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WETLAND RESTORATION

Wetland Ecological Restoration and Payment for Ecosystem Service Standard: A Case Study of Ganjiangyuan National Wetland Park

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Abstract
Wetland resources in wetland parks are unique natural resources. Discussing the ecological restoration and compensation standards of wetland parks plays an important guiding role in the construction of wetland protection systems. Based on the characteristics of wetland resources, using wetland ecosystem evaluation, ecosystem services evaluation, alternative cost, and conditional value methods, nine secondary indices were determined to evaluate the ecosystem services of Ganjiangyuan National Wetland Park. The results are as follows: (1) Ganjiangyuan National Wetland Park ecosystem evaluation result was "excellent," the ecosystem service value of the wetland park is 43,922,014.39 yuan/hm^2·year, among which the hydrology regulation value is the largest (19,257,869.14 yuan/hm^2·year) and the food production value is the smallest (12,900.76 yuan/hm^2·year). (2) The ecological restoration of Ganjiangyuan National Wetland Park should be based on improvements in hydrological regulations, waste treatment, entertainment culture, and biodiversity conservation. In conjunction with the strategic needs of wetland protection and social economy, wetland park restoration can contribute to urban development. (3) The upper and lower limits of the ecological compensation standard in the study area were calculated to be 310.49 and 257.87 yuan/hm^2·year, respectively. Research shows that the ecosystem service value of wetland parks is huge, especially in terms of water conservation and waste treatment. It is necessary to pay attention to ecological benefits while reaping the economic benefits of wetland parks. Therefore, the results of this study provide a theoretical reference for the ecological compensation of wetland parks.

Keywords Wetland parks · Ecological restoration · Ecological compensation standard · Ecosystem services · Value evaluation

Introduction

Known as the "Kidneys of Earth", wetlands are one of the world's three major ecosystems, along with oceans and forests. Compared to oceans and forests, the ecosystem services of wetlands rank first. Wetlands are ecosystems located at the intersection of land and water (Peh et al. 2014). It provides important functions and services for human beings, such as water storage and flood control, climate regulation, pollution degradation, tourism, and water transport (Jiang et al. 2016; Wang et al. 2019). The function of ecological regulation is outstanding, however, unreasonable development and utilization of wetland resources pose a serious threat. Relying on existing administrative means cannot coordinate the contradictions of wetland protection. Wetland Ecological compensation is an effective economic means that stimulates people to participate in wetland protection and coordinates the problem between wetland protection and utilization.

The term ecological compensation first appeared in 1950. Subsequently, the United Nations defined it in the Rio Declaration on Environment and Development in 1992 as "the complementary role of prices, markets, government finance, and economic policies in the formulation of environmental policies; environmental costs should be reflected in the decisions of producers and consumers; prices should reflect the value and scarcity of resources and help prevent

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environmental degradation." Internationally, the common concept of "Ecological Compensation" is "Payment for Ecological/Environmental Services, PES". Ecological Compensation is based on ecosystem services through economic means, adjusting the protector and beneficiaries in the interests of the relationship. As far as its definition is concerned, there is not yet a unified understanding (Pagiola et al. 2011). Early understanding of ecological compensation was mostly based on the response of organisms to environmental changes. With the transformation of the ecological environment, its connotation has gradually evolved into an economic means of protecting the environment (Wang and Wolf 2019). Scholars and managers have recognized ecological compensation as an effective means of solving the externalities of public goods. Many scholars have conducted exploratory research on ecological compensation and have proposed various methods. Pagiola et al. (2007) believed that ecological compensation is an efficient, market-oriented, and environmentally economic means to realize the allocation of natural resources. Pagiola et al. (2011) tended to understand payments for Ecological/Environmental Services as an economic method, which is significant for improving the efficiency of natural resource management and protecting biodiversity. Kreye and Pienaar (2015) examined existing habitat protection policies in Florida and proposed that a mixed strategy of government regulation and market mechanisms would more effectively curb the decline of wetlands.

Current research on ecological compensation is gradually intensifying; the objects are primarily focused on watersheds, farmlands, minerals, natural reserves, and forests, while little research has been conducted on wetlands (Liu et al. 2021). Wetland parks have received extensive attention from academia (Das and Basu 2020; Li and Gao 2016; Olander et al. 2018). Current research mostly uses theoretical methods to analyze the concepts, elements, and mechanisms of compensation standards. Because compensation standards involve multidisciplinary collaboration and the complexity of the ecosystem, a unified research method for compensation standards has not yet been developed (Wan et al. 2019), and needs to be further studied. The evaluation methods of the compensation standard include the Market Value Method, Opportunity Cost Method, Cost Analysis Method, Asset Value Method, and Conditional Value Method (Yan et al. 2022). In many ways, the CVM in survey respondents intends to be easily accepted by recipients and obtain the value of ecosystem services. The willingness to pay (WTP) and willingness to accept (WTA) survey methods is a common way to assess the non-use value of public goods, and more flexible. Wetland Ecological compensation has become an important means for alleviating wetland crises in the international community. Determining reasonable and fair compensation standards is directly related to the effect of wetland ecological compensation. Mittag et al. (2001) studied payment for ecological services of the Patassent River wetlands and believed that the loss of wetland ecosystem services was the basis for compensation. Bonds (2004) used the minimum cost of a simulated wetland bank and believed that wetland compensation deposits could be adapted according to the ecosystem services of wetland compensation. Bendor and Brozović (2007) studied the factors influencing wetland ecological compensation standards. Austen and Hanson (2008) conducted a compensation assessment for wetlands in Canada. Rubec (2009) discusses payments for Ecological Services in the Canadian wetlands. Although wetland ecosystem services accounting methods are theoretical and scientific, their values are often too high; therefore, they need to correct directly calculated wetland ecosystem services, as the highest standards of ecological compensation.

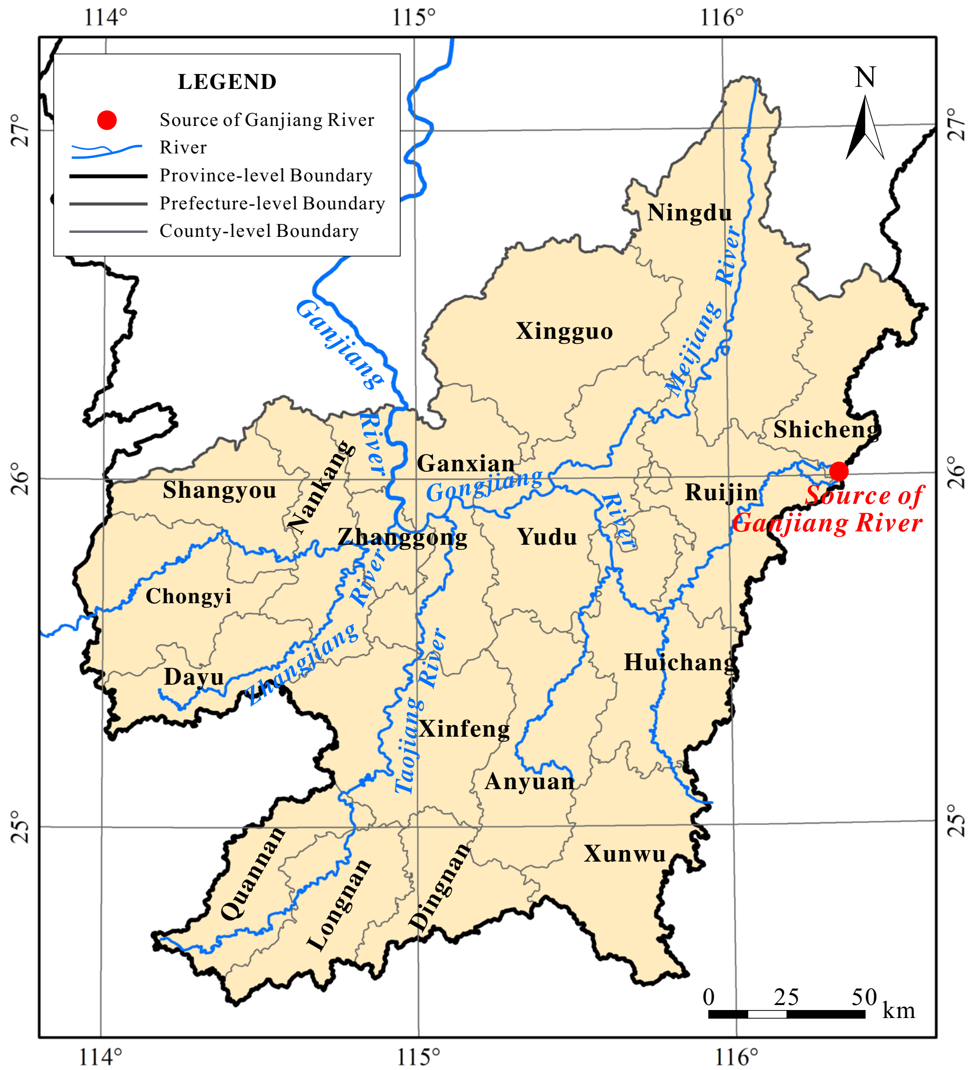
Studies on ecological compensation for wetlands play an important role in balancing the contradictions between protection and utilization and promoting sustainable social and economic development. However, a system of ecological compensation for wetlands has not yet been established, and the current compensation mechanism needs to be improved. It is imperative to maintain the ecosystems of wetlands, conduct assessments of the ecosystem services of wetlands, and formulate compensation standards. This study uses Ganjiangyuan National Wetland Park (GNWP) as the object, using the wetland ecosystem evaluation method, ecosystem services evaluation method, alternative cost method, and conditional value method. Nine secondary indexes were determined to evaluate the GNWP. Therefore, we discuss wetland park ecological restoration and compensation to provide a theoretical reference for establishing a wetland compensation mechanism.

Materials and Methods

Study Area

Shicheng County is a hilly, low-mountain area in southeastern China. The northeast is surrounded by mountains, the southwest is hilly, and the center is flat. It has a humid, subtropical, monsoon climate, with an annual average temperature of 18.1℃ and annual precipitation of 1919.6 mm, geographical coordinates 116°09′58″’’E–116°35′20’’E, 26°04′35’’N–26°29′24’’″ N (Kuang et al. 2014). GNWP in Shicheng, Jiangxi covers seven towns: Gaotian, Fengshan, Qinjiang, Hengjiang, Ganjiangyuan, Pingshan, and Dayu. It mainly includes the Qinjiang River and its tributaries, the Dayhe River, the Hengjiang River, the Ruikeng River, and the Yanling Reservoir (Fig. 1). With a total area of 1254.6 hm^2, of which the wetland area of 982.1 hm^2, accounting for 78.3% of the total area of the park (Kuang

Fig. 1 Study area



et al. 2014). The various wetlands in GNWP are unique in nature, biodiversity, and landscape, and have high scientific value, socioeconomic value, and conservation value.

GNWP is rich in animal and plant resources and is a paradise for many migratory birds. The park is a humid forest area in eastern China with a subtropical evergreen broad-leaved forest belt. The vegetation type in the park is woody and wetland vegetation. Herbaceous vegetation included *Imperata cylindrica*, *Polygonum hydropiper*, and *Cynodon dactylon*. Water vegetation included *Azolla imbricata*, *Colocasia antiquorum*, and *Peperomia tetraphylla*. A total of 205 wild vertebrate species have been found in wetland parks (Lai et al. 2020). There are 5 orders, 11 families, and 43 species of fish, 13 species of amphibians in 2 orders and 6 families, 21 species of reptiles in 2 orders and 8 families, 116 species of birds in 17 orders and 38 families, and 12 species of mammals in 6 orders and 6 families (Mao et al. 2016). Fourteen wild animal species are listed in *China's Class II Key Protection*.

Theoretical basis

Sustainable development first appeared in the International Union for the Conservation of Nature World Conservation Strategy in 1980. It has been proposed that "natural, social, ecological, economic, and basic relationships in the process of using natural resources must be studied to ensure global sustainable development" (Zhang and Xiao 2020). Sustainable development theory provides theoretical support for wetland park protection and development. Under the guidance of the sustainable development theory, wetland parks should focus on the selection of protection methods and scales. We should not only meet the needs of contemporary people but also consider future generations for wetlands. The sustainable conservation of wetland parks requires the introduction of scientific means to support the supervision and conservation of wetlands (Gruner and Power 2017; Semeraro et al. 2021).

Ecological compensation is an important management approach for global ecological protection (Moros et al. 2020; Wang and Wolf 2019). In natural resource conservation, it is difficult to achieve optimal management because of externalities. Ecological compensation is an effective means to promote the occurrence of behaviors in an external economy and is used to solve externality problems (Wang et al. 2022). Figure 2 shows the basic logic behind wetlands ecological compensation. The provider has resources that can provide ecosystem services such as wetlands. If the provider converts wetlands into farmland, the gain is *A,* and the losses are $D+E+F$. If the provider maintains the original utilization method, the benefit is *B,* and the opportunity cost is *A-B*. As an economic man, the best choice for a provider is to convert wetlands into farmlands. If the provider maintains wetland resources, beneficiaries or users should compensate the provider as *C*, which is greater than the opportunity cost *A-B* and less than the loss of ecosystem services $D+E+F$. At this point, the benefit to the provider is $B+C$, which is greater than *A* and less than $D+E+F$. For providers and beneficiaries, the benefits increase. Wetland are typical areas for ecological compensation. Wetland Ecological compensation is one of the most important policy instruments for protecting wetland in the GNWP. Based on the general theoretical framework of ecological compensation, this paper analyzes the core issues of wetlands ecological compensation and concludes that determining standards is the key to constructing wetlands ecological compensation.

Research methods

Statistical analysis methods

The evaluation score of wetland park ecosystems was calculated using the following formula (Costanza et al. 1997; Xie et al. 2008).

$$V = \sum \varepsilon_i W_i \tag{1}$$

where ε_i is the weight of the wetland park ecosystem typicality factor, area ratio factor, ecosystem uniqueness factor, species diversity factor, and water resources factor; W_i is the evaluation score of the factors; *V* is the evaluation score of the wetland park ecosystem. The evaluation criteria for wetland parks are listed in Table 1.

The formula for calculating the ecosystem service value of the wetland park is as follows:

$$ESV = \sum A_k \times VC_k \tag{2}$$

$$ESV_f = \sum (A_k \times VC_{fk}) \tag{3}$$

where *ESV* is the total ecosystem services of the wetland park in the study area (yuan), A_k is the area of the k land use types in the study area (hm^2), VC_k is the ecosystem services coefficient (yuan/hm^2·a), ESV_f is the value of a single ecosystem service (yuan), VCf_k is the value coefficient of a single ecosystem service function (yuan/hm^2·a).

An alternative cost method can be used to estimate the restoration costs of wetland park.

$$Zj = Cj + Pj * Rc \tag{4}$$

where Z_j is the wetland park conversion fee, C_j is the wetland park annual operating fee, P_j is the wetland park investment, and R_c is the benchmark investment rate.

According to the related literature (Ahiale 2020; Moayeri et al. 2019), the average WTP can be calculated using the mathematical expectation formula for the discrete variable. Owing to the low result of the conditional value method,

Table 1 Evaluation criteria for wetland parks

Score	Percentage	Evaluation
W ≥ 80	≥ 60%	Excellent
80 < W ≤ 70	≥ 60%	Good
70 < W ≤ 60	≥ 60%	Acceptable
W < 60	< 60%	Unqualified

The evaluation was calculated based on a total score of 100 points for the project using the above-mentioned ratio.

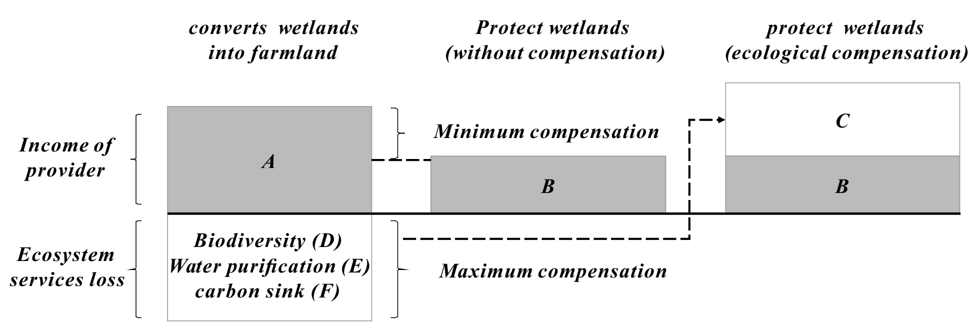


Fig. 2 Basic logic of wetlands ecological compensation

to reduce the difference, this study uses the upper limit of the survey value to be multiplied by the probability of the interview.

$$E(WTP) = \sum A_i P_i \quad (5)$$

where A_i is the respondent willingness to pay, P_i is the probability that the respondent chooses this amount.

Data Acquisition Methods

The data in this study included official statistics, interview data, and questionnaire data. A questionnaire was designed to investigate the willingness of people around the study area to protect wetlands, including the status quo and existing problems of wetland park protection, people's willingness to protect wetlands, and suggestions for wetland park protection. The results of the questionnaire survey were used as auxiliary data for analysis. Area change data for the study area were obtained from Google Earth. The animal and plant resources, land planning, and water storage capacity of the study area were obtained from the statistical yearbooks. Land resource survey data for relevant departments. Service value calculation methods and accounting standards were drawn from the relevant published literature.

Results and Discussion

Evaluation of Wetland Ecosystem

According to the wetland ecosystem evaluation methods, the total score of the wetland park evaluation was 84.8 points. Moreover, the score of a single-factor evaluation was not less than 60% of the evaluation items. The overall evaluation result of wetland park is "Excellent". The results of the wetland park ecosystem service value evaluations are presented in Table 2. The GNWP will provide an ecosystem service value of 43,922,014.39 yuan/hm^2/year. Among them, hydrological regulation accounted for 43.85%, waste disposal accounted for 36.95%, entertainment culture accounted for 8.82%, biodiversity conservation accounted for 4.95%, and climate regulation accounted for 4.46%; This indicates that the ecosystem service value of GNWP is mainly embodied in hydrological regulation, waste disposal, entertainment culture, and biodiversity conservation, which is consistent with the current development and utilization of wetland parks. The wetland ecosystem is a fragile system, and complex correlations exist among the elements of the wetland park system. A certain service cannot be ignored because it accounts for only a small proportion. For example, the proportion of soil conservation is 0.36%, which is an important indicator of ecosystem health. Soil degradation leads to the degradation of ecosystem structures and other functions. Therefore, when using wetland parks, we must protect the wetland environment and realize the sustainable use of wetland resources.

Ecological Restoration

Wetland ecological restoration refers to the reconstruction of degraded wetland systems with the help of certain ecological technologies to restore the basic structure and system function. Strengthening the ecological restoration capacity of existing wetland resources is crucial for the construction of an ecological environment. To make GNWP perform hydrological regulation, water purification, biodiversity protection, and cultural and recreational functions, conservation strategies for wetland resources are briefly discussed, and repair methods for wetland parks with local characteristics are proposed.

Construction of an aquatic plant community through water body restoration refers to the use of artificial physical, chemical, and biological methods to restore the ecological functions of the water body (Bradshaw 1996; Gann et al. 2019; Rivera-Monroy et al. 2019). According to the principle of ecology, the aquatic plant community elements of

Table 2 Ecosystem service value of Ganjiangyuan National Wetland Park (yuan/hm^2/year)

Types of ecosystem services	Service or function	Value	Proportion
Supply service	Food production	12,900.76	0.03%
	Primary production	121,316.78	0.31%
Regulating services	Atmospheric regulation	94,260.46	0.28%
	Climate regulation	1,959,102.90	4.46%
	Hydrology regulation	19,257,869.14	43.85%
	Waste disposal	16,229,244.90	36.95%
Support Services	Soil conservation	157,496.43	0.36%
	Biodiversity conservation	2,172,601.62	4.95%
Cultural Services	Entertainment culture	3,917,222.40	8.92%
Total	-	43,922,014.39	100

GNWP were constructed to play a role in water self-purification (Fig. 3). Submerged plants have roots in wetland soil and leaves that sink below the surface of the water. Submerged plants play an important role in aquatic ecosystems. Submerged plants provide aquatic animals with living habitats and hiding places, increase the dissolved oxygen in the water, purify water quality, and expand the effective living space of aquatic animals (Li 2022). At the same time, young parts of submerged plants can be eaten by aquatic animals, thus improving the entire aquatic ecosystem. Submerged plants can choose *Vallisneria natans*, *Hydrilla verticillate*, and *Ceratophyllum*. An emergent plant has an upper part of the leaf above the water, and the lower part is submerged. Most of the emergent plant roots dig into the soil and absorb nutrients. Because they are easily affected by the environment, the root, stem, and leaf remnants of hydrous plants are often mixed and deposited on the wetland shore, and their decomposition will have a great impact on the wetland ecosystem. Emergent plants include *Phragmites australis*, *Scirpus validus*, *Iris pseudacorus*, *Arundo donax var. versiocolor*, etc. The leaves of floating leaf plants are generally oval and round, which can protect them from the impact of wind and waves to the greatest extent. The leaves of floating plants provide shelter for underwater organisms and provide a platform for frogs and birds to stay and roost, which is an important part of ecological waters. Leave floating plants are typically in shallow water with a depth of 1 ~ 2 m, such as *Nymphoides peltate*, *Nelumbo nucifera*, and *Nymphaea tetragona*. The optimized configuration of emergent plant belts and floating leaf plant belts will purify the water quality of the wetland, combined with the functions of precipitation, removal, absorption, and degradation of toxic substances and water purification of the wetlands (Rubec 2009).

Based on wetland function partitioning, it is reasonable to conduct ecological restoration. There are five functional zones in GNWP: conservation, restoration and reconstruction, education and exhibition, rational use, and management service (Fig. 4). Wetland conservation areas have a relatively complete ecosystem and rich biodiversity. Mainly through wetland protection and restoration, improving wetland habitats, protecting biodiversity, and maintaining the integrity of ecosystem structure and function. The restoration and reconstruction areas can be used for the cultivation of degraded wetlands. This includes water restoration, waterfront protection, and bird habitat protection. The education and exhibition areas can be used for wetland service function displays and educational activities. The landscape of wetland parks can be designed according to the dominant functions of the different zones. The design of wetland landscapes should be considered in several ways. Wetland landscape facilities must meet the participants' leisure space and integrate into the wetland environment. The rational use area can be used for ecotourism, ecological breeding, and other utilization activities that do not damage wetland ecosystems. Wetland parks managers can use the management service area to carry out management and service activities.

Payment for Ecosystem Service Standard

Evaluation Index System Construction

With the development of ecological, environmental, and natural resource economics, scholars have conducted extensive research on the classification of ecosystem service value. Ecosystem service values can be divided into five categories: direct, indirect, choice, heritage, and existence. At present, the functions of ecosystem services are usually divided into four categories: supply (e.g., providing food and water), regulation (e.g., controlling floods and disease), support (e.g., the nutrient cycle that sustains life on Earth), and cultural services (e.g., recreational and cultural benefits) (Du et al. 2019). Related studies have shown that different classification methods lead to the double counting of service values

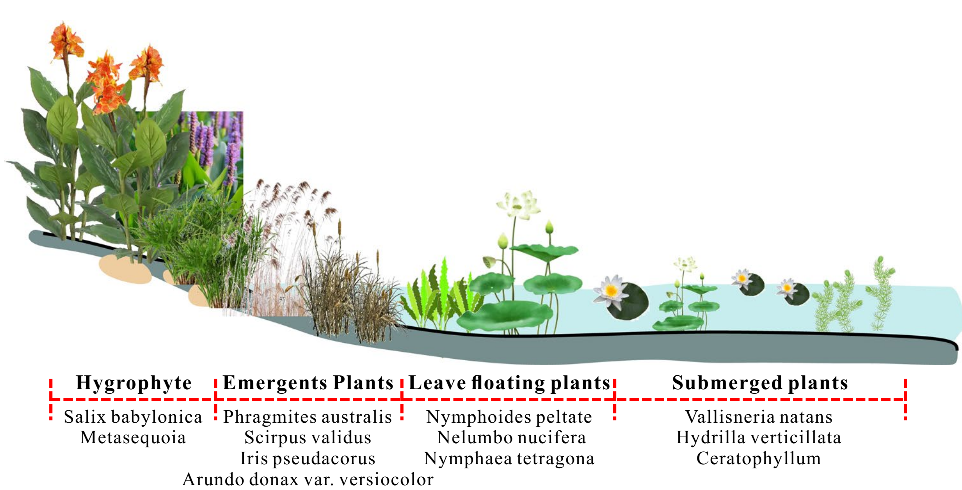


Fig. 3 The Construction of an aquatic plant community in the Wetland Park

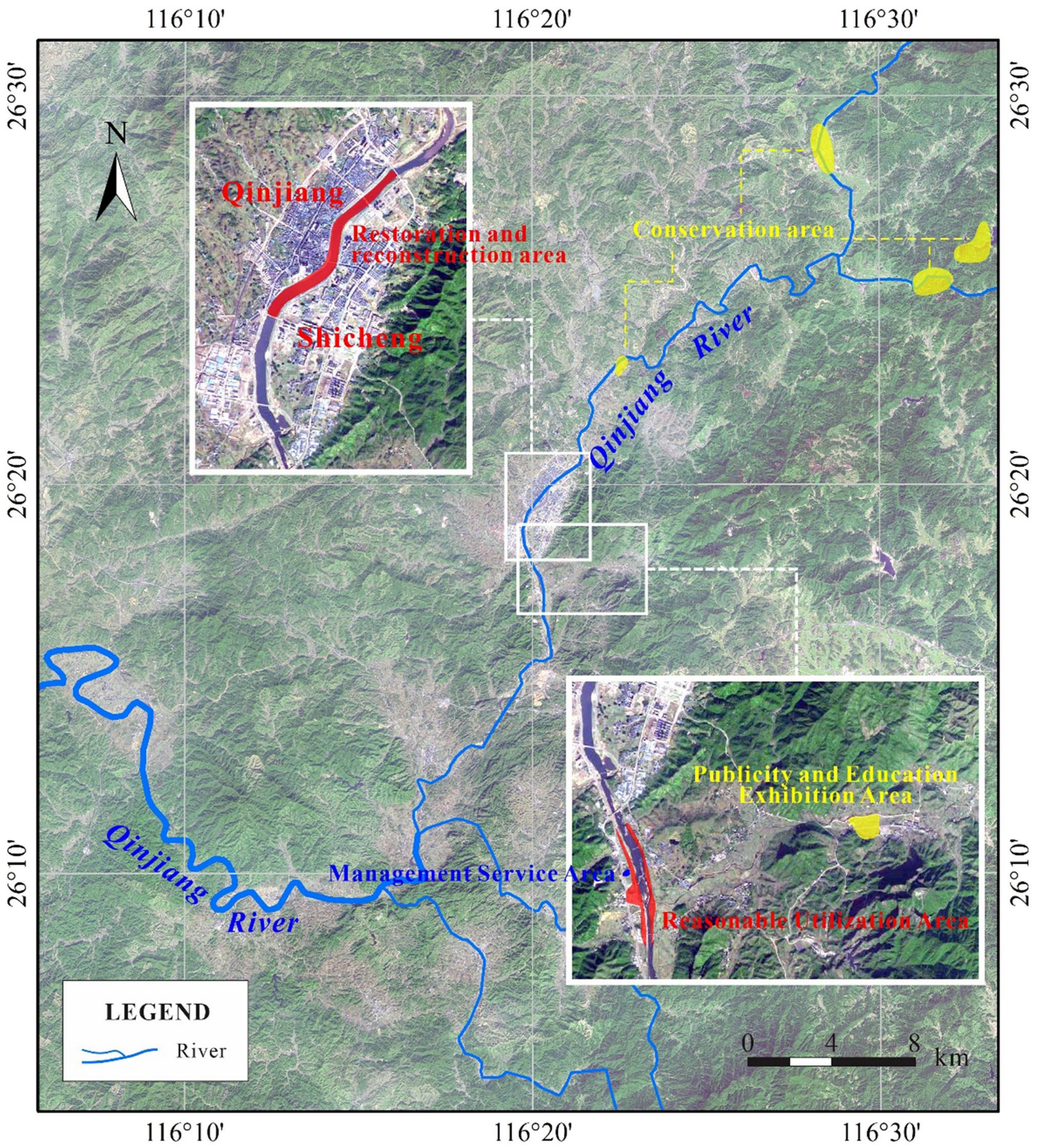


Fig. 4 Functional zoning and restoration area planning of Wetland Park

(Coelho-Junior et al. 2021). Therefore, this study analyzed the reasons for double counting and examined the relationship between ecosystem services in the study area.

According to this analysis, support services indirectly affect human benefits through the processes of maintaining supply, regulation, and cultural services; therefore, the value provided by support services can be grouped into three categories (Høibjerg 2020). In addition, the calculation of the ecological compensation standard focuses on direct values. In the calculation process, service supply cannot be directly quantified. The value of supply and cultural services in the research area can be realized in market transactions (commodity transactions, tourism consumption) and other forms (scientific research papers, etc.), and in the well-being of citizens (and children) (Battisti et al. 2018; Pedersen et al. 2019). Specific types of wetlands have different roles, local histories, processes, threats, and circumstances, making any wetland unique, and therefore, possessing different service values. As human beings have already benefited from supply and cultural services, this is not part of the basis for compensation in the calculation of ecological compensation.

Since this study used a small data sample, the Shapiro–Wilk test was performed on the above data to determine its normality (Table 3). The results show that the *P*-values passed the significance test at the 1% level. *S-W* tests were all greater than 10%. This indicates that the research data can be used for regression analysis. The *VIF* values of ecosystem services had a collinear relationship. Ridge regression analysis is required to accurately determine the relationships between variables.

The ridge regression analysis results show that the *P-values* passed the significance test at the 1% level. The R^2 value of the model was 0.885 and the model performance was relatively good. From Table 4, it can be concluded that the total value was.

$$\begin{aligned}\text{Total value} &= \alpha_0 + \alpha_1 * AR + \alpha_2 * SE + \alpha_3 * WP + \alpha_4 * WS + \alpha_5 * CR \\ &= 12.216 - 0.358 * AR + 3.524 * SE + 0.315 * WP + 3.421 * WS + 0.416 * CR\end{aligned}$$

AR: atmospheric regulation; *SE*: slow down soil erosion; *WP*: water purification; *WS*: water supply and storage; *CR*: climate regulation.

The Upper Limit of the Payment for Ecosystem Service Standard

According to calculations, the upper limit of ecological compensation in the study area was 315.55 yuan/hm^2·year from 2010 to 2015 and 305.43 yuan/hm^2·year from 2015 to 2020. To reduce the error and calculate it on average, the upper limit of the GNWP payment for ecosystem service was 310.49 yuan/hm^2·year. The results showed that compared to 2010–2015, the wetland area decreased significantly from 2015 to 2020 (Table 5). The reduction rates of service value and wetland area increased, but the ecological compensation standard decreased.

In recent years, large-scale unreasonable land reclamation has caused the wetlands to shrink. The reduction in wetland areas has led to the degradation of the overall ecosystem services of wetland parks. Ecological compensation is not directly based on ecosystem services in the wetland park but uses the value of ecosystem services reduced due to environmental degradation as the theoretical upper limit of ecological compensation. Therefore, a decrease in the value of wetland services per unit area manifests as a decrease in ecological compensation. This reminds people of the need to protect the ecological environment of wetlands and increase their awareness of wetland protection.

The Lower Limit of the Payment for Ecosystem Service Standard

According to the formula of WTP, the willingness payment for GNWP is 257.87 yuan/hm^2·year (lower limit). The survey showed that 89.5% of respondents believed that wetlands should be protected. Among them, 65.7% were willing to contribute at least ten yuan/month. In addition to the residents of the study area, the selected interviewees included experts and scholars. Among the interviewed population, those with a bachelor's degree or higher accounted for 35% of the total sample number. This reduces the bias in the survey to a certain extent because of the positive responses of the respondents to make a choice that satisfies the investigator (Wang et al. 2019). The survey found that people have realized that wetlands play an important role in human survival and development. Most people have a positive attitude towards improving the wetland park environment. They were also willing to compensate for the wetlands without affecting their living standards. However, some interviewees refused to pay

Table 3 Linear regression analysis results

Variable	*B*	*S. E*	*Beta*	*t*	*P*	*VIF*	R^2	$Adj.R^2$	*F*
Atmospheric regulation	0.134	5.622	0.021	0.018	0.913	28. 224	0.894	0.910	27.357 (0.001***)
Slow down soil erosion	3.384	3.554	0.208	0.896	0.401	8.584			
Water purification	-0.612	2.067	-0.124	-0.257	0.764	32.184			
Water supply and storage	4.235	3.367	0.438	1.269	0.246	16.047			
Climate regulation	0.602	0.462	0.504	0.937	0.357	33.974			
C	5.14	18.813	-	0.334	0.6795	-			

***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively

Table 4 Ridge regression analysis results

Variable	*B*	*S. E*	*Beta*	*t*	*P*	R^2	*Adj.* R^2	*F*
Atmospheric regulation	-0.358	1.284	-0.029	-0.284	0.846	0.885	0.819	21.875 (0.002***)
Slow down soil erosion	3.524	1.547	0.349	1.886	0.094			
Water purification	0.315	0.384	0.058	0.436	0.847			
Water supply and storage	3.421	1.345	0.548	2.254	0.034**			
Climate regulation	0.416	0.184	0.302	2.847	0.028**			
C	12.216	5.427	-	2.18	0.075*			

***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively

because their family income was too low, the government should be responsible for wetlands, and they did not understand wetland ecosystem services.

These findings have implications for wetland managers, planners, and practitioners. Wetland managers can learn about different approaches to ecological restoration. They can efficiently manage different restoration methods for water bodies, waterfronts, habitats, and river vegetation (Wang et al. 2019). In addition, wetland managers can use scientific methods to formulate effective compensation schemes and provide scientific advice for wetland park planning (Janousek et al. 2021). Understanding the value of different ecosystem services is strategic for planners. For example, in the decision-making step of the restoration ecological cycle (Mountford et al. 2006), planners can assign conservation measures to different wetlands based on the role of each service value to highlight the relevance of the measures (Xie et al. 2008). At the same time, protection practitioners of wetland ecosystems, especially ordinary people, will have a better understanding of the value of wetland ecosystem services, which will attract the attention of practitioners to the protection of wetlands (Jiang et al. 2016; Xie et al. 2008).

Conclusion

In this study, guided by the theory of sustainable development and payment for ecosystem services, we propose a wetland park ecological restoration plan and calculate the ecological compensation standard of wetland parks. The main conclusions of this study are as follows:

(1) According to the wetland ecosystem evaluation methods, the total score of the GNWP was 84.8 points, and the overall evaluation result of the wetland park is "Excellent". The ecosystem service value of GNWP is 43,922,014.39 yuan/hm^2·year, among which the hydrology regulation value is the largest and the food production value is the smallest.

(2) Based on the evaluation of wetland park ecosystem services, this study constructed a service value index system that focuses on regulating services. The payment for the GNWP mainly consists of water supply and storage, water purification, climate regulation, soil erosion reduction, and atmospheric regulation.

(3) According to the principle of the Ecological compensation, the upper limit payment for ecosystem services in the study area is 310.49 yuan/hm^2·year, and the lower limit payment for ecosystem services is 257.87 yuan/hm^2·year.

This research conducted a preliminary study on the ecological restoration of wetland parks and ecological compensation, which has scientific value in improving the planning system of wetland parks. Although the estimation results of ecosystem services in the study area have a certain accuracy, the trend of the ecosystem services in the wetland park can be determined. However, due to different research data sources and calculation methods, the compensation standard and the actual value of ecosystem services are different. In addition, payments for ecosystem service mechanisms have been progressing and improving, but many scientific issues remain that cannot be resolved. In future research, it will be necessary to optimize and supplement the measurement methods of the ecological compensation standard.

Table 5 Service value and wetland area change of wetland park

Item	2010–2015	2015–2020
Service value change (yuan)	-2.27	-3.868
Service value change rate	-2.74%	-4.72%
Wetland area Change (hm^2)	-2.76	-4.82
Wetland area change rate	-1.95%	-3.77%
Upper limit (yuan/hm^2·year)	315.55	305.43

"-" means decrease

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Author Contributions Yu Zhou, Liya Zhao, and Zhaohua Li were responsible for the overall design of the study and contributed to proofreading the manuscript. Yu Zhou performed the experiments, interpreted the data, and wrote and proofread the manuscript. Zhaohua Li and Liya Zhao designed the study and proofread the manuscript. All authors have read and approved the final manuscript.

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Data Availability The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Conflicts of Interest The authors declare that they have no competing interests.

References

Ahiale DE (2020) Effect of Collective Action on Willingness to Accept (WTA) in Payment for Environmental Services in Northern Ghana. Journal of Economics and Development Studies 8:1–10. https://doi.org/10.15640/jeds.v8n2a8

Austen E, Hanson A (2008) Identifying wetland compensation principles and mechanisms for Atlantic Canada using a Delphi approach. Wetlands 28:640–655. https://doi.org/10.1672/07-170.1

Battisti C, Fanelli G, Bertolino S, Luiselli L, Amori G, Gippoliti S (2018) Non-native invasive species as paradoxical ecosystem services in urban conservation education. Web Ecology 18(1):37–40. https://doi.org/10.5194/we-18-37-2018

Bendor T, Brozović N (2007) Determinants of Spatial and Temporal Patterns in Compensatory Wetland Mitigation. Environmental Management 40:349–364. https://doi.org/10.1007/s00267-006-0310-y

Bonds M (2004) Calculating Wetland Mitigation Banking Credits: Adjusting for Wetland Function and Location. Natural Resources Journal 43:961–977. https://doi.org/10.1016/S0308-597X(03)00007-1

Bradshaw AD (1996) Underlying principles of restoration. Canadian Journal of Fisheries and Aquatic Sciences 53(SUPPL. 1):3–9. https://doi.org/10.1139/cjfas-53-s1-3

Coelho-Junior MG, de Oliveira AL, da Silva-Neto EC et al (2021) Exploring plural values of ecosystem services: Local peoples' perceptions and implications for protected area management in the atlantic forest of Brazil. Sustainability 13:1–20. https://doi.org/10.3390/su13031019

Costanza R, Charles P, Cutler JC (1997) The development of ecological economics. Edward Elgar Publishing, Cheltenham, Glos, UK

Das A, Basu T (2020) Assessment of peri-urban wetland ecological degradation through importance-performance analysis (IPA): A study on Chatra Wetland. India Ecological Indicators 114:106274. https://doi.org/10.1016/j.ecolind.2020.106274

Du J, Liu F, Zhou Y et al (2019) A Review of Ecosystem Services Assessment and Valuation of Protected Areas. Research of Environmental Sciences 32:1475–1482. https://doi.org/10.13198/j.issn.1001-6929.2019.03.22 (in Chinese)

Gann GD, McDonald T, Walder B et al (2019) International principles and standards for the practice of ecological restoration. Second Edition Restoration Ecology 27(S1):S1–S46. https://doi.org/10.1111/rec.13035

Gruner RL, Power D (2017) Mimicking natural ecosystems to develop sustainable supply chains: A theory of socio-ecological intergradation. J Clean Prod 149:251–264. https://doi.org/10.1016/j.jclepro.2017.02.109

Høibjerg R (2020) Rethinking service systems and service ecosystems. Revue Europeenne d' Economie et Management Des Services. 9 (pp. 57–75). https://doi.org/10.15122/ISBN.978-2-406-10604-3.P.0053 (in French). Classiques Garnier

Janousek CN, Bailey SJ, Brophy LS (2021) Early Ecosystem Development Varies with Elevation and Pre-Restoration Land Use/Land Cover in a Pacific Northwest Tidal Wetland Restoration Project. Estuaries Coasts 44:13–29. https://doi.org/10.1007/s12237-020-00782-5

Jiang B, Wong CP, Cui L et al (2016) Wetland economic valuation approaches and prospects in China. Chinese Geographical Science 26:143–154. https://doi.org/10.1007/s11769-015-0790-x

Kuang RM, Luo W, Zhang M, Wan WT, Yang HC, Li DQ (2014) Assessment of the ecological environment in Ganjiang source region based on remote sensing. Journal of Jiangxi University of Science and Technology 35(05):34–39. https://doi.org/10.13265/j.cnki.jxlgdxxb.20140703.002 (in Chinese)

Kreye MM, Pienaar EF (2015) A critical review of efforts to protect Florida panther habitat on private lands. Land Use Policy 48:428–436. https://doi.org/10.1016/j.landusepol.2015.06.018

Lai SF, Yu ZL, Chen SQ, Liu H, Zeng ZG (2020) Characteristics of composition and species diversity of the amphibian community in Ganjiangyuan area of Jiangxi Province. Acta Ecologica Sinica 40(21):8005–8013. https://doi.org/10.5846/stxb201909201964 (in Chinese)

Li T, Gao X (2016) Ecosystem services valuation of Lakeside Wetland Park beside Chaohu Lake in China. Water 8:301. https://doi.org/10.3390/W8070301

Li YH (2022) Ecological restoration technology of the northern wetland park: Take the Liuli river wetland park an an example. Acta Hydrobiologica Sicina 10-1535-11. https://doi.org/10.7541/2022.2022.0150 (in Chinese)

Liu XK, Hua GD, Zou LL, Zhang CX, Liu CX, Jia XR (2021) Bibliometric Analysis of Wetland Ecological Compensation Research in China. Forestry and Environmental Science 02-0062-08. https://doi.org/10.3969/j.issn.1006-4427.2021.02.010 (in Chinese)

Mao C, Liao N, Wang XJ (2016) Investigation on wild vertebrate resources in Ganjiangyuan National Wetland Park in Shicheng, Jiangxi Province. Anhui Agricultural Sciences 44:14–16. https://doi.org/10.13989/j.cnki.0517-6611.2016.35.005 (in Chinese)

Mittag M, Brown KP, Rambo K et al (2001) Evaluation of Alternative Options for Freshwater Emergent Wetland Compensation at Naval Air Station Patuxent River. Wetlands Engineering and River Restoration Conference 1–12. https://doi.org/10.1061/40581(2001)35

Moayeri F, Dunt D, Hsueh Y et al (2019) Cost-utility analysis of telephone-based cognitive behavior therapy in chronic obstructive pulmonary disease (COPD) patients with anxiety and depression comorbidities: An application for willingness to accept concept. Expert Rev Pharmacoecon Outcomes Res 19:331–340. https://doi.org/10.1080/14737167.2019.1536550

Moros L, Corbera E, Vélez MA et al (2020) Pragmatic conservation: Discourses of payments for ecosystem services in Colombia. Geoforum 108:169–183. https://doi.org/10.1016/j.geoforum.2019.09.004

Mountford JO, Roy DB, Cooper JM, Manchester SJ, Swetnam RD, Warman EA, Treweek JR (2006) Methods for targeting the restoration of grazing marsh and wet grassland communities at a national, regional and local scale. Journal for Nature Conservation 14(1):46–66. https://doi.org/10.1016/j.jnc.2005.09.001

Olander LP, Johnston RJ, Tallis H et al (2018) Benefit relevant indicators: Ecosystem services measures that link ecological and social outcomes. Ecological Indicators 85:1262–1272. https://doi.org/10.1016/j.ecolind.2017.12.001

Pagiola S, Arcenas A, Platais G (2011) Can Payments for Environmental Services Help Reduce Poverty? An Exploration of the issues and the evidence to date from Latin America. World Development 33:237–253. https://doi.org/10.1016/j.worlddev.2004.07.011
Pagiola S, Ramirez E, Gobbi J et al (2007) Paying for the environmental services of silvopastoral practices in Nicaragua. Ecological Economics 64:374–385. https://doi.org/10.1016/j.ecolecon.2007.04.014
Pedersen E, Weisner SEB, Johansson M (2019) Wetland areas' direct contributions to residents' well-being entitle them to high cultural ecosystem values. The Science of the Total Environment 646:1315–1326. https://doi.org/10.1016/j.scitotenv.2018.07.236
Peh KSH, Balmford A, Field RH et al (2014) Benefits and costs of ecological restoration: Rapid assessment of changing ecosystem service values at a U.K. wetland. Ecology and Evolution 4:3875–3886. https://doi.org/10.1002/ece3.1248
Rivera-Monroy VH, Elliton C, Narra S et al (2019) Wetland biomass and productivity in coastal Louisiana: Base line data (1976–2015) and knowledge gaps for the development of spatially explicit models for ecosystem restoration and rehabilitation initiatives. Water 11:2054. https://doi.org/10.3390/w11102054
Rubec CDA (2009) Wetland mitigation and compensation: Canadian experience. Wetlands Ecol Manage 17:3–14. https://doi.org/10.1007/s11273-008-9078-6
Semeraro T, Radicchio B, Medagli P et al (2021) Integration of ecosystem services in strategic environmental assessment of a peri-urban development plan. Sustainability 13:1–26. https://doi.org/10.3390/su13010122
Wan X, Adamowski JF, Wang G et al (2019) Farmers' willingness to accept compensation to maintain the benefits of urban forests. Forests 10:691. https://doi.org/10.3390/f10080691
Wang F, Zhang S, Hou H et al (2019) Assessing the changes of ecosystem services in the Nansi Lake Wetland, China. Water 11:788. https://doi.org/10.3390/w11040788
Wang P, Wolf SA (2019) A targeted approach to payments for ecosystem services. Global Ecology and Conservation 17:e00577. https://doi.org/10.1016/j.gecco.2019.e00577
Wang HY, Li ZK, Yu YQ (2022) Ecological compensation in China: A Review of the Theories and Researches. Ecological Economy 03-164-07 (in Chinese)
Xie GD, Zhen L, Lu CX et al. (2008) Expert Knowledge Based Valuation Method of Ecosystem Services in China. Journal of Natural Resources Science 23:911–919. https://doi.org/10.11849/zrzyxb.2008.05.019 (in Chinese)
Yan HM, Zhang Y, Li W, Yang HC, Jiang QO (2022) Review of methods to estimate the ecological compensation standard. Journal of Hebei University (Nature science) 05-0533-08. https://doi.org/10.13763/j.cnki.jhebnu.nse.202205011 (in Chinese)
Zhang H, Xiao Y (2020) Planning island sustainable development policy based on the theory of ecosystem services: A case study of Zhoushan archipelago, East China. Island Studies Journal 15:237–252. https://doi.org/10.24043/isj.105