Valuation and Preference Heterogeneity of Wetland Ecosystem Services in the Sanjiang Plain: A Choice Experiment Study (Postprint)

Authors: Mao Biqi, Ao Changlin, Jiao Yang, Gao Qin, Liu Yuxing

Date: 2017-03-08T00:00:00+00:00

Abstract

Maintaining and protecting ecosystem services is fundamental to achieving sustainable development, and the quantitative evaluation of the economic value of wetland ecosystem services has become a cutting-edge research topic in the field of ecology. This study takes the Sanjiang Plain wetlands as the research object, applies the choice experiment method, selects four wetland attributes including wetland area, biodiversity, water conservation, and natural landscape, employs the Random Parameter Logit (RPL) model to monetarily evaluate them, and combines it with the Latent Class Model (LCM) to verify and explain the heterogeneity of public preferences for wetland ecosystem services. The results demonstrate that the values of wetland ecosystem services rank in the following order: water conservation > wetland area > biodiversity > natural landscape. The total value for maintaining current wetland ecosystem services is 14.61 billion yuan/a, while the improvement value is 98.58 billion yuan/a. Moreover, the study finds that respondents can be categorized into three latent categories: resource-preference type, landscape-preference type, and price-sensitive type, with different groups exhibiting distinct preferences for wetland ecosystem services; female respondents and those with higher education levels show stronger preferences for resource protection, high-income respondents and those who frequently visit scenic areas demonstrate stronger preferences for landscape protection, while respondents with lower education and income levels tend to select wetland management schemes with lower prices. This research contributes to the optimal design of wetland sustainable management policies and provides a theoretical basis for the formulation of relevant environmental policies.

Full Text

Preamble

ACTA ECOLOGICA SINICA
ChinaXiv Partner Journal
Vol. 37, No. 4, Feb. 2017
DOI: 10.5846/stxb201604120669
Pages 1297–1308

Evaluation of Preference Heterogeneity of Ecosystem Services in the Sanjiang Plain Wetlands Based on Choice Experiments

Mao Biqi, Ao Changlin*, Jiao Yang, Gao Qin, Liu Yuxing
Department of Management Science and Engineering, Northeast Agricultural University, Harbin, China 150030

Abstract

Maintaining and protecting ecosystem services forms the foundation for achieving sustainable development. Quantitative assessment of the economic value of wetland ecosystem services has become a leading research frontier in ecology. This study examines the Sanjiang Plain wetlands as its research object, employing choice experiments to monetarily evaluate key wetland attributes including wetland area, biodiversity, water conservation, and natural landscapes. A random parameter logit (RPL) model is used for monetary valuation, while a latent class model (LCM) confirms and explains public preference heterogeneity for wetland ecosystem services.

The results reveal that the relative values of wetland ecosystem services are ranked as follows: water conservation > wetland area > biodiversity > natural landscape. The total willingness to pay (WTP) for maintaining current wetland ecosystem service functions is RMB 14.61 billion per year, while the WTP for improvement is RMB 98.58 billion per year. The study identifies three latent classes among respondents: resource-preferring, landscape-preferring, and price-sensitive types. Different groups exhibit distinct preferences for wetland ecosystem services. Female respondents and those with higher education levels show stronger preferences for resource conservation, while high-income respondents and those who frequently visit scenic areas demonstrate greater preference for landscape protection. Conversely, respondents with lower education and income levels are more sensitive to price and tend to select wetland management options with lower costs. These findings can inform the optimization of wetland sustainable management policies and provide a theoretical basis for environmental policy formulation.

Keywords: Sanjiang Plain Wetlands; ecosystem services; preference heterogeneity; choice experiment method; random parameter logit; latent class model

1. Study Area Overview

The Sanjiang Plain, located in the northeastern corner of China, is the largest freshwater marsh distribution area in the country. Formed by the confluence and alluvial deposits of the Heilongjiang, Songhua, and Wusuli Rivers, it lies between 129°11 20 -135°05 26 E and 43°49 55 -48°27 40 N. The plain features numerous pristine wetlands with scattered lakes and ponds, creating diverse and colorful wetland landscapes. As a crucial ecological functional zone, the Sanjiang Plain hosts several national nature reserves including the Honghe, Sanjiang, and Xingkai Lake International Nature Reserves, with five wetlands listed in the International Important Wetland Directory. This region represents a key area for international wetland biodiversity conservation and holds a prominent global position.

Since reclamation began in the 1950s, extensive wetland areas have been converted to farmland. Currently, the remaining natural wetlands face the risk of disappearance. The conflict between agricultural development and wetland conservation has severely impacted the overall ecosystem service functions. With shrinking wetland area and expanding cultivated land, the total service function value of the wetland and farmland ecosystems is declining. The construction of numerous drainage canals has neglected wetland ecological water requirements, while large-scale rice cultivation has accelerated ecosystem degradation. Many species have lost their habitats, water and soil conservation functions have deteriorated, and biodiversity protection capacity continues to decline, posing serious threats to ecological security and socioeconomic sustainability. Urgent action is needed to regulate and manage wetland ecosystem service functions.

2. Methodology

2.1 Choice Experiment Method

Choice experiments (CE) represent an important non-market resource valuation technique grounded in consumer theory and random utility theory. The value of each evaluated object is determined by multiple attributes, where changes in attribute levels may alter respondent preferences or choices. Respondents always aim to maximize utility in each selection. Researchers typically provide respondents with a series of choice sets reflecting different attribute states of the study object, with each set containing at least one monetary attribute. By analyzing and comparing people' s choices, the economic value of each environmental function and attribute can be derived.

According to random utility theory, individual q' s utility for alternative i consists of a deterministic component and a random error term:

$$U_{iq} = V_{iq}(Z_i, S_q) + \varepsilon_{iq}$$

where Z_i represents attributes of wetland management alternative i, and S_q

represents socioeconomic attributes of individual q. The probability that individual q chooses alternative i from a choice set J with j options is:

$$P_{iq} = P[U_{iq} > U_{jq}; \forall j \in J]$$

If the random error term follows an extreme value distribution (EV1) and is independently and identically distributed (IID), the multinomial logit (MNL) model is obtained, where the probability of individual q choosing the best alternative i can be expressed as:

$$P_{iq} = \frac{\exp(V_{iq})}{\sum_{j=1}^{J} \exp(V_{jq})}$$

The deterministic component V_{iq} typically includes alternative specific constants (ASC), attributes of alternative i (Z_i), and socioeconomic characteristics of individual q (S_q).

2.2 Random Parameter Logit Model

The RPL model addresses heterogeneity among individuals in basic logit models by allowing utility parameters to vary randomly, thereby capturing preference heterogeneity. The indirect utility of RPL is decomposed into a deterministic component and a random error term:

$$U_{iq} = V_{iq}(Z_i, \beta) + \varepsilon_{iq}$$

Since individual preference heterogeneity can vary with the random component η_i and socioeconomic attributes S_i, specifying distributions for error terms ε and η yields the probability of choosing alternative i from choice set J. The deterministic component is assumed to be a function of choice attributes Z_i with parameters β. By interpreting unobserved heterogeneity, the choice probability can be derived.

2.3 Latent Class Model

The latent class model (LCM) is a semi-parametric approach that does not require assumptions about parameter distributions. It divides the sample into a finite number of identifiable classes where preferences are homogeneous within each class but heterogeneous between classes. LCM can estimate choice probabilities for individuals in each class and analyze how socioeconomic attribute variables influence these probabilities, thereby explaining the formation mechanism of preference heterogeneity.

Assuming the sample consists of latent classes s that capture unobservable heterogeneity through different parameter vectors in the utility function, if individual q belongs to class s, the choice probability for individual q in class s

can be expressed as:

$$P_{iq|s} = \frac{\exp(V_{iq|s})}{\sum_{j=1}^{J} \exp(V_{jq|s})}$$

Considering individual classification membership functions, respondents can be assigned to s potential categories. The classification membership function for individual q belonging to class s is:

$$M_{qs} = \lambda_s S_q + \xi_{qs}$$

Classification membership is influenced by observable socioeconomic attributes S_q. Assuming the random error term of the classification membership function follows an extreme value distribution, the probability H_{qs} of individual q being in class s can be expressed as:

$$H_{qs} = \frac{\exp(\alpha \lambda_s S_q)}{\sum_{s=1}^{S} \exp(\alpha \lambda_s S_q)}$$

where α is a scale factor, and λ_s represents class-specific parameters to be estimated. Combining the choice equation and classification equation, the unconditional probability of choosing alternative i is:

$$P_{iq} = \sum_{s=1}^{S} H_{qs} \cdot P_{iq|s}$$

2.4 Compensating Surplus Value

Hanemann proposed compensating surplus (CS) consistent with demand theory. Once parameter vector estimates β are obtained, welfare changes resulting from attribute set changes can be calculated. The compensating surplus value from initial state V^0 to new state V^1 is:

$$CS = -\frac{1}{\beta_p} \left[\ln \left(\sum_i \exp(V_i^1) \right) - \ln \left(\sum_i \exp(V_i^0) \right) \right]$$

If utility for all attributes is a linear function, the WTP for improving a specific environmental attribute level r is:

$$WTP_r = -\frac{\beta_r}{\beta_p}$$

where β_r and β_p represent estimated parameters for environmental attribute r and price attribute p, respectively.

3. Choice Experiment Design

This study aims to estimate the ecosystem service value of Sanjiang Plain wetlands, with the critical step being the determination of wetland attributes and their level combinations. Through literature review and expert consultation, the research team analyzed and discussed regional public perspectives to identify final attributes important to the public, their levels, and appropriate survey language. Four wetland attributes were selected: wetland area, biodiversity, water conservation, and natural landscape, with a payment price attribute to determine monetary values.

Wetland area has three levels, while water conservation and natural landscape each have three levels. Wetland area is fundamental to ecosystem service functions. The conflict between agricultural development and wetland protection in the Sanjiang Plain has severely affected overall ecosystem service value, making wetland area' s economic value highly relevant. The wetland ecosystem serves as a carrier for biodiversity, making it an indispensable attribute. Water conservation is a critical service function formed through wetlands' special hydrological roles, distinguishing them from forests, grasslands, and other ecosystems. Beyond ecological benefits, wetland natural landscapes provide recreational and cultural values that cannot be ignored.

shows the wetland attributes and management levels used in the choice experiment. Considering practical feasibility, orthogonal experimental design methods and software were used to select choice sets with different wetland attribute level combinations. Each choice set contains two wetland management alternatives and one status quo alternative. The status quo represents the current environmental state without any management measures, which is consistent with demand theory and facilitates welfare estimation.

4. Choice Experiment Data Collection

This study focused on the Sanjiang Plain wetlands to evaluate ecosystem service values. A pre-survey was conducted between May and June 2015 to determine the price attribute and sample size, test questionnaire design, and revise inaccurate questions and expressions to ensure survey efficiency and reliability. The final questionnaire included three sections: (1) respondents' knowledge and attitudes toward Sanjiang Plain wetlands and environmental protection; (2) the core choice experiment with 12 choice sets; and (3) respondents' socioeconomic attributes including gender, age, education, income, and number of visits to the area.

The survey was administered through face-to-face interviews in Heilongjiang Province in July 2015. Survey personnel received prior training and clearly explained the meaning of each attribute and option to respondents before the interview. A total of 1,200 questionnaires were distributed (400 per version), yielding 1,182 valid questionnaires (394 valid observations) after removing incomplete and extreme responses.

5. Sample Characteristics

In addition to choice data, collecting respondents' socioeconomic attribute data is essential for explaining sample representativeness and discussing preference heterogeneity. presents the descriptive statistics. The sample comprised 52.28% females and 47.72% males, with a relatively balanced gender distribution. Age distribution was also reasonable, with respondents aged 26–59 accounting for 65.98%. Education levels were concentrated in high school and college, reflecting relatively high cultural literacy. Income distribution was relatively even across categories.

6. Model Parameter Estimation

6.1 Random Parameter Logit Model Estimation

Based on dummy coding of attribute levels and respondent characteristics, the basic model was analyzed to demonstrate how selected attributes explain choices among alternatives. The model included alternative specific constants (ASC), four wetland attributes specified as normally distributed random parameters, and payment price specified as non-random. presents the RPL model results.

All wetland attributes passed significance tests and showed signs consistent with prior expectations. Under constant conditions, any increase in a single attribute increases the probability of a management alternative being selected. The positive coefficients for wetland area, natural landscape, biodiversity, and water conservation indicate respondents' positive attitudes toward ecosystem service improvements. The significantly negative payment price coefficient shows that higher prices reduce the probability of an alternative being selected.

6.2 Latent Class Model Parameter Estimation

The first step in LCM analysis is determining the number of classes. Wetland area, biodiversity, water conservation, and natural landscape attributes were used as utility function parameters, while respondents' socioeconomic attributes served as classification membership function parameters. shows the LCM classification results based on AIC, BIC, and AIC3 criteria.

The log-likelihood ratio improves with more classes, but AIC and BIC values decrease and then increase. The three-class model was selected as optimal. shows the relative importance of parameters across three latent classes. In Class 1 (resource-preferring), water conservation is most important. In Class 2 (landscape-preferring), natural landscape importance far exceeds other attributes. In Class 3 (price-sensitive), payment price is the most important attribute.

presents the LCM parameter estimates. The three latent classes are: **- Class 1 (Resource-preferring, 68.88%)**: All wetland attribute coefficients are significant. Gender and education significantly affect classification membership, with females and highly educated respondents showing stronger resource conservation preferences. - **Class 2 (Landscape-preferring, 15.70%)**: Only natural landscape and biodiversity coefficients are significant. Income and visit frequency positively affect membership, indicating high-income, frequent visitors prefer landscape protection. - **Class 3 (Price-sensitive, 15.42%)**: Payment price coefficient is significantly negative. Education and income are negatively correlated with membership, showing less educated and lower-income respondents are more price-sensitive.

6.3 Attribute Value Accounting

Public valuation of wetland management attributes ranks as: water conservation > wetland area > biodiversity > natural landscape. This aligns with Zhang Yiran' s findings on inland wetland ecosystem service values. The high priority for water conservation may relate to the Sanjiang Plain's reputation as a famous rice-producing region, where water quality directly affects grain yield and quality. shows the marginal WTP values: wetland area (RMB 82.68), biodiversity (RMB 41.12), water conservation (RMB 118.57), and natural landscape (RMB 59.38).

6.4 Compensating Surplus Values

Compensating surplus values increase with improved wetland ecosystem service functions. shows the average WTP for maintaining current services is RMB 38.11 per respondent, and RMB 257.18 for improvement. Multiplying by Heilongjiang's 2014 permanent population (38.33 million) yields total WTP of RMB 14.61 billion annually for maintenance and RMB 98.58 billion for improvement.

7. Conclusions

This study applied choice experiments to evaluate the marginal benefits of Sanjiang Plain wetland ecosystem services and analyzed preference heterogeneity using RPL and LCM models. Key findings include:

1. Public WTP for wetland area, biodiversity, water conservation, and natural landscape are all positive, with water conservation receiving the highest marginal WTP, followed by wetland area, then biodiversity and natural landscape. This demonstrates that protecting Sanjiang Plain wetlands generates substantial economic benefits alongside ecological sustainability.

2. The conflict between agricultural development and wetland conservation has severely impacted ecosystem service values. Future policies should strengthen wetland protection and restoration, prohibit overdevelopment, restore wetland area, and prioritize water quality and biodiversity rehabilitation.

3. Respondents can be classified into three latent classes with distinct preferences: resource-preferring, landscape-preferring, and price-sensitive. So-

cioeconomic attributes significantly influence these preferences. Females and highly educated individuals prefer resource conservation; high-income and frequent visitors prefer landscape protection; lower education and income groups are price-sensitive. As incomes and environmental awareness rise, WTP for wetland conservation will increase. Enhanced environmental education and promotion of wetland ecological civilization will strengthen public ecological consciousness and positively influence WTP.

8. Discussion

Compared to contingent valuation methods, choice experiments more scientifically and accurately assess WTP and preferences for different wetland attributes. However, since valuation is based on hypothetical markets, questionnaire design, question order, and respondent comprehension may affect results. This study' s purpose was not precise value estimation but rather measuring marginal values of wetland attributes to identify their relative importance, explore group preferences, and explain heterogeneity mechanisms.

Future research should examine how psychological perception factors and geographic context influence WTP, as well as the effects of questionnaire information and cognition on choices. While wetland ecosystem service valuation methods continue evolving, only a minority of known services can be quantified standardizedly. As services become more finely categorized and wetland types diversify, choice experiment-based valuation can capture public ecological preferences, inform social perspectives on conservation responsibility allocation, and help determine management priorities to serve decision-making and human welfare.

Acknowledgments

We thank the Heilongjiang Provincial Forestry Department, Honghe National Nature Reserve Administration, Sanjiang National Nature Reserve Administration, and Xingkai Lake National Nature Reserve Administration for their support during field research.

References

[1] Chinese ecosystem benefit valuation. 2000, 45(1): 17-22.
[2] Costanza R, D' Arge R, De Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O' Neill RV, Paruelo J, Raskin RG, Sutton P, Van Den Belt M. The value of the world' s ecosystem services and natural capital. Nature, 1997, 387: 253-260.
[3] Contemporary ecological research in China. Science Press, 2013.
[4] Kataria M, Bateman I, Christensen T, Dubgaard A, Hasler B, Hime S, Ladenburg J, Levin G, Martinsen L, Nissen C. Scenario realism and welfare estimates in choice experiments—a non-market valuation study on the European water

framework directive. Journal of Environmental Management, 2012, 94(1): 25-33.

[5] Kosenius AK, Markku O. Ecosystem benefits from coastal habitats—a three-country choice experiment. Marine Policy, 2015, 58: 15-27.

[6] Ndunda EN, Mungatana ED. Evaluating the welfare effects of improved wastewater treatment using a discrete choice experiment. Journal of Environmental Management, 2013, 123: 49-57.

[7] Provencher B, Bishop RC. Does accounting for preference heterogeneity improve the forecasting of a random utility model? A case study. Journal of Environmental Economics and Management, 2004, 48(1): 793-810.

[8] Bliem M, Getzner M, Rodiga-Labnig P. Temporal stability of individual preferences for river restoration in Austria using a choice experiment. Journal of Environmental Management, 2012, 103: 65-73.

[9] Price JI, Janmaat J, Sugden F, Bharati L. Water storage systems and preference heterogeneity in water-scarce environments: a choice experiment in Nepal's Koshi River Basin. Water Resources and Economics, 2015, 13: 6-18.

[10] Brennan N, Van Rensburg TM. Wind farm externalities and public preferences for community consultation in Ireland: a discrete choice experiments approach. Energy Policy, 2016, 94: 355-365.

[11] Train KE. Recreation demand models with taste differences over people. Land Economics, 1998, 74(2): 230-239.

[12] Boxall PC, Adamowicz WL. Understanding heterogeneous preferences in random utility models: a latent class approach. Environmental and Resource Economics, 2002, 23(4): 421-446.

[13] Garrod G, Ruto E, Willis K, Powe N. Heterogeneity of preferences for the benefits of environmental stewardship: a latent-class approach. Ecological Economics, 2012, 76(1): 104-111.

[14] Bestard AB. Substitution patterns across alternatives as a source of preference heterogeneity in recreation demand models. Journal of Environmental Management, 2014, 144: 212-217.

[15] Carlsson F, Frykblom P, Liljenstolpe C. Valuing wetland attributes: an application of choice experiments. Ecological Economics, 2003, 47(1): 95-103.

[16] Birol E, Karousakis K, Koundouri P. Using a choice experiment to account for preference heterogeneity in wetland attributes: the case of Cheimaditida wetland in Greece. Ecological Economics, 2006, 60(1): 145-156.

[17] Newell LW, Swallow SK. Real-payment choice experiments: valuing forested wetlands and spatial attributes within a landscape context. Ecological Economics, 2013, 92: 37-47.

[18] Dias V, Belcher K. Value and provision of ecosystem services from prairie wetlands: a choice experiment approach. Ecosystem Services, 2015, 15: 35-44.

[19] Ecological benefit loss assessment of Jiaozhou Bay wetland reclamation based on choice experiments. 2014, 33(12): 80-86.

[20] Environmental resource attribute valuation and empirical research based on choice experiments. 2015, 37(1): 68-75.

[21] Empirical study on willingness to pay for cultivated land ecological compensation from choice experiment perspective: based on Wuhan questionnaire

survey. 2013, 35(10): 2061-2066.
[22] Economic value evaluation of forest park resources and management attributes based on choice experiments. 2015, 37(1): 193-200.
[23] Wetland reserve ecological compensation policy research based on choice experiments. 2016, 31(2): 241-251.
[24] Research on ecological environment changes in Sanjiang Plain in recent years. 2013, 38(2): 42-45.
[25] Importance of wetland ecosystem service functions in Sanjiang Plain. 2012, (1): 59-60.
[26] Trade-off between wetland protection and cultivated land reclamation in Sanjiang Plain. 2006, 28(1): 39-42.
[27] Lancaster KJ. A new approach to consumer theory. Journal of Political Economy, 1966, 74(2): 132-157.
[28] Marschak J. Binary-choice constraints and random utility indicators // Arrow KJ, Karlin S, Suppes P, eds. Mathematical Methods in the Social Sciences. Stanford: Stanford University Press, 1960: 312-329.
[29] Manski CF. The structure of random utility models. Theory and Decision, 1977, 8(3): 229-254.
[30] McFadden D, Train K. Mixed MNL models for discrete response. Journal of Applied Econometrics, 2000, 15(5): 447-470.
[31] Smith VK. Arbitrary values, good causes, and premature verdicts. Journal of Environmental Economics and Management, 1992, 22(1): 71-89.
[32] Revelt D, Train K. Mixed logit with repeated choices: households' choices of appliance efficiency level. The Review of Economics and Statistics, 1998, 80(4): 647-657.
[33] Bhat CR, Gossen R. A mixed multinomial logit model analysis of weekend recreational episode type choice. Transportation Research Part B: Methodological, 2004, 38(9): 767-787.
[34] Hess S, Bierlaire M, Polak JW. Estimation of value-of-time using mixed logit models. General Information, 2004, 39: 221-236.
[35] Greene WH, Hensher DA. A latent class model for discrete choice analysis: contrasts with mixed logit. Transportation Research Part B: Methodological, 2003, 37(8): 681-698.
[36] Bhat CR. An endogenous segmentation mode choice model with an application to intercity travel. Transportation Science, 1997, 31(1): 34-48.
[37] Tabi A, Saz-Salazar SD. Environmental damage evaluation in a willingness-to-accept scenario: a latent-class approach based on familiarity. Ecological Economics, 2015, 116: 280-288.
[38] Swait J. A structural equation model of latent segmentation and product choice for cross-sectional revealed preference choice data. Journal of Retailing and Consumer Services, 1994, 1(2): 77-89.
[39] Hanemann WM. Discrete/continuous models of consumer demand. Econometrica, 1984, 52(3): 541-561.
[40] Liu XH, Lu XG, Ming J, Zhang CL, Wang LG. Evaluation of greenhouse gas emissions from wetland and agriculture ecosystems in Sanjiang Plain. International Journal of Sustainable Development and World Ecology, 2010, 17(6):

462-467.
[41] Do TN, Bennett J. Estimating wetland biodiversity values: a choice modelling application in Vietnam' s Mekong River Delta. Environment and Development Economics, 2009, 14(2): 163-186.
[42] Valuation of inland wetland ecosystem service value in China based on 93 wetland cases. 2015, 35(13): 4279-4286.
[43] Louviere JJ, Hensher DA, Swait JD. Stated Choice Methods: Analysis and Application. Cambridge: Cambridge University Press, 2001.
[44] Semi-parametric models and empirical research in double-bounded dichotomous choice CVM data analysis. 2016, 36(3): 854-862.
[45] Distance decay of ecological protection value: a case study of Sanjiang Plain wetlands. 2013, 33(16): 5109-5117.
[46] Spatial differentiation of non-use value WTP based on residents' ecological cognition: a case study of Sanjiang Plain wetlands. 2014, 34(9): 2332-2338.
[47] The state of the art of environmental valuation with discrete choice experiments. 2010, 69(8): 1595-1603.
[48] Zhalong wetland ecosystem service value evaluation. 2016, 36(3): 828-836.

Note: Figure translations are in progress. See original paper for figures.