

## Research Article

### Review of Wetland Ecosystem Services Valuation in China

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**Abstract:** The wetland ecosystem not only supplies human with the production of ecosystem goods, such as pharmaceuticals, food, but also is one of the foundations of civilization and life support systems. With the in-depth understanding of the wetland ecosystem functions, the research of wetland ecosystem services evaluation has attracted much attention. This study summarizes connotation, classification and assessment methods of wetland ecosystem services. The several commonly used the methods of wetland ecosystem services valuation were chose, including market value, forestation cost, carbon tax, shadow project costs and travel cost. On this basis, the existing problem and the future development of wetland ecosystem service evaluation in China were discussed. Some suggestions were proposed in the future wetland ecosystem valuation and management in China. More attention should be paid to the systematic, integrity evaluation system establishment of wetland ecosystem service. Automatic continuous online monitoring system of wetland should be established, in order to provide more detailed and reliable dynamic data for the evaluation of wetland ecosystem service.

**Keywords:** Assessment methods, China, ecosystem service, valuation, wetland

## INTRODUCTION

Wetland refers to a land area that is saturated with water, either permanently or seasonally, as well as less than six meters deep at low tide waters. Wetlands are the link between the terrestrial and aquatic ecosystems. They are transition zones where the flow of water and produce a unique ecosystem characterized by hydrology, soils and biological characteristics making these areas very important features of a watershed. In terrestrial ecosystems of wetlands are considered the highest production ecosystem. And wetland plays an important role in climate regulation, biodiversity conservation, soil functions maintenance, disasters mitigation, environment purification and sensory, mental and spiritual adjustment. Therefore, wetland is known to be "kidney of the earth". With in-depth awareness of wetland functions, wetland ecosystem service value and its evaluation have become the research frontier in areas such as ecology, ecological economics in China.

However, with the rapid development of industry, agriculture, population and urbanization, due to the attraction of short-term, private-sector profits and irrational use and development, continues to drive the destruction and degradation of wetlands. According to statistics, since the nineteenth century, more than half of wetland system disappeared, only the United States,

wetlands reduced by 54% (Barbier, 1993). In China only coastal wetland lost by almost 51% in nearly fifty years. Along with the shortage of land resources, many wetlands have been repurposed in China, such as reclaiming land from wetland and lake, which accelerate wetland shrinking.

How to restore wetland ecosystems? The best approach is to respect the laws of nature and wetland ecosystem gradually restores its function without human intervention. However wetland ecosystem is infinite in value, we hope its value can be brought into full play, while carrying on the wetland ecological system restores. This needs to include ecology system into economic and political decision making. Through conducts the integrated management to the wetland, found the optimal path of solving the problem. And then the valuation of wetland ecosystem services and its value occupied a very important position and receiving more and more attentions.

Ecosystem service is the important component of ecology and an integrated ecological research method. The valuation of ecosystem service value made people have a more comprehensive and profound understanding to the ecosystem functions. This greatly strengthens consciousness of ecological and environmental conservation. Ecosystem services assessment is integrated with environmental ecology, ecological economics and environmental ethics and the

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content of other related disciplines. Valuation of wetland ecosystem service is a research method of ecology, which wetland ecosystem service value will be represented in the form of currency, through analysis of wetland functions and stakeholders. It has been recognized that wetlands not only provide some of the products, but also possess some of eco-efficiency, such as soil and water conservation, climate regulation. And especially eco-efficiency may be unable to obtain the value even if people pay a lot of money. Therefore, we can be punish and compensate to destroyer of wetland and loser respectively based on wetland ecosystem services economic value. And the economic impact of the ecological problems has been incorporated in the Government's comprehensive decision-making process. This study summarizes connotation of wetland ecosystem services and its valuation methods. And the existing problems and shortcomings of the current assessment methods were discussed.

### CONNOTATION OF WETLAND ECOSYSTEM SERVICES

Ecosystem services function imply that natural environmental conditions and effectiveness maintain human survival from the ecosystems and ecological processes (Daily, 1997; Ouyang *et al.*, 1999). Including tangible or intangible natural products, environmental resources and eco-efficiency were provided by the ecosystem to human society of the production, consumption and circulation, restore and control (Sheng *et al.*, 2009). The earliest research of ecosystem services appears in the 20<sup>th</sup> century 40s in oversea, however starts relatively late in China. Investigator began to research forest ecosystem services in the 1980s including water conservation, prevention windstorms and fastening sand, which is oldest research about ecosystem services in China (Zhao *et al.*, 2004).

According to the connotation of wetland ecosystem services, we believe that wetland ecosystem services imply that wetland ecosystem and its species provide the conditions and processes to sustain human life needs, including the physical, chemical and biological processes. Based on the services and functions of wetlands, valuation of wetland ecosystem services employs a certain methods to assess the economic, ecological and social benefits of wetland and represent more clearly and concisely in the form of digit.

Wetland ecosystem function is a process to build an organism physiological functions, which is the foundation and the prerequisite that wetland ecosystem provide services. In terms of human survival wetland ecosystem service is that the wetland ecosystem function induced the beneficial effects, such as biological products, the ecological landscape effect, the atmosphere regulation, water purification and conservation and so on. Wetland ecosystem services assessment also highlighted the need for human. The people willingly pay currency for all wetlands

ecosystem services. Costanza *et al.* (1997) estimated the current economic value of 17 ecosystem services for 16 biomes, based on published studies and a few original calculations, in which the wetland ecosystem services value per year can be generated US\$4879 $\times 10^9$ . In China the ecosystem services were evaluated by using method of Costanza *et al.* (1997) and the results displayed the value of wetland ecosystem service is US\$4332.1 $\times 10^8$  year<sup>-1</sup> (Chen and Zhang, 2000).

Because of ecosystem service loss, it is an attempt to adopt alternatives to compensate for loss of ecological services. This not only is expensive, but also is not realistic in the long-run. According to ecosystem services value defined and the related document associated with the wetland ecosystem services evaluation (Costanza *et al.*, 1997; Zhao *et al.*, 2003), connotation of wetland ecosystem services can be divided into 6 categories.

#### **Organic production and ecological products:**

Wetlands generate a huge variety of plant, animal and mineral products and can offer foods, raw materials, medical resources and energy. Through the evaluation of wetland ecosystem service, the value of the Lalu wetland forage production was US\$51 $\times 10^4$  year<sup>-1</sup> (Zhang *et al.*, 2005). In the valuation of Taihu Lake wetland ecosystem services, the aquatic product value was estimated to be US\$8 $\times 10^7$  year<sup>-1</sup>. And plant resources only reeds produce the value to be US\$162 $\times 10^4$  year<sup>-1</sup> (Xu *et al.*, 2010).

**Water conservation and disaster mitigation:** Storm protection, flood control, drought recovery and other aspects of habitat response to environmental variability mainly controlled by vegetation structure (Costanza *et al.*, 1997). Wetland ecosystem has strong ability of water storage and supply water. During period of flooding, the wetland can be storage the large amount of flood in order to alleviate loss caused by flood. At the same time, in the dry season wetland can provide production and living water. In the valuation of Honghu lake wetland ecosystem services, the value of flood control effect was US\$1.68 $\times 10^8$  and that of water conservation was US\$2.27 $\times 10^7$  (Mo *et al.*, 2008). The value of flood control effect for Dongting Lake wetlands was US\$17.4 $\times 10^8$  year<sup>-1</sup> (Zhang and Zhang, 2012).

**Water purification:** Wetland ecosystems have an important ecological function to be in the purified water. The wetland ecosystems achieve contaminant removal by a series of physical, chemical and biological processes of wetland soil and plants. In China the wetland resources are very unevenly distributed in order to mitigate water pollution problems, constructed wetlands systems were establish in some cities to simulate the water purification function of nature wetlands ecosystem. The research indicated that wetland ecosystem have a good treatment effect on

commonly pollutants, such as nitrogen, phosphorus, heavy metals and micro-organisms (Bragato *et al.*, 2006; Zhang *et al.*, 2013). However, wetlands as a water purification system have certain requirements for water pollution load, otherwise secondary contamination will be created easily. Therefore, using wetlands to improve the water quality need carefully use and avoid secondary pollution.

**Regulation:** Wetland is a special ecosystem in water saturated state with lots of vegetation. Therefore, wetland can regulate of atmospheric chemical composition, global temperature, precipitation, the surface runoff and other biologically mediated climatic processes at global or local levels. Wetland can fix CO<sub>2</sub> and release O<sub>2</sub> by photosynthesis. This is very important to control the dynamic balance of CO<sub>2</sub> and O<sub>2</sub> in the atmosphere. The research showed that the value of Chongming Dongtan wetland ecosystem Climate regulation services in China was US\$6.68×10<sup>7</sup> (Ji and Wen, 2013). During the process of evaluation on Honghu Lake wetlands ecosystem, the mount of fixed CO<sub>2</sub> and release O<sub>2</sub> were 0.405×10<sup>8</sup> and 0.3×10<sup>8</sup> kg, separately (Mo *et al.*, 2008).

**The conservation of biological diversity:** Wetland ecosystems with rich biodiversity, because of the special structure, provide habitat and refuge of wild animals and plants and play a decisive role on global biodiversity conservation.

**Cultural values:** Wetland ecosystem with water, wetlands and a variety of birds, animals and plants, provides a place for the leisure and entertainment and has become a tourist destination. In addition, the wetland has abundant historical and cultural value and certain research value. Therefore the wetland ecosystem not only is cheerful mood and inspiring, but also is the spiritual source of many literary works.

**Wetland ecosystem services classification:** For the classification of ecosystem services, there are different classification criteria based on the type of wetland ecosystem functions. Although classification criteria can often be different, wetland ecosystem services classification basically can be divided into two major categories, namely the use value and non-use value. This can be further divided as direct use values, indirect use values, selective value and existence value

(Ouyang *et al.*, 1999). According to the classification of ecosystem service, the classifications of wetland ecosystem services are summarized in Table 1.

### WETLAND ECOSYSTEM SERVICES ASSESSMENT METHODS

Evaluation of ecosystem services is still in the exploratory stage. The different evaluation methodology was adopted because of different focus and different research areas of different scholars. Various methods have been used to estimate both the market and non-market components of the value of ecosystem services (Costanza *et al.*, 1997). For wetland ecosystem services evaluation, the following methods are more commonly used.

**Market value:** This method provides mainly a similar assessment according to the market prices of the products and services provided by ecosystem service. It is a more intuitive evaluation method for physical products (Zhang *et al.*, 2005; Jiang *et al.*, 2011), including fishing resources, plant products, water resources and so on. Because of its intuition, so that it becomes an assessment method the most widely used. However, the application of this method has certain limitations because of its one-sided.

**Afforestation cost and carbon tax:** The two methods used to assess the wetland ecosystem service value of climate control and air conditioning. Afforestation cost method is mainly based net production of afforestation costs on unit area of the, combined with total area of wetland plant, calculation wetland ecosystem services value. However, it is important that the wetland ecosystem can release not only O<sub>2</sub> but also the greenhouse gas, including CH<sub>4</sub> (primary) and N<sub>2</sub>O (secondary). Because these gases can produce adverse effects on atmosphere, the adverse effects should be subtracted from the positive benefits from CO<sub>2</sub> fixation and O<sub>2</sub> release (Duan *et al.*, 2005).

The carbon tax calculates the amount of fixing CO<sub>2</sub> and O<sub>2</sub> release by wetland plant on the basis of photosynthesis reaction equation. According to the CO<sub>2</sub> emission standards, the value of the regulation of climate and atmospheric were calculated. The value of Wuliangsu wetland atmospheric regulation is US\$5.3×10<sup>7</sup> by using the afforestation costs (Duan *et al.*, 2005). Using the method of afforestation costs to

Table 1: The classifications of wetland ecosystem services

Use value		Non-use values	
Direct use values	Indirect use value	Select value	Existence value
Wildlife	Clean water	Contemporary people are willing to pay the cost in order that they, their offspring or others can use wetland ecosystem service in the future	It is independent of human existence, such as: pollen value
Fuelwood, peat	Protection of biological diversity		
Landscape and tourism	Biogeochemical cycles		
Scientific research	Atmosphere and climate regulation		
Value of education			

assess the eastern Fujian coastal wetland ecosystem service, its value of climate regulation is US\$1.05×10<sup>8</sup> (Su *et al.*, 2012).

**Shadow project cost:** The shadow project cost is to construct artificial project replacing primary ecosystem functions after the environment has been degraded. The cost of artificial project was assessed as the value of ecosystem service. It mainly uses to assess climate regulation, the flood regulation, water purification and so on. The research showed that Haihe river wetland water purification values duo to total nitrogen and total phosphorus removal are US\$1.9×10<sup>7</sup> and 7×10<sup>7</sup> by using shadow project cost method, respectively (Jiang *et al.*, 2011). By using shadow project cost method to calculate the value of hydrological Lalu wetland is US\$4.6×10<sup>6</sup> (Zhang *et al.*, 2005).

**Travel cost:** Travel cost is the earliest evaluation methods of non-market goods. According to tourists pay for the tourism activities, recreational value of wetland ecosystem was assessment.

#### THE PROSPECT OF WETLAND ECOSYSTEM SERVICES VALUATION

Above all, although the importance of wetland ecosystem has gradually been recognized in China, wetland ecosystem service evaluation is still at the initial stage. Because of the complexity of the wetland ecosystem services assessment, more perspectives integrated assessment is wished to be involved in the study. Therefore, these methods are employed in researches all have some defects.

First of all, wetland ecosystem is a complex ecosystem which involves physical, chemical and biological processes. Due to interaction between wetland ecosystem components, ecological processes in it are very complex. However, the existing evaluation models for further research on this aspect are less. Therefore, the evaluation of wetland ecosystem system is not systematic and complete at present. Secondly, the evaluation of the wetland ecological system focuses more on economic aspects. Although the digital representation can concisely and clear express the value of wetland ecosystem, this is an assessment of ecological system after all, if economic value evaluation were overly focused on, the ecological system itself can be neglected. Some evaluation methods avoid these disadvantages, such as condition value assessment method. However, the method needs many sample data, because the long-term and continuous monitoring records are absent, the use of this method was limited in China. Therefore, the current methods of wetland ecosystem services evaluation are not absolute advantage.

Accordingly, in the future it is necessary to comprehensive understanding the complexity and the integrity of the wetland ecosystem. A long-term, continuous and automatic wetland ecological monitor system should be established, in order to provide a large number of reliable and space-time dynamic change data for the evaluation of wetland ecosystem services.

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#### REFERENCES

- Barbier, E.B., 1993. Sustainable use of wetlands valuing tropical wetland benefits: Economic methodologies and applications. *Geogr. J.*, 159(1): 22-32.
- Bragato, C., H. Brix and M. Malagoli, 2006. Accumulation of nutrients and heavy metals in *Phragmites australis* (Cav.) Trin. ex Steudel and *Bolboschoenus maritimus* (L.) Palla in a constructed wetland of the Venice lagoon watershed. *Environ. Pollut.*, 144(3): 967-975.
- Chen, Z. and X. Zhang, 2000. The value of the ecosystem services in China. *Chinese Sci. Bull.*, 45(1): 17-22.
- Costanza, R., R. d'Arge, R. de Groot, S. Farberk, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Suttonkk and M. van den Belt, 1997. The value of the world's ecosystem services and natural capital. *Nature*, 387(15): 235-260.
- Daily, G.C., 1997. *Nature's Services: Societal Dependence on Natural Ecosystems*. Island Press, Washington, D.C.
- Duan, X., X. Wang and Z. Ouyang, 2005. Evaluation of wetland ecosystem services in Wuliangshuai. *Resour. Sci.*, 27(2): 110-115.
- Ji, L. and Y. Wen, 2013. Wetland ecosystem services valuation of chongming dongtan. *Chinese Agric. Sci. Bull.*, 29(5): 160-166.
- Jiang, B., Z. Ouyang, H. Miao, H. Zheng, Y. Bai, C. Zhuang and Y. Fang, 2011. Ecosystem services valuation of the Haihe River basin wetlands. *Acta Ecol. Sinica*, 31(8): 2236-2244.
- Mo, M., X. Ren, X. Wang and R. Xiao, 2008. Ecosystem service function and economical profit and loss evaluation of honghu lake wetland. *J. Wuhan Univ., Nat. Sci. Edn.*, 54(6): 725-731.

- Ouyang, Z., R. Wang and J. Zhao, 1999. Ecosystem services and their economic valuation. *Chinese J. Appl. Ecol.*, 10(5): 635-640.
- Sheng, L., J. Ma and W. Wang, 2009. *Environmental Ecology*. 2nd Edn., Higher Education Press, Beijing.
- Su, S., D. He, R. Wang, J. Cai, L. Lin, X. Liao, Z. Zhang, Z. Chen and P. Huang, 2012. Evaluation of ecosystem services of the costal wetland in Eastern Fujian. *Wetland Sci. Manage.*, 8(3): 14-18.
- Xu, Y., J.F. Gao and J.C. Huang, 2010. Ecosystem service valuation of taihu wetland. *Resour. Environ. Yangtze Basin*, 19(6): 646-652.
- Zhang, Y. and G. Zhang, 2012. Analysis on benefits of services and functions of wetland ecosystem in Dongting Lake. *Chinese Agric. Sci. Bull.*, 28(8): 276-281.
- Zhang, T., L. Chen, P.B.D. Ba, Q. Huang and J. Xu, 2005. Evaluation of Lahu Wetland ecosystem services in Lhasa, Tibet. *Acta Ecol. Sinica*, 25(12): 3176-3180.
- Zhang, D.Q., T. Hua, R.M. Gersberg, J. Zhu, W.J. Ng and S.K. Tan, 2013. Fate of caffeine in mesocosms wetland planted with *Scirpus validus*. *Chemosphere*, 90(4): 1568-1572.
- Zhao, T., Z. Ouyang, X. Wang, H. Miao and Y. Wei, 2003. Ecosystem services and their valuation of terrestrial surface water system in China. *J. Nat. Resour.*, 18(4): 443-452.
- Zhao, T., Z. Ouyang, H. Zheng, X. Wang and H. Miao, 2004. Forest ecosystem services and their valuation in China. *J. Nat. Resour.*, 19(4): 480-491.