation models and geographic information system (GIS). In terms of actual ecosystem services, the total economic value of forest ecosystem services in Xingshan County is estimated to be 582.96 million yuan per year. According to partial valuation results of the global ecosystem services obtained by Costanza et al. (1997), on the basis of the responses of the ecological questionnaires from 200 Chinese specialists, Xie et al. (2003) established the value unit area of ecosystem services in the Chinese terrestrial ecosystems, and estimated the values of ecological assets on the Tibetan Plateau as 936 billion yuan yr^{-1}, which accounted for 17.68% of the annual ecosystem services value of China and 0.61% of the world. In the fifth national investigation of forest resources (1994–1998), Yu et al. (2005) estimated that the total value of the forest ecosystem services in China was 3.06 trillion yuan yr^{-1}, based on the method proposed by Costanza et al. (1997), and found that the indirect economic value was 14.94 times the direct economic value. In addition, there were also many influential studies of the valuation of ecosystem services in China (see Jiang and Zhou, 1999; Chen and Zhang, 2000; Zhang et al., 2007c). These studies estimated the economic value of main ecosystem types at different levels using various methods, and provided scientific bases for environmental protection and ecological construction in China. It is especially worth noting that Li (2008) reviewed the valuation theories and methods of ecosystem services, introduced several case studies on forest, grassland, farmland and wetland, and pointed out the practical difficulties in ecosystem service valuation as well as ways to overcome them.

3. Findings from the Ecosystem Services Research

3.1. Systematic Valuation on Ecosystem Services in China

China has all the ecosystem types that occur in the northern hemisphere, including forest, grassland, desert, wetland, coast and marine, and farmland ecosystems, which play an important role in

[1] The four essays in Lü Shi Chun Qiu (Master Lü's Spring and Autumn Annals), namely, 'Shang Nong' (meaning 'lay stress on agriculture'), "Ren Di' (meaning 'Capacity of the soil'), 'Bian Tu' (meaning 'Work the ground') and Shen Shi (meaning 'Fitness of the Season'), which was completed in 239 B.C., can be claimed as the earliest agricultural treaties in China. These essays are not written specifically for agriculture. Yet, taken together they form a complete set of treaties with a deep system opinion.

[2] *Nong zheng Quan shu* emerged in the late Ming Dynasty. It is a scientific work on agriculture and is honored as an encyclopedia on the Chinese ancient agriculture science. It inherits the tradition of the Chinese ancient agronomy, and absorbs knowledge on agriculture and water conservancy from the west. The book looks at the agriculture manufacturing from the view of farming. This brings the agriculture manufacturing into prominence.

[3] *Qi Min Yao Shu* can be considered as an important work, written for the people's welfare in 630–640 AD. It is also a summary of the peoples' experiences in agricultural cultivation, soil improvement, rotational intercropping, fine variety breeding, sowing, farm management, irrigation and fertilization.

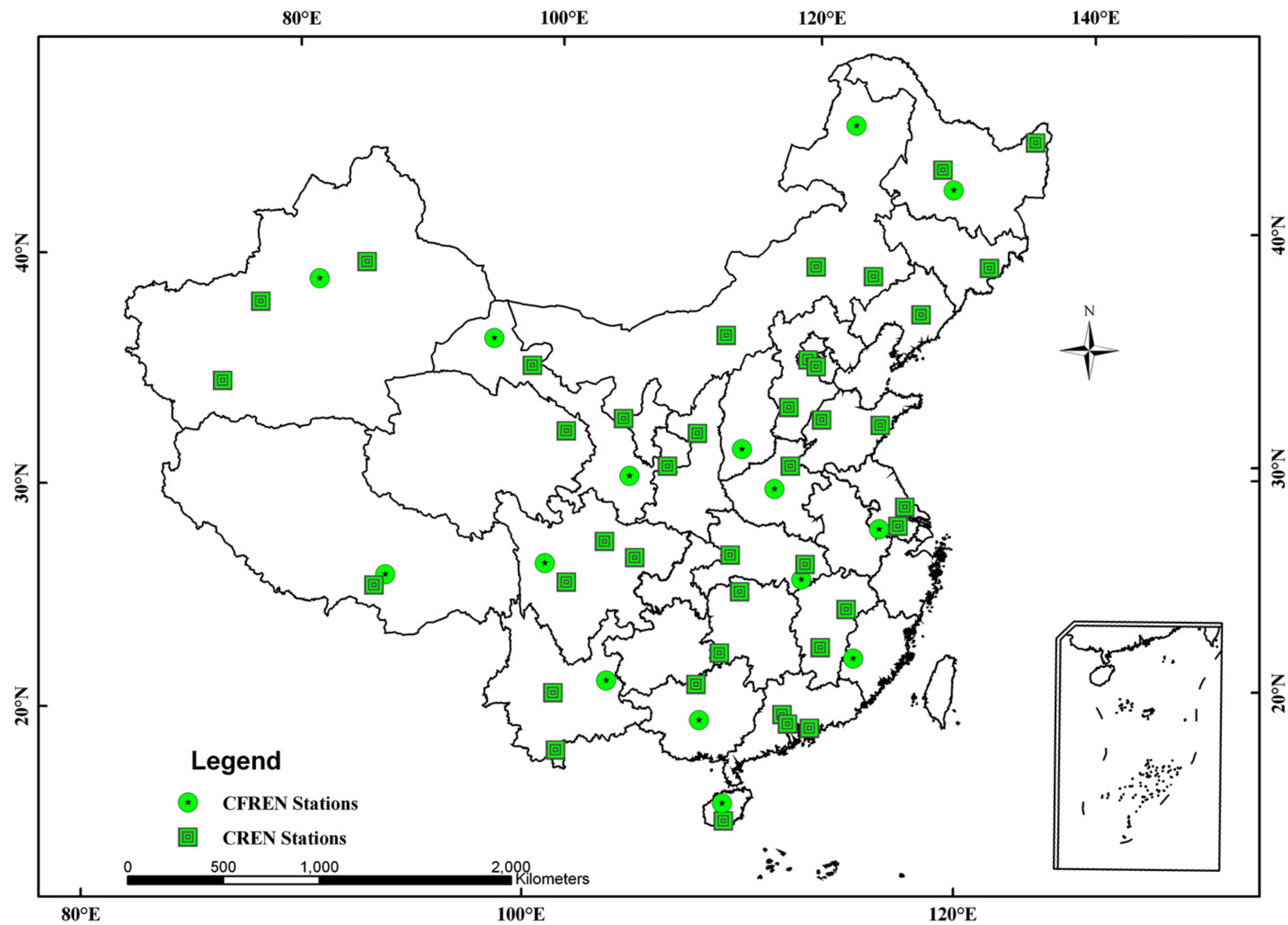

Fig. 1. CERN and CRERN Observation Stations Distribution.

improving the Chinese standard of living. In the past two decades, these ecosystem services and their economic values have been systematically evaluated at various levels across China (Table 1).

Forest ecosystem services and their values received considerable attention from the national to the local levels. According to the forest inventory data from the third national investigation of forest resources (1984–1988) and the global average values of forest ecosystem services given by Costanza et al. (1997), Jiang and Zhou (1999) evaluated the values of ecosystem services of major forests in China to be about 117 billion $ annually. Using long-term measurement of forest ecosystems, together with relative data provided by forest resources inventory, and hydraulic and meteorological departments, Zhou and Jiang (1999) estimated the forest benefits of Heilongjiang Province. Transferring the 'products' to currency value using equivalent replacement of beneficial products for currency and standard dimension, they found that the total value was 49.87 billion yuan. In addition, Gao et al. (2008) used cost expenditure method, opportunity cost method and replacement cost method to calculate the forest ecosystem service value in Shenyang. Results showed that the total ecosystem service value was 359.63 billion yuan. In addition, Xue et al. (1999) used market pricing method, shadow engineering method, opportunity cost method and replacement cost method to value the functions of the forest ecosystem in Changbaishan Mountain Biosphere Reserve. The valuation results revealed that the total ecological function value in 1996 was about 1765 million yuan *per annum*.

Table 1
Case studies of different ecosystem types with multi-scales.

Ecosystem type	Scale				Total
	National	Provincial	Municipal	Local	
Forest	8	25	12	59	104
Grassland	3	5	2	7	17
Wetland	–	2	4	25	31
Farmland	2	–	6	3	11
River	3	–	4	6	13
Marine	–	–	1	5	6
Regional ecosystem	7	6	14	21	48
Total	23	38	43	126	230

Note: derived from the published papers searched in China National Knowledge Infrastructure (http://www.cnki.net) from1990 to 2008.

3.2. Raised Public Awareness of Ecosystem Conservation

The benefits of wild ecosystems often are underestimated, because most of the ecological benefits cannot be reflected in the traditional marketplace. Unfortunately, in China natural resources have been over-exploited for a long period with insufficient understanding of the ecosystem services. Ecosystem valuation can help resource managers to assess the effect of the market failures by measuring their cost to society in terms of the lost economic benefits. Therefore, the valuation of ecosystem services has been used by many environmentalists as an attempt to rectify the pessimistic attitude of the people, and has become an effective way to evaluate the multiple benefits provided by these natural ecosystems.

At present, the ecosystem service studies in China have greatly raised public awareness of the valuable services provided by nature.

Table 2
The programs about forest ecological compensation in China.

Programs	Scope	Regions	Subsidy input (yuan ha^{-1} yr^{-1})
Natural Forests Protection Program (NEPP)	The primeval forest, natural secondary forest, protection forest and special-use forest	The natural forests located in 17 provinces (autonomous regions and municipalities) on the upper reaches of the Yangtze River, middle and upper reaches of the Yellow River, which areas were 73 million ha	Forest conservation: 210 Aerial seeding: 750 Artificial afforestation: 3000 (the upper reaches of the Yangtze River); 7000 (the upper and middle reaches of the Yellow River)
Sloping Land Conversion Program (SLCP)	Sloping lands above 25° which subject to soil erosion, sandstorms and damages	Returning farmland to forests located in 25 provinces (autonomous regions and municipalities) on the upper reaches of the Yangtze River, the upper and middle reaches of the Yellow River and Xinjiang production and construction crops, which areas were 22.93 million ha	Seedling: 750 Living allowance: 300 Grain: 2250 kg (the upper reaches of the Yangtze River); 1500 kg(the upper and middle reaches of the Yellow River)
Forest Ecological Compensation Fund (FECF)	Key public ecological forests and spares forests, shrub forests and new planting sites in serious desertification and water and soil loss area	The stocked forest around China which covering 26 million ha	Compensatory spending: 67.5 Public management: 75

Source: Task Force on Eco-compensation Mechanisms and Policies (2007).

Given the crucial role that ecosystems and their services play in supporting human, animal, plant, and microbial populations, the enormous value of these ecosystem services has been widely recognized and emphasized, ranging from the individual to government level in China.

3.3. Scientific Basis Provided for Payment for Ecological Benefit

In recent years, a large number of ecosystem services studies have shown that the ecological or environmental value of an ecosystem is often several times its market value, and the eco-compensation mechanisms have gradually become considered as potentially valuable tools to better address ecological conservation and environmental issues. Moreover, the eco-compensation policies of forest and nature reserves, watershed, mineral resources and watersheds have been carried out based on the ecosystem service research in China (Task Force on Eco-compensation Mechanisms and Policies, 2007). The public fiscal transfer measures for Forest Ecosystem Services Compensation (FESC) in China are mainly Natural Forest Protection Program (NFPP), Sloping Land Conversion Program (SLCP) and Forest Eco-Compensation Fund (FECF). Table 2 shows the scope, regions and subsidies of the programs regarding FESC. The NEPP project makes a contribution to the growth and restoration of natural forest through logging prohibition, inducing commercial timber production, and reemployment program of the forestry staff in a planned way. The state invested 102 billion yuan in the project during the pilot implementation from 1998 to 1999, and the total capital investment will have reached 962 billion yuan over the period 2000–2010. The main objective of SLCP is to reduce soil erosion by converting cropland on steep slopes and some degraded land into grassland and forestland. The total investment in this program had reached 103 billion yuan by the end of 2005. The FECF is used for the planting, tending, protection and management of the forest resources. Starting from 2004, the total compensation fund was increased from one billion to two billion yuan, and standard current compensation was 75 yuan ha^{-1} yr^{-1} for the key state nurseries and nature reserves in the forest sector.

3.4. Standardization of the Assessment Indicators and Methods for Forest Ecosystem Services

Although there has been an almost exponential growth in publications on the benefits of natural ecosystems to human society in China, the significant difference of assessment indicators, calculation approaches, and reference prices among various case studies of ecosystem services valuation is very common. For example, Ouyang et al. (1999) estimated the Chinese terrestrial ecosystem services and their indirect economic values as 30.49 trillion yuan yr^{-1} based on ecological function analysis. However, He et al. (2005) estimated the values as 9.17 trillion yuan yr^{-1}, with the measurement of the net primary productivity and vegetation coverage fraction based on remote sensing data. In addition, Jin et al. (2005) divided the forest ecosystem services into eight types (timber and other products, recreation and eco-tourism, water storage, C fixation and O_2 release, nutrient cycling, air quality purifying, erosion control, and habitat provision), and estimated the total value of forest ecosystems in China was 3.06 trillion yuan yr^{-1}. Nevertheless, Zhao et al. (2004) established an index system of 13 indicators for forest ecosystem services (such as timber and other products, weather regulation, C fixation, water storage, erosion control, air quality purifying, nutrients cycle, windbreaks, cultural diversity, recreation and eco-tourism, O_2 release, and provisioning of habitat), and estimated the total value of forest ecosystems in China as 1.41 trillion yuan yr^{-1} based on the service mechanism analyses.

In May 2008, The State Forestry Administration of China issued the 'People's Republic of China Forestry Standard: Forest Ecosystem Service Valuation Norms', which consists of 14 indexes (Table 3). The standard proposes some assessment formulas and reference prices to normalize and guide forest ecosystem services valuation in China. Although there are still many controversies, deficiencies and problems that need to be further studied, the standard developed the first general framework, provided guidance for the valuation of forest ecosystem services, and made a useful and necessary attempt to standardize ecosystem services research in China.

Table 3
Evaluation indicators of the specification for forest ecosystem services in China.

Categories	Indicators
Water conservation	Hydrological regulation Water purification
Soil conservation	Soil fixation Fertilizer conservation
Carbon fixation and oxygen released	Carbon fixation Oxygen released
Nutrient accumulation	Nutrient accumulation
Atmosphere environment purification	Negative-ion supply Absorb atmospheric pollutant Reducing noise Dust retention
Action of forest against natural calamities	Action of forest against natural calamities
Biodiversity conservation	Species conservation
Forest recreation	Forest recreation

Source: State Forestry Administration of China (2008).

4. Debates and Challenges

4.1. Inadequate Recognition in the Relationship Between Ecosystem Structure and Function

With the further study of ecosystem services, many scientists have recognized the importance of the complex relationship among ecosystem services, structure and process (Xie et al., 2006). Therefore, a fundamental recognition of the relationship between ecosystem structure and function is the key to evaluating ecosystem services. In the past two decades, the number of papers on ecosystem services has increased exponentially in China. However, more than 90% of these researches were confined to the ecosystem services valuation for different ecosystem types or in different regions, and only a few studies explored and analyzed the relationships among certain ecosystem structures, processes, functions and ecosystem services. Obviously, if there are many uncertainty factors, it is very hard to come to accurate conclusions about the value of ecosystem services. Moreover, the lack of knowledge about the relationship between ecosystem structure and function often impairs the credibility of the evaluation results of ecosystem service studies.

4.2. Reliability of Foreign Valuation Standards for Ecosystem Services Assessment in China

In recent years, ecosystem services valuation has gained more and more attention, and many studies of ecosystem functions and their benefits have been carried out in China. Very often, however, the evaluation index systems and the pricing standards in many case studies are only a copy or an imitation of the foreign valuation standard, and not much consideration has been given to the difference between China and other countries in terms of the social and economic situation. For example, the reforestation cost approach is more suitable than the shadow price from Carbon Tax in Sweden to calculate the carbon sequestration value of ecosystems in China. It is perhaps a common or normal phenomenon to simply copy foreign valuation standards at the early stage of ecosystem services research. Therefore, current ecosystem valuation study in China is still at the learning stage, imitating and gradually maturing. For future research on ecosystem services, the suitability of other counties' standards for China's ecosystem services should be discussed.

4.3. Random Selection of the Evaluation Indicators for Ecosystem Services

It is very difficult to divide ecosystem services into certain independent evaluation indicators, considering the complex relationship between ecosystem structure and function, as well as the high interdependency among different ecosystem services. Therefore, the classification of ecosystem services is one of the most vigorous debate issues (de Groot et al., 2002; Wallace, 2007; Fisher et al., 2009). Table 4 shows the evaluation indexes used in five case studies of forest ecosystem services valuation in China. It can be seen that the differences of valuation indicators are too great to allow universal conclusions. Thus, it is urgent to obtain a set of consistent evaluation systems for the ecosystem services in China, otherwise the incomparability of the valuation results in different ecosystem services studies will continue to exist.

4.4. Inadequate Consideration of the Spatial Heterogeneity of Ecosystem Functions

Ecosystems are spatially heterogeneous at a range of levels, and the essential processes depend on that heterogeneity (Pickett et al., 1997). Therefore, the heterogeneity of some ecosystems' structures results in the spatial variability of their functions (Guo and Gan, 2003). For example, the forests located in different regions provide different key ecosystem services for local communities, and even the trees in the same forest ecosystem can play different roles due to their different categories, structures or sites. At present, however, the ecosystem is often viewed as a homogeneous unit in many case studies, and the spatial heterogeneity of ecosystem services are seldom considered. Although these studies could estimate the price of the entire ecosystem, they can hardly reveal the spatial variation of ecosystem functions and services.

Table 4
Evaluation indicators of forest ecosystem service in five case studies.

	Hebei[a]	Gansu[b]	Heilongjiang[c]	Qinghai[d]	Tibet[e]
Timber production			+		+
Tourism	+		+	+	+
Gas regulation	+	+		+	+
Water conservation	+	+	+	+	+
Soil conservation	+	+	+	+	+
Soil formation			+		+
Water purification		+			
Air purification	+	+	+	+	+
Nutrient accumulation				+	
Increasing Crop	+				
Species conservation				+	
Increasing employment	+				+

[a] Bi et al. (1998).
[b] Zhang et al. (2007a).
[c] Zhou and Jiang (1999).
[d] Zhang et al. (2007b).
[e] Wang et al. (2007).

4.5. Applicability of the Valuation Results in Ecosystem Management

Most ecosystem services are public goods, which means that they may be enjoyed by some people without affecting other peoples' enjoyment. For example, an aesthetic view is a pure public good. No matter how many people enjoy the view, others can also enjoy it. Other services may be quasi-public goods, that is, people's enjoyment may be diminished at a certain usage level. A public recreation area, for instance, might be open to everyone. But crowding can seriously decrease people's enjoyment of the area. The problem with public goods is that, although people value them, no one has an incentive to pay to maintain the goods. Moreover, because the valuation results of the present ecosystem services research are often several times or even a dozen times larger than the real trade value of ecosystem goods, few governments or groups can afford the real cost of conserving nature. Therefore, the applicability of ecosystem services valuation in actual ecosystem management has often aroused a great deal of controversy.

5. Future Directions for Ecosystem Services Research in China

5.1. Definition and Classification Systems for All Ecosystems in China

As Wallace (2007) points out, clearly defining and organizing the concept of ecosystem services is not just a semantic decision, but it is integral to operationalize something that can clearly illuminate tradeoffs in natural resource management. Although plenty of studies about the definition and classification of ecosystem services have been published recently (Fisher et al., 2009; Fisher and Tuner, 2008), the use of one (or several) definition and classification systems for all ecosystems is inadequate. For example, artificial ecosystems need different standards from natural ecosystems. Furthermore, how to deal with relationships between human behaviors and ecosystem services is a complex and necessary topic of research. Therefore, the corresponding definition and classification systems for all ecosystems (natural and artificial ecosystems) in China are the foundation of ecosystem services research.

5.2. In-depth Studies of the Relationships Between Ecosystem Structure and Functions

A large number of case studies have showed that the research on ecosystem services and their value relies on a thorough understanding of the relationships among ecosystem structure, processes, functions and services. Therefore, the future ecosystem service research in China should focus on the essential structure, process, functions and interactions among organisms and their environment. Besides, it is of great importance to gradually expand and enhance the long-term ecology observation on the ecosystem processes and functions, and to accumulate more precise and reliable data for the ecosystem service valuation in China.

5.3. Standardization of the Evaluation Indicators and Methods

Based on different understanding and realization on ecosystem services, several classification systems have been developed (Costanza et al., 1997; Daily, 1997; de Groot et al., 2002). Besides, there are still various criticisms of the monetary evaluation methods for ecosystem services (Yang et al., 2007). Methods of valuing ecosystem services include revealed-preference approaches, stated-preference approaches, cost-based approaches, individual index-based methods and group-based methods. And some valuation methods are more appropriate for an ecosystem service than for others (Farber et al., 2006). Table 5 shows the major methods of environment valuation of Chinese scholars in recent years. However, most of the case studies in ecosystem services valuation in China were based on the valuation results given by Costanza et al. (1997). Therefore, an urgent and important task for the future ecosystem services studies is to develop and standardize the corresponding evaluation indicators and approaches for the ecosystem services in China.

5.4. Spatial and Temporal Changes of Ecosystem Services

There is a spatial heterogeneity in the functions of ecosystem services, and the monetary value of ecosystem services maybe change at different valuation dates. However, the present researches on the ecosystem service valuation in China are basically through static assessments, that is, only the value per unit area at one time is considered and the spatial and temporal differences of ecosystem services and their values are ignored. Gradually, the static assessment results of the ecosystem service value cannot meet the challenges of the ecosystem services studies. Thus, the task of the Chinese ecologists is to find the internal mechanism and change patterns from the long-term ecological observations, and construct regional dynamic models for the ecosystem services. And these dynamic models should integrate ecology and economy and could reflect the impacts of marginal changes in the ecosystem services.

5.5. Practical Application of Economic Valuation of Ecosystem Services

The development of the ecosystem services paradigm has enhanced our understanding on how the natural environment affects the human societies (National Research Council, 2004). At present, ecosystem valuation has been a widely used tool in determining the impact of the human activities in an environmental system. In China, the ecosystem services evaluation has also been applied in the environment impact assessment in land use program (Wang et al., 2006; Cai et al., 2007; Xu et al., 2008). However, there still has a considerably big gap in the complete utilization of the ecosystem services valuation towards better environment decision-making. Therefore, how to gradually bring the evaluation results of ecosystem services into the traditional cost-benefit analyses of land use strategy, and how to construct a comprehensive accounting system for ecosystem services and natural capital, are the important tasks for the future ecosystem services research in China.

6. Conclusion

In the last decade or so, ecosystem services valuation has become one of the most significant and fastest developing areas for the ecology and ecological economics in China. Major types of ecosystem, such as forest, grassland, wetland, farmland, and so on, have been studied at various scales. These studies have revealed the enormous economic value of ecosystems, which often was neglected by human in the past years. Due to so many uncertainties in the exact values of ecosystem services, we can only evaluate them roughly. Therefore, the current ecosystem services valuation is facing many debates and challenges, and there is a long way to go for the ecosystem services research in China. However, the fundamental purpose of ecosystem services valuation is not to put a price tag on an ecosystem or its components, but to express the effect of a marginal change in the ecosystem services provision in terms of the trade-off rate against other things that people value (Randall, 2002). In the future, there should be more research programs to be established in China to strengthen the international cooperation and exchange of ecosystem service research, which would actively promote the advances of the ecosystem service valuation in China.

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Table 5
Major methods of environment valuation of Chinese scholars in recent years.

Content	Method	Source
Ecological loss of China Three Gorge Project	Shadow engineering method, bidding game method	Fu and Wang (1987)
Chinese environmental pollution loss	Market pricing method, opportunity cost method, replacement cost method, human capital approach	Guo (1990)
Ecological and economic benefits of tourism	Travel cost method	Wu (1992)
Use value of scenery of the Three Gorges	Travel cost method	Wang and Chen (1993)
Environmental quality through price of real estate	Hedonic pricing method	Liu (1994)
Economic loss for desertification in China	Shadow engineering method, market pricing method	Zhang and Ning (1996)
Travel value of Changbaishan Mountain Biosphere Reserve of China	Cost expenditure method,travel cost method, contingent valuation method	Xue et al. (1999)
Economic value of the forest biodiversity in Labagoumen forest region	Market pricing method, shadow engineering method, opportunity cost method, replacement cost method	Cheng et al.(2000)
Water conservation value of forest	Shadow engineering method	Jiang (2003)
Ecosystem services value of urban inland river in Shanghai	Contingent valuation method	Zhao and Yang (2004)

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