Wetland Economic Valuation Approaches and Prospects in China

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Abstract: Ecosystem services valuation seeks to increase the social relevance of ecosystem characteristics, the underlying biological mechanisms that support services, by making the contribution of ecosystems to human well-being explicit. Economic valuation can help management by clarifying the full range of benefits and costs of proposed management actions. In the past two decades, economic valuation of wetland ecosystem services has become one of the most significant scientific priorities for wetland protection. In this paper, we provide an overview of ecosystem services, and summarize the main interdisciplinary approaches to measure and value wetland ecosystem services. We identified four main methodological gaps preventing progress on wetland valuation of ecosystem services in China, which are: 1) confusion on terminology like intermediate and final ecosystem services, 2) lack of ecological production functions to link ecosystem characteristics to final ecosystem services, 3) static valuation making it difficult to evaluate the trade-offs and synergies among ecosystem services, and 4) lack of clear guidance on relating ecological compensation programs to conservation targets. Overcoming these gaps is important to inform wetland compensation mechanisms and conservation policies. We propose future research on wetland ecosystem services in China should be focused on: 1) defining final ecosystem services based on beneficiary preferences and underlying biophysical mechanisms, 2) establishing wetland monitoring programs at specific sites to collect data on final ecosystem service indicators and ecosystem characteristic metrics to create ecological production functions for economic valuation and rescaling techniques, and 3) incorporating wetland ecosystem service values into decision-making processes to inform wetland management.

Keywords: ecosystem services; wetlands; economic valuation; methodological gaps; China

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1 Introduction

China has all the wetland types delineated by the Ramsar definition (RCS, 2006), which are considered critical to solving China's daunting water problems. Wetlands currently cover 5.6% of China's terrestrial area (China News, 2014), which supply 96% of China's freshwater resources, and filter over 100 t nitrogen and 13 t phosphorus per square kilometer (PRC CPG, 2014). Furthermore, wetlands are socially and economically im-

portant for fish and reed production, climate regulation, flood regulation, erosion control, tourism, and spiritual meaning (MA, 2005). Despite their importance, wetlands are the most threatened ecosystems in China because of land reclamation, pollution, overexploitation of biological resources, water and soil loss, siltation, and unwise use of water resources (Lei and Zhang, 2005). The Chinese Government recognizes the social importance of wetlands, and has implemented multiple policies to reverse wetland declines. However, a significant

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challenge for policymakers is creating effective incentives to encourage cooperation among stakeholders on wetland protection.

The ecosystem service concept is gaining increased attention among decision-makers as a way to increase the social relevance of wetlands to improve wetland management (Daily, 1997; de Groot *et al.*, 2002). Information on ecosystem services can reveal mutual benefits and highlight socioeconomic connections to encourage cooperation. In particular, economic valuation is useful when comparing ecosystem services to other social goods and services using cost-benefit analysis or tradeoff curves. In the past two decades, scientists developed several ecosystem services frameworks (Nahlik *et al.*, 2012) and valuation approaches (de Groot *et al.*, 2002; Freeman, 2003; NRC, 2005; Farber *et al.*, 2006; US EPA, 2009; TEEB, 2010), resulting in a rapid growth in ecosystem services studies (Zhang *et al.*, 2010; Seppelt *et al.*, 2011). However, the majority of ecosystem services research has concentrated on ecosystem services valuation (Zhang *et al.*, 2010; Logsdon and Chaubey, 2013) with minimal work on quantifying the linkage between ecosystem functions, ecosystem services, and human benefits (NRC, 2005; Egoh *et al.*, 2007).

Currently we lack sufficient tools to effectively integrate ecosystem services into management (de Groot *et al.*, 2010) because of methodological challenges on quantifying and valuing ecosystem services. In China, a scientific priority is advancing the measurement and valuation of wetland ecosystem services for management. In this paper, we first provide an overview of wetland ecosystem services, and the three main interdisciplinary approaches to measure and value them. Next we evaluate several domestic case studies on valuing wetland ecosystem services to identify methodological gaps. Lastly we summarize the methodological gaps, and conclude with suggestions to advance future wetland ecosystem services research in China. The objective of this paper is to explore possible steps to advance interdisciplinary approaches on measuring and valuing ecosystem services in China.

2 Wetland Ecosystem Services

Ecosystem services are commonly defined as 'the benefits people obtain from ecosystems' (MA, 2005). Eco-

system services provide a means for understanding the influence of ecosystems on human well-being (Daily, 1997; MA, 2005). Ecosystem services clarify the multiple ways nature contributes to our lives (Daily *et al.*, 2009; US EPA, 2009; TEEB, 2010), and the value we place on those contributions (Costanza *et al.*, 1997; Chen and Zhang, 2000). The notion of environmental benefits or human reliance on nature is not new (Westman, 1977; Ehrlich and Mooney, 1983), thus the novelty of ecosystem services lies in integrating across a diversity of disciplines to incorporate ecosystems into decision-making (US EPA, 2009; TEEB, 2010). To understand ecosystem services requires learning about ecosystem processes (ecology), human welfare benefits (health and social sciences), human values (economics and the humanities), and the negotiation of multiple interests (political science).

The ecosystem services approach provides a holistic framework to help decision-makers and the public understand the full range of tradeoffs between society and ecosystems, but interdisciplinary challenges are preventing progress (Cook and Spray, 2012). The concept of ecosystem services has increased global understanding on the social relevance of ecosystems for policy-making, which was heightened by the Millennium Ecosystem Assessment (MA, 2005; Fisher *et al.*, 2008; Johnston and Russell, 2011). However, the complex and multi-disciplinary nature of ecosystem services has led to inconsistent definitions. We need a commonly accepted definition and consistent metrics to provide effective guidance to ecologists on measurement, economists on valuation, and decision-makers on management actions (Nahlik *et al.*, 2012; Reyers *et al.*, 2013). For economic valuation, we need an ecosystem services definition that separates intermediate and final ecosystem services (MA, 2005; Boyd and Banzhaf, 2007; Fisher *et al.*, 2009; US EPA, 2009; Kontogianni *et al.*, 2010; TEEB, 2010; Johnston and Russell, 2011; Nahlik *et al.*, 2012). The MA (2005) classified ecosystem services into four categories: provisioning, regulating, cultural, and supporting services, which span both intermediate and final services (MA, 2005; Polasky and Segerson, 2009). Intermediate services are the intermediate biophysical outputs of an ecosystem required to generate final services. Intermediate services are analogous to ecosystem processes and functions commonly known as supporting and regulating services in the MA (2005). In

contrast, final ecosystem services are the ultimate biophysical outputs directly related to human benefits, which economists can value (Boyd and Banzhaf, 2007; Nahlík *et al.*, 2012). In the valuation process, it is important to separate ecosystem functions as intermediate services from final services to avoid double-counting to create legitimate cost-benefit analyses for decision-making (Boyd and Banzhaf, 2007; Fisher *et al.*, 2009; TEEB, 2010).

The US EPA (2009) and TEEB (2010) created an operational definition of ecosystem services as 'the direct and indirect contributions of ecosystems to human well-being'. This definition describes ecosystems as inputs to human welfare benefits. The production of ecosystem services is represented by an 'ecological production function' in which ecosystem processes are inputs to ecosystem services. Ecological production functions in conjunction with economic valuation functions make the connections between ecosystems and human well-being explicit (Polasky and Segerson, 2009; US EPA, 2009). The challenge is establishing monitoring programs to collect final ecosystem service indicators and relevant ecosystem characteristic metrics (Ringold *et al.*, 2013) to integrate the complexity of ecosystems into ecosystem service valuation for trade-off analyses (Hails and Ormerod, 2013).

Wetlands provide a diversity of ecosystem services, which make them valuable to society. Based on the US EPA (2009) and TEEB (2010) definition wetland ecosystem services are the direct and indirect contributions of wetland ecosystems to human well-being. Two key aspects of this definition are: 1) wetland ecosystem services must originate from ecological phenomena, and 2) not all wetland ecosystem services are directly utilized (Fisher *et al.*, 2009). According to the MA (2005) categories, wetlands supply multiple provisioning services that include food, freshwater, fiber, fuelwood, biochemical products, and genetic materials. Also they supply regulating services like climate regulation, air quality regulation, flood control and storm protection, human disease regulation, and water purification and wastewater treatment. Furthermore wetlands produce cultural services, such as aesthetic, educational, spiritual, inspirational, and recreational values. Lastly, the supporting services are the ecological processes underlying the production of all preceding services, such as soil formation, photosynthesis, primary production, nu-

trient cycling, and water cycling (MA, 2005). Provisioning and cultural services often, although not always, are final services that directly affect human welfare. In contrast, regulating services can be either intermediate services or final services depending on the demands of beneficiaries. For example, water purification and wastewater treatment are intermediate services since they are inputs to the final service of drinkable freshwater to maintain domestic life. Alternatively, flood regulation and storm protection are final services since they are regulating services that provide direct human benefits. Supporting services differ from the other three types of services in only making indirect contributions to human welfare. Whether an ecosystem service is an intermediate service or final service is beneficiary dependent (Fisher *et al.*, 2009; Johnston and Russell, 2011), but it is important to know how to classify intermediate services and final services to meet the objectives of the particular study. In Table 1, we categorize the major wetland ecosystem services using the MA (2005) categories we do not distinguish the difference between intermediate services and final services. Also we provide cited examples of ecological and economic studies in the literature and the respective services that were valued.

3 Wetland Ecosystem Services Valuation

The value of wetland ecosystems can be divided into three general types: ecological, socio-cultural, and economic (de Groot *et al.*, 2002; NRC, 2005; US EPA, 2009; TEEB, 2010). The ecological value is the importance that people attribute to an ecologically healthy wetland (TEEB, 2010). Ecological value can be measured with ecological indicators, such as ecosystem integrity, ecosystem health, species diversity, naturalness, and/or resilience. These ecological indicators mainly describe the supporting and regulating services outlined in Table 1 (de Groot *et al.*, 2010). The socio-cultural value is the non-material well-being of wetlands influencing national, ethical, religious, and spiritual values in a society (de Groot *et al.*, 2010; TEEB, 2010). The economic value is the monetary value of goods and services produced by wetlands in which people's preferences are expressed through choices and trade-offs. Total economic value (TEV) is the sum of the values of all wetland ecosystem service flows from providers to beneficiaries over the given spatial and temporal scales.

Table 1 Wetland ecosystem services and ecological and economic studies

Wetland ecosystem services	Description	Ecological and economic studies
Provisioning services		
Aquaculture	Production of fish, clams, algae, invertebrates, <i>etc.</i>	Barbier <i>et al.</i> , 2008
Freshwater consumptive use	Provision of water for domestic, irrigation, drinking, and industrial water storage	Wei <i>et al.</i> , 2007
Freshwater non-consumptive use	Power generation and transportation	Wang <i>et al.</i> , 2010a
Fiber and fuel	Production of timber, straw hats, fuel wood, peat, fodder, <i>etc.</i>	Morrison <i>et al.</i> , 2012
Biochemical and medicinal	Extraction of medicines and other materials from wetland biota	Morrison <i>et al.</i> , 2012
Regulating services		
Climate regulation	Regulation of greenhouse gases, temperature, humidity, precipitation, and other climatic variables	Engle, 2011
Air quality regulation	Capturing and mitigating dust and particulate matter like PM _{2.5}	Costanza <i>et al.</i> , 1997
Hydrological regimes	Alteration of hydrological indicators that influence groundwater recharge/discharge and overland flow	Wei <i>et al.</i> , 2007
Water purification and waste treatment	Waste treatment by retention, dilution, and removal of water pollutants, such as excess nutrients and contaminants	Engle, 2011 Spencer and Harvey, 2012
Erosion control	Retention of soils thus reducing wind erosion and water erosion	Wei <i>et al.</i> , 2007
Natural hazard regulation	Dampening the magnitude of extreme flood and storm events	Engle, 2011
Biological regulation	Control of pest species and pollution	Spencer and Harvey, 2012
Cultural services		
Recreational	Landscape features and wildlife that provide opportunities for tourism and recreational activities	Crane and Gillespie, 2008
Aesthetic	Natural scenery appreciation	Hamilton, 2007
Science and education	Features to advance scientific value and educational tools	Mitsch <i>et al.</i> , 2008
Cultural heritage and identity	Heritage landmarks and places of belonging	Smardon, 2006
Spiritual and artistic inspiration	Subjects possessing inspirational value evident in art and religious expressions	Allen <i>et al.</i> , 2002
Supporting services		
Water cycling	Water cycles through the biosphere via key processes, such as evapotranspiration, infiltration, runoff, and precipitation	Zhou and Zhou, 2009
Nutrient cycling	Maintenance, recycling, processing, absorption, and acquisition of nutrients	Spencer and Harvey, 2012
Physical structural	Habitats for resident or transient species	Murphy <i>et al.</i> , 2012
Biodiversity	Diversity of biotic species	Spencer and Harvey, 2012
Primary production	The assimilation or accumulation of energy and nutrients by vegetation or alga	Tong <i>et al.</i> , 2007

Notes: For this classification system (de Groot *et al.*, 2002; MA, 2005), the ecosystem services span the full array of wetland ecosystems (i.e., river, lake, marsh, reservoir and pond, coastal wetlands). The cited references are ecological and economic case studies that either assessed the biophysical quantities or economic values of wetlands

Most development decisions are decided on economic grounds thereby making it important to accurately assess the monetary consequences of these decisions. Economic valuation is a powerful tool since it provides a means to measure and quantify the trade-offs between multiple wetland uses (Barbier *et al.*, 1997) via monetary metrics. Although factors other than economic values can influence management choices, the TEV framework helps to determine trade-offs between social goods and environmental quality, which is important to advise policy-making (NRC, 2005). In this review, we only focus on the economic values and their valuation

methods. However, it is important to note that economic valuation in particular monetary valuation can only capture a portion of the total value of a wetland not all the ecological and socio-cultural values (de Groot *et al.*, 2010).

The theory of economic valuation is based on individual demands and preferences either through stated willingness to pay (WTP) or willingness to accept (WTA) in the market (NRC, 2005). However, many of the services humans derive from wetland ecosystems often exhibit public good attributes that are naturally non-rival or non-excludable to the degree that individu-

als can not be precluded from use and where use by one individual does not reduce availability to others (e.g., climate regulation service and air regulation service, *etc.*). Without explicit market values, non-market services are difficult to measure, which is evident in the high threat and damage to ecosystems (Kareiva *et al.*, 2011). To address the 'free-rider' or 'economic externality' problem of public ecosystem services, conservationists are working to improve the valuation of wetland ecosystem services.

Managers need information on how human welfare may change from marginal changes in wetland ecosystems due to human activities, thus the interdisciplinary approach of the ecological production function was developed to improve valuation. Currently there are two main methods to value regulating services and cultural services: 1) the use of land use and land cover (LULC) maps and benefit transfer, and 2) stated preference methods using contingent valuation or choice models. The total value of ecosystem services provides little information to decision-makers because they need values that allow them to compare alternative management actions to identify where they can make improvements (Keeler *et al.*, 2012). Economists recommend ecologists develop ecological production functions to improve economic valuation. Below we present the three main approaches to measure and value ecosystem services: 1) ecological production functions (biophysical measurement), 2) primary economic valuation, and 3) value transfer (i.e., benefit transfer).

3.1 Biophysical measurement: ecological production function

The ecological production function is an emerging method that is gaining widespread acceptance as a scientific method to measure the biophysical supply of ecosystem services (TEEB, 2010; Kareiva *et al.*, 2011). Instead of relying on lookup tables, ecological production functions are regression models that describe the mathematical relationships between ecosystem structure and processes and ecosystem services (NRC, 2005; Haines-Young and Potschin, 2009; Polasky and Seger, 2009; US EPA, 2009). The inputs to ecological production functions are ecosystem structures and processes, and the outputs are final ecosystem services. The statistical relationships clarify the role of ecosystem structures or functions (i.e., intermediate services) as

inputs in the production of final ecosystem services. For example, the ecological production function for nutrient retention uses nitrogen and phosphorous processes (e.g., denitrification, plant uptake, and burial) as inputs to calculate an output of water clarity and safe drinking water in a meaningful metric (Keeler *et al.*, 2012). Ecological production functions are useful in determining ecosystem services since they can help: 1) quantify synergies and tradeoffs among ecosystem services across different temporal and spatial scales under different management scenarios, 2) reduce double counting by separating intermediate services from final services, and 3) lead to interdisciplinary cooperation across ecology, economics, and environmental policy. Furthermore, scientists can combine ecological production functions with LULC to generate spatially explicit maps of ecosystem services (Kareiva *et al.*, 2011). This allows scientists to identify: 1) variation in service delivery between habitats, 2) the temporal and spatial scale of service provision, 3) the distribution of service beneficiaries, and 4) trade-offs among ecosystem services under different management actions.

3.2 Primary economic valuation approaches and methods

Biophysical values alone make it difficult to assess the costs and benefits to society from wetland conservation or degradation (Bockstael *et al.*, 2000), thus economic valuation can help determine the monetary tradeoffs or synergies among multiple ecosystem services or other social investments like roads, hotels, or factories. Biophysical outputs measured in different units are ineffective for comparing ecosystem services to other social goods and services. Biophysical outcomes in some cases are often sufficient to advise management on wetland targets, such as water quality management or biodiversity (Tallis and Polasky, 2009). Policymakers also may use biophysical values without monetization for environmental compensation. For example, managers may use habitat area units to measure the scale of compensation to offset lost welfare values from wetland damages (US EPA, 2009). However economic valuation is considered useful because it allows managers to compare ecosystem services to other social goods and services. Ecological production functions when combined with economic methods provide scientists a means to value ecosystem services. Economic methods are specialized

techniques used to estimate the value of market and non-market goods and services. The five main monetizing approaches to value ecosystem services are presented in Table 2.

3.3 Benefit transfer

Benefit transfer is a popular economic valuation approach that uses available ecological and social information or existing valuation estimates from an established study site and transfers them to a policy site (Costanza *et al.*, 1997; NRC, 2005; Plummer, 2009; US EPA, 2009; O'Higgins *et al.*, 2010; TEEB, 2010). Ecosystem service values are transferred from the study site to a policy site in four different ways: 1) unit value transfer, 2) adjusted value transfer, 3) value function transfer, and 4) meta-analytic value function transfer (Table 2).

Scientists use benefit transfer to generate valuation estimates in a relatively inexpensive and timely manner, and is used when there is a lack of system specific in-

formation (TEEB, 2010). Benefit transfer uses look-up tables, literature values, and reference values to estimate ecosystem functions and economic values, which are expressed as per unit area of a given ecosystem. Ecological and economic values from a study site are applied to a policy site using LULC maps. If used correctly benefit transfer in particular meta-analysis value function is a useful approach to estimate the value of wetland ecosystem services. However, this approach is prone to large transfer errors if used incorrectly (Brouwer *et al.*, 1999; Woodward and Wui, 2001; Brander *et al.*, 2006; Eigenbrod *et al.*, 2010). Importantly benefit transfer only works if there are sufficient primary valuation studies available. It is important to note that benefit transfer can never replace primary valuation rather it acts as a secondary approach when primary valuation is not possible (TEEB, 2010). When using benefit transfer one must be aware of certain challenges, such as the difficulty of finding the most appropriate unit values to transfer from the study site to the policy site.

Table 2 Economic valuation methods to value ecosystem services

Valuation approach	Definition	Valuation method	Description
Market price-based	Prices for ecosystem services sold on market	Market prices	Valuation using exchange values of ecosystem services bought and sold in markets
Cost-based	Costs incurred from losing ecosystem services	Replacement cost	Valuation of cost to replace losses in ecosystem services
		Avoidance cost	Valuation of avoided costs or damages arising from losses in ecosystem services
Production function-based	Contribution of ecosystem services to enhancement of income or productivity	Production function	Valuation of impacts of ecosystem services on economic outputs
Revealed preference	Determined from observed economic behavior	Travel cost	Valuation of amenities determined by costs incurred to enjoy and visit locations
		Hedonics	Valuation using people's willingness to pay for a service through purchases in related markets, such as housing
Stated preference	Determined from surveyed responses to elicit economic behavior	Contingent valuation	Valuation using people's direct willingness to pay or accept compensation from a change in an ecosystem service.
		Conjoint analysis	Valuation using people's rankings of ecosystem services in mixed combinations
Benefit transfer	Existing ecological, social and/or valuation estimates from an established study site transferred to a policy site	Unit value	Multiplication of study site mean unit value by quantity of service at policy site
		Adjusted value	Simple alterations to values to reflect site characteristics
		Value function	Value function from a study site using parameter values from policy site
		Meta-analytic value	Value function from multiple studies using parameter values from policy site

Sources: de Groot *et al.*, 2002; Freeman, 2003; NRC, 2005; Farber *et al.*, 2006; US EPA, 2009; TEEB, 2010

4 Current Status of Wetland Valuation in China

4.1 Current approaches in China

In the past two decades, Chinese scientists have implemented a diversity of wetland valuation studies at different scales across China (Zhang *et al.*, 2010) spanning various wetland sizes, spatial scales, geographic locations, wetland types, and government designation levels. Zhang *et al.* (2010) found that 44 out of 230 valuation studies were on wetlands ranging from local to national scales based on search results from China's National Knowledge Infrastructure (<http://www.cnki.net>) from 1990 to 2008.

We conducted a simple literature analysis using ISI Web of Knowledge articles from 1995 to 2010 using the terms 'ecosystem service' and 'ecosystem services' in the title, which resulted in 389 articles. Subsequently we only chose articles on the economic valuation of wetlands in China matching the Ramsar Convention wetland definition (RCS, 2006), which resulted in seven articles. We categorized the seven articles by temporal extent (static or dynamic), ecological and social data used (primary or secondary), assessment methods (process-based models, land cover maps and valuation methods), and trade-off analysis. In our review, we found that only two out of the seven studies used LULC maps, and more than a half used secondary social and ecological data (i.e., not directly measured or collected). No studies

used biophysical models to quantify wetland ecosystem services, and no studies examined biophysical and economic trade-offs among ecosystem services. In Table 3 we summarize the seven studies that calculated the total economic value of wetland ecosystem services in China. Overall we found that Chinese scientists are using two main approaches to value wetland ecosystems in China. The first approach is benefit transfer using the constant value per hectare from Costanza *et al.* (1997) and Xie *et al.* (2003) where values are transferred using land cover data. The second approach is ecosystem function indicators to measure ecosystem services, which is valued using primary economic methods (e.g., market price method, shadow price method, replacement cost method, travel cost method, contingent valuation method, and benefit transfer method) with no separation between intermediate and final services.

4.2 Gaps in current approaches

Overall China has made progress on wetland economic valuation, however current approaches on measuring and valuing ecosystem services in China are still in the development stage (Zhang *et al.*, 2010). Current studies in China mostly focus on economic valuation with no consideration of the underlying biological mechanisms that support services and the actual beneficiaries that demand services. The economic value is helpful in recognizing the social value of wetland ecosystems, however, we need ecosystem services studies in China

Table 3 Summary of case studies in China estimating economic value of wetland ecosystem services

	Citation	Wetland type	Valuation		
			Valuation method	Dynamic or static	Total economic value
1	Zhao <i>et al.</i> , 2004	Coastal wetland and tidal flat	Benefit transfer method using coefficients of Costanza <i>et al.</i> (1997)	Dynamic	Dongtan 1990–2000 (10^6 \$/yr): from 316.77 to 120.40
2	Tong <i>et al.</i> , 2007	River wetland	Market price and contingent valuation (willingness to pay)	Static	Sanyang wetland (yuan (RMB)/(ha·yr)): potential value: 55332; current value: 5807
3	Yang <i>et al.</i> , 2008	Constructed wetland	Contingent valuation and shadow price method	Static	Constructed wetland (10^6 yuan (RMB)/yr): contingent valuation: 0.04; shadow price: 1.20
4	Chen <i>et al.</i> , 2009	Constructed wetland	Replacement cost method and market price method	Static	Beijing wetland (\$/(ha·yr)): 206740
5	Zhang and Lu, 2010	Marshes	Analysis hierarchy process to include social weight. Market price, travel cost, and shadow pricing method	Static	Ruoergai wetland (10^9 \$/yr): 9.97
6	Liu <i>et al.</i> , 2010	Shrimp pond	Market price method, carbon tax rate method, reforestation cost method, and contingent valuation method	Static	Leizhou shrimp net value (10^6 yuan (RMB)/yr): 389.96
7	Wang <i>et al.</i> , 2010b	Coastal wetlands	Market price method, shadow projects method, travel cost method, hedonic price method, contingent valuation method, and benefit transfer method	Static	Xiamen island economic loss (10^6 \$/yr): 19.3

connected to policy targets. Chinese scientists need to create credible valuations to clarify the marginal connections between wetland ecosystems and human well-being on policy targets.

Based on our review of the literature, we identified four main gaps in current wetland valuation methods in China. The first gap is confusion on terminology on the difference between intermediate and final ecosystem services. The lack of clarity on terms has led to double-counting in many economic valuation studies on ecosystem services. Double-counting can inflate values thereby seriously impacting the creditability of wetland economic values (Johnston and Russell, 2011). The second gap is methodological challenges in linking ecosystem characteristics (i.e., intermediate services) to final ecosystem services. In China, the current methods to measure and value ecosystem services either measure and value ecosystem functions instead of final ecosystem services (Fu *et al.*, 2011; Nahlik *et al.*, 2012) or they use land cover proxy-based data and benefit transfer with no consideration of actual beneficiaries and biological mechanisms. In China, we currently lack ecological production functions to connect intermediate services to final services. The third gap is static valuation that does not adequately reflect the tradeoffs and synergies among ecosystem services (Lu and Jiang, 2004). Static analyses are unable to meet managers' needs because they can not account for the full range of economic trade-offs among ecosystem services across varying spatial-temporal scales. The last gap is lack of clear guidance on relating ecological compensation programs to conservation targets. Payment for ecosystem services (PES) can serve as an effective ecological compensation mechanism to translate ecosystem services values into financial incentives to integrate conservation into socioeconomic development (Dasgupta *et al.*, 2008; Wunder *et al.*, 2008; Bennett, 2009). However, we need to generate evaluation methods to assess the effectiveness of PES programs on improving the environment and advancing human welfare.

5 Prospects for Wetland Ecosystem Services Valuation in China

Ecosystem services valuation has the potential to encourage wise use of wetland resources, however, we need to overcome several methodological gaps across

ecology and economics. The most significant challenges are linking ecosystem characteristics to final ecosystem services, and choosing the appropriate economic methods to value final ecosystem services. Ecologists and economists have significantly advanced ecosystem services classification systems, ecological modeling, and economic valuation methods. However, a major problem limiting the effectiveness of economic valuation is double counting where both intermediate services and final services are valued (Fu *et al.*, 2011; Johnston and Russell, 2011; Reyers *et al.*, 2013; Ringold *et al.*, 2013), and an over reliance on the benefit transfer method.

The primary purpose of wetland ecosystem services valuation is to provide useful information to management to sustain wetlands for multiple benefits (Zhang *et al.*, 2010). A diversity of efforts is required to advance the use of economic values of ecosystem services in China. We need to develop interdisciplinary approaches among ecologists, social scientists, and managers to begin measuring the marginal contributions of ecosystem characteristics to economic values of wetlands. Social scientists and managers can help ecologists identify valid final ecosystem services to separate intermediate services from final services. Economists and ecologists should cooperate to create ecological production functions to identify marginal changes of wetland ecosystem characteristics on final ecosystem services to avoid double-counting. Economists then can use available economic valuation methods to value final wetland services to inform policymakers on trade-offs.

Development of ecological production functions and the application of non-market valuation methods require ecological and social data, which are currently unavailable in China. Hence in the near term, we suggest Chinese scientists should first cooperate on identifying final service indicators based on stakeholder concerns and relevant ecosystem characteristic metrics known to produce final services. The Chinese Government then can establish monitoring programs to collect the necessary data on final service indicators and their relevant ecosystem characteristic metrics to create production functions in the future. As our foundational understanding of wetland ecosystem services improves using site-specific methods then scientists can apply benefit transfer for 'upscaling' to value wetland ecosystem services at broad geographical scales with more confidence and accuracy (Fig. 1).

Fig. 1 Outlined is framework to measure and value wetland ecosystem services using site-specific methods. The short dashed boxes are the three stages for wetland ecosystem services valuation. The long dashed box is the method to link ecosystem characteristics to final ecosystem services for tradeoff analyses with the objective of increasing scientific confidence and accuracy of the benefit transfer method

6 Conclusions

Ecosystem service is an emerging, transdisciplinary concept that integrates economics and ecology to determine the contributions of ecosystems to human well-being. In the past two decades, ecosystem services valuation has become one of the most studied areas in ecology and economics. Scientists have developed a diversity of ecosystem services assessment approaches, however there have been few ecosystem services studies where wetland economic values have been implemented by management. Chinese scientists currently need to develop more case studies to improve the credibility and legitimacy of economic valuation for management. The grandest challenge is to identify final service indicators and relevant ecosystem characteristic metrics to create ecological production functions that adequately account for the complexity of wetland ecosystems in service valuation.

In this paper, our aim was to reduce confusion on

ecosystem services terminology to advance the science of creating interdisciplinary approaches on measuring and valuing ecosystem services. We provide an overview of ecological production functions, primary economic valuation, and benefit transfer approaches. We also summarized the current status of domestic research on wetland ecosystem services in China. In the future, Chinese scientists need to work with policymakers to establish monitoring programs to collect data on final service indicators and ecosystem characteristic metrics to create ecological production functions. Also Chinese scientists need to advance a diversity of economic valuation methods to clarify economic trade-offs to guide wetland management.

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