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Valuation of ecosystem services using choice experiment with preference heterogeneity: A benefit transfer analysis across inland river basin

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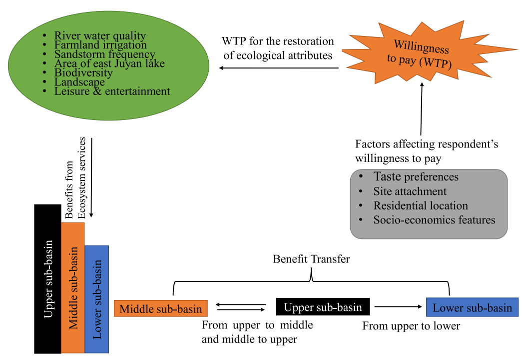
HIGHLIGHTS

- Willingness to pay estimates is different across sub-basins.
- Highest willingness to pay was estimated for water quality in all 3 sub-basins.
- Lowest willingness to pay was estimated for Leisure & entertainment conditions.
- Insertion of taste heterogeneity reduced transfer errors in mixed logit model.
- The transferability of benefit transfer exists across sub-basins.

GRAPHICAL ABSTRACT



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ABSTRACT

River ecosystem services offer a variety of benefits to the inhabitants of inland areas. For the valuation of environmental goods and services in the context of attaining a better environmental status across Heihe River basin (HRB), Northwest of China by 2020, a survey was conducted employing choice experiment approach across the entire river basin. The selected ecological attributes were defined in combination with ecological improvements in the three sub-basins namely upper, middle and lower sub-basins. For estimating spatial preference heterogeneity, the benefits for the inhabitants were estimated by conditional logit and mixed logit models. Results indicated that the willingness to pay (WTP) estimates for river water quality, farmland irrigation, sandstorm days, lake area, biodiversity, landscape and leisure & entertainment were significantly different across sub-basins. The WTP for water quality in upper basin was RMB 126.6 per year, while in middle and lower sub-basin was RMB 97.1 and 66.4 per year respectively. The estimates of mixed logit model indicated the reduced transfer errors with the insertion of taste heterogeneity. However, transferring benefits from middle sub-basin to upper sub-basin the estimated transfer errors were 27.3%, from lower to middle the transfer errors were 23.4% and from upper to lower the transfer errors were 14.1%. Our obtained results recommend the transferability of non-market benefits among sub-basins.

1. Introduction

The prevailing problems of water resources in the Heihe river basin (HRB) are the main emphasis of the conflicts among the functions of ecosystem services and the fundamental theme about ecological

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development and water-ecological interface. During the past few decades, the ecological systems of HRB are constantly threatened by pollution and environmental degradation (Yan et al., 2015). Therefore, the research regarding improvements in the ecosystem services is inevitable to evaluate policies to guarantee sustainable management of degraded environmental conditions.

Valuation of environmental goods and services is of prime importance in policy making decisions, but, is limited by time and financial constraints. Valuation techniques are burdensome and very expensive, limiting the ability of decision-makers to investigate and thereof produce an original valuation assessment. However, the availability of valuation results increasingly proliferate as reported in numerous valuation studies worldwide. Consequently, there has been an increasing interest to implement the practice of benefit transfer. For benefit transfer estimation, the available values of public goods and services from a single or multiple locations (study sites) are applied to forecast the value for similar or identical goods and services at another location (policy site) (Wong et al., 2015). In spite of numerous limitations that affect the valuation process, there is a legitimate need to estimate the value of the environment to take into account people's preferences in the process of policy and decision-making (Barbera, 2010).

At present, there is convincing indication that spatial configurations are followed by the preferences for few environmental goods and services. The foremost justification is that there are variations in spatial pattern of environmental amenities so that preferences adapt to individuals' environments (Nielsen et al., 2007) and the availability of substitutes (Johnston et al., 2017). Another reason is residential sorting i.e., the public decisions about their residential site depends on their preferences for environmental amenities, thus preferences tend to be associated with quality of environment or with distance to environmental goods (Changlin et al., 2015).

Spatial heterogeneity denotes the unequal dissemination of landscape or population and its socio-economic appearance in a specific area (Anselin, 2010). It refers to the phenomenon that the value of attribute at one site is different from its surroundings. A landscape with spatial heterogeneity for example, is composed of concentrations of numerous biological species of plants or animals origin, terrain formations (geological) or environmental attributes (e.g. rainfall, temperature, wind) included in the area. A population showing spatial heterogeneity is one where various concentrations of individuals of this species are unevenly distributed across an area (Wang et al., 2016). Similarly, spatial preferences denote an assumption which demonstrates that residents of a river basin living at different locations value environmental goods differently (Brouwer et al., 2010). Likewise, spatial choices are those choices which are selected between specific alternatives at a specific site (Fotheringham, 1988). Different areas of China exhibit spatial preference heterogeneity (Liu and Ying, 2017), and the qualities and forms of ecosystem services vary across the region (Zhou et al., 2015), which ultimately affect willingness to pay for the environmental improvements.

Previously, the coastal habitats have been taken into account for benefits from ecosystem services (Kosenius and Markku, 2015), additionally, to our knowledge, till now only Khan et al. (2018) has reported the estimation of benefit transfer in inland river basin. However, no research work has reported benefit transfer in the inland Heihe river basin. Careful evaluations are required to assess the benefits of non-marketed goods and services from the restoration of ecological attributes and to check the transferability of the benefits across the Heihe river basin. Moreover, there is a dire need to explore possible future variation in the ecosystem services that represent supporting, regulating and providing services, in particular consideration to the part of spatial heterogeneity in the valuation of ecosystem services. We therefore conducted an explicitly spatial choice experiment technique to estimate the economic valuation of ecosystem services by interviewing the respondents about their WTP for the improvements in degraded ecosystem services (Da Costa and Hernandez, 2019). The welfare estimates for the improvements of selected ecological attributes in the Heihe river sub-basins were based upon individual's responses regarding valuation of ecosystem services.

Though a river basin provides numerous benefits to the residents, but to concise the current study for ecosystem benefits, we carefully chose a total of seven key ecological attributes that were very important and likely to affect the environmental and social developments of the inhabitants in the study area. As there are significant variations in sub-basins of stated inland river in terms of public demographic factors, livelihood conditions and ecosystems (Aregay et al., 2016), findings of the current study may have remarkable and practical policy implications.

The next section is about methodology applied in the current study which is further divided into description of the study site, econometric model for the evaluation of ecological attributes, survey design and data collection technique followed by the results and discussion. The last section comprises of concluding remarks of the results and discussion, and practical implications of spatial preference heterogeneity for environmental policy.

2. Methodology

2.1. Study site

The Heihe River Basin (98°–101°30′ E, 37° 50′–42°_40′ N) originates in the North of Qilian Mountains and approaches towards the South Inner Mongolia (Fig. 1). It is the 2nd largest inland river spread over an area of 116,000 km^2 with a length of 821 km with approximately $14.2 \times 104\ km^2$ catchment area. It is situated in the arid region of central Hexi corridor which faces a severe water shortage problem. The topography of the river is lower in East & North whereas higher in the West & South. Differences in the elevation caused ecological landscape and climate condition has obviously vertical zonation law (Ty et al., 2012; Wu et al., 2015). The unique topographical location and arid climatic conditions creates the stronger winds and high sunshine frequency, still there are fluctuations in the temperature of day and night (Wu et al., 2014). Similarly, there is also a large fluctuations in the seasonal precipitation and temperature, for instance there is an abundance of precipitation in the rainy season while less precipitation in spring (Zhan et al., 2015). The yearly rainfall in the upper sub-basin (Qilian Mountains) is in the range of 300–500 mm, in middle sub-basin (Hexi corridor) annual rainfall is about 100–250 mm, while in the lower reaches (Ejinaqi oasis) average annual rainfall is below 45 mm (Li et al., 2015).

Some serious ecological problems are faced by the three sub-basins. For instance, the major ecological problems in the upper-sub basin are: the deterioration and desertification of grassland, dispersion of toxic weeds, and decrease in the productivity of grassland and so on. Likewise, middle sub-basin faces desertification and salinization of land and water contamination. The most brittle eco-environment zone is the lower sub-basin in the whole river basin, which faces four major ecological problems which are; disappearing of the terminal lake i.e. east Juyan lake, enhancement in sand source, reduction in area under oasis and speedy desertification. The degradation of current ecological attributes restricted the social and regional environmental development as well poses a serious constraint to the environmental security of the entire basin (Chen et al., 2016).

2.2. Description of the econometric model

Choice experiment approach was employed for the assessment of the public preferences regarding the improvements in the ecosystem services and getting improved ecological circumstances by 2020 in the entire river basin. Usually in choice experiment assessment, by introducing an imaginary choice task, respondents frequently go through the comparison of the relative costs for the upgradation of current ecosystems. The respondents usually chose those alternatives in each

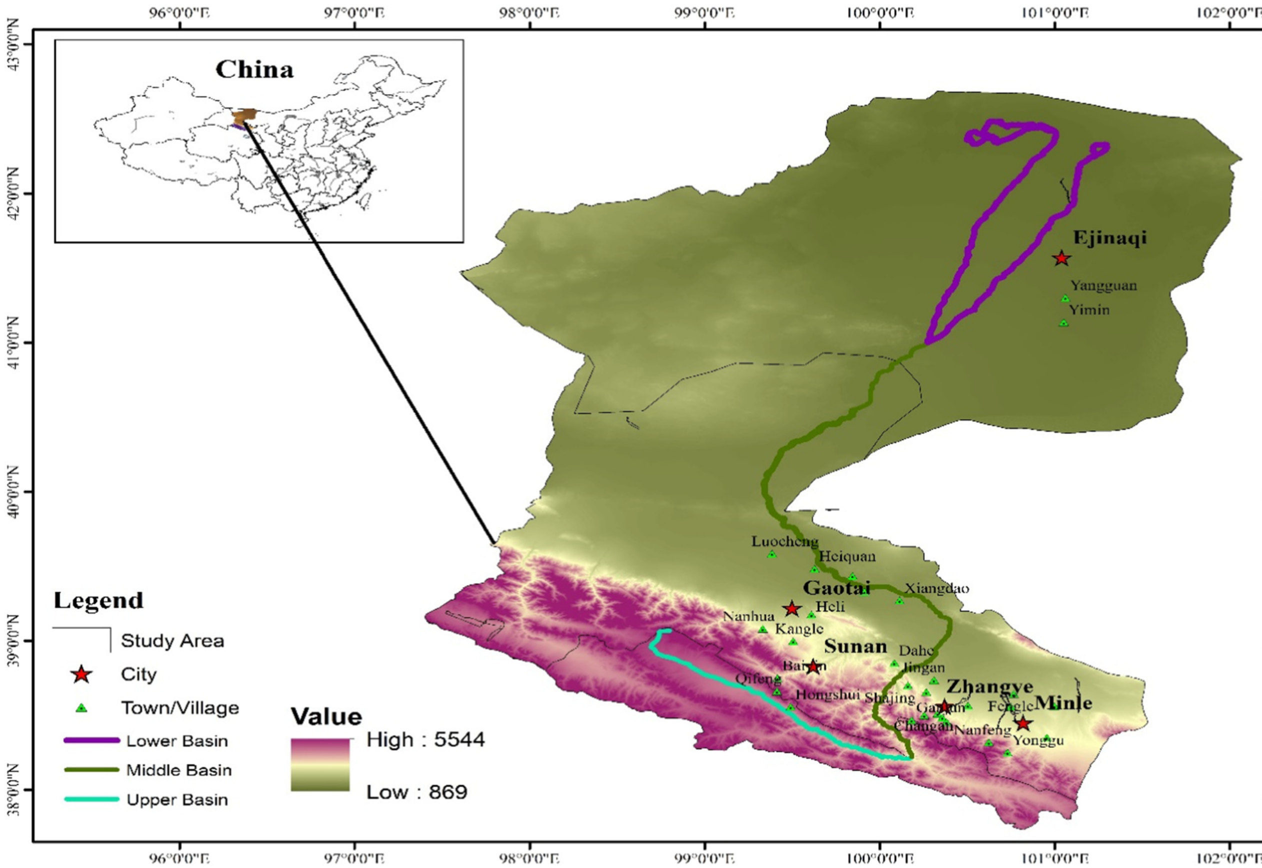

Fig. 1. Heihe River Basin (Arc GIS 10.3).

choice set that provide them maximum utility U. The maximizing utility function is shown as below:

$$MaxU\ (x_1, x_2, \ldots\ldots x_k) subject\ to\ P(x_1, x_2, \ldots\ldots x_k) + d = y \quad (1)$$

The $x_{i,\ i=1,\ \ldots,\ k}$ are the alternatives describes by the ecological attributes and are selected on the basis of respondent's preferences and practical implication. The cost/payment for the improvements is the selected ecological attributes is denoted by $p(x_1, x_2, \ldots\ldots, x_k)$ with ordinary goods d not exceeding the available income y (Bennett and Blamey, 2001; Ledoux and Turner, 2002).

The theory of utility maximization is related to the econometric model in RUM (random utility model) framework. In RUM the utility obtained by respondent n from the alternative j is stated below:

$$U_{nj} = V_{nj} + \epsilon_{nj} = \alpha_j ASC_j + \sum_k \beta_{nk} X_{njk} + \sum_k \gamma_{nk} X_{njk} C_n + \mu_{nj} ASC_{nj} C_n \epsilon_{nj} \quad (2)$$

where V_{nj} denotes to the deterministic component of utility and ϵ_{nj} to the unobserved component. The coefficient α_j, with alternative-specific constant ASC_j, refers to the utility that captures the mean effect of latent variables, related to the preference for the upgradation of the ecosystem services.

The estimation of econometric models having choice data examine the impact of ecological attributes X_{njk} the choice of a specific alternative. The coefficients β_{nk} are interpreted differently in various models i.e. β_{nk} in CL model reveals the individual's taste for attribute X_{njk}, whereas β_{nk} in mixed logit model reveals the aggregate taste of individual β_k and $stde_{nk}$ denotes the standard deviation from the average taste. Accumulating the random approach, tastes heterogeneity can be presented analytically as the interactions of characteristics of individual C_n with attributes X_{njk} or alternative specific constants ASC_{nj}, γ_{nk} and μ_{nj} being the associated constants (Kosenius and Markku, 2015).

β_s are the estimated coefficients which are used to measure the marginal willingness to pay (MWTP) values. For CL model, the expected marginal WTP for attribute k can be calculated as:

$$MWTP_{k,CL} = -\beta_k / \beta_p \quad (3)$$

which explains the negative ratio of the coefficient of ecological attribute k and the coefficient of payment/cost parameter p, keeping other factors constant. While expected MWTP for mixed logit model is given as follow:

$$MWTP_{k,mixed\ logit} = -(\beta_k stde_k * rna_k)/\beta_p \quad (4)$$

where $stde_k$ denotes the estimated standard deviation of parameter β_k while rna_k denotes draw from a random distribution (Greene, 2005).

The assessment of ecosystem benefits transfer across different regions or residents either need the parity of welfare measures ($MWTP_{k,\ model}$) or the parameters of the utility function (β_k).

Various methods can be applied for the assessment of benefits transfer in a specific policy site, for instance unit value transfers, benefit function transfer method and meta-regression analysis and so on (Jiang, 2017). In the current research, for environmental attributes and scenarios, we applied the unit value transfer method and compare the overlapping of 95% CI for the evaluation of equality of marginal willingness to pay and use transfer errors for the estimation of the precision of the environmental value transfer (Brouwer and Bateman, 2005).

$$Transfer\ error_i(TE_i) = \frac{|\,WTP_s - WTP_p\,|}{WTP_p} * 100 \quad (5)$$

where S denotes the study site from which the benefits are expected to transfer to the policy site P. The TE values depend on whether heterogeneity in individual's taste is arbitrary, accurate, theoretical or non-theoretical (Bateman et al., 2011a; Colombo et al. (2007)).

2.3. Survey design and data collection

This section demonstrates the sampling technique to range all the sampling households for the collection of data regarding upgradation of current ecological conditions in Heihe river basin (HRB). For data collection, a detailed survey was conducted in five major cities and adjacent rural areas on a pretested and well-designed questionnaire. Three basins i.e. upper, lower and middle basin were recognized on the basis of existing administrative divisions. For this purpose, Sunnan was nominated from upper sub-basin, Zhangye, Gaotai & Minle were chosen from middle sub-basin, while Ejinaqi was chosen from the lower sub-basin. The surrounding rural areas were considered for the fact to reflect the current environmental and economic features of the mentioned cities. Moreover, a stratified random sampling technique was employed for the selection of corresponding villages and townships. Following this procedure, 3–8 townships were randomly selected from respective county and 2–7 villages were randomly selected from each corresponding township. At the end, proportional allocation technique was used to select 10–30 respondents from each village. A primary data of 1680 respondents was collected from five main cities and 33 surrounding rural areas. Out of total respondents, 201 were interviewed from Sunnan region, 304 from Gaotai region, 280 from Minle region, 695 from Zhangye region and 199 respondents were interviewed from Ejinaqi region. Following previous studies (Khan et al., 2018; Kosenius and Markku, 2015) and by applying proportional allocation technique, it is argued that the current sample size is sufficient to represent the targeted region.

Initial discussions with environment regulatory authorities and respondents were intended to attain proper and practical depiction of the issues under valuation. For identification of the relevant ecological attributes and their corresponding levels, a pilot survey was initially organized involving 70 local households of the study area. The pilot survey helped in the inhabitants views about the existing conditions and problems with ecosystem services. Some valuable additions come through the discussions with local ruling bodies and detailed review of previous studies. Table 1 represents seven river ecological attributes that reflect these undervaluation issues: river water quality, farmland irrigation security, reduction in the frequency of sandstorm days, increase in the east Juyan Lake area, natural landscape, biodiversity and conditions for leisure & entertainment. The attributes levels were created on the basis of the ecological models for the consequences of executing the integrated river basin management of HRB.

Due to the interconnection of ecosystem services it is sometimes challenging to arrange a group of ecological attributes that are not interconnected. The impact of this causal interrelation could be on estimation of individual's WTP by varying the values of ecological attributes. Nonetheless, the insertion of causal prior attributes alters the attributes than the biases of the estimates (Yu et al., 2014). In the current research, causality indicates the improvement effect in river water quality level & landscape safety on the other selected ecological attributes. For restoration policy a premeditated amount is defined by the inhabitants, which permits for the valuation of ecological attributes.

2.4. Choice experiment

The attributes and their corresponding levels are demonstrated in the choice set (see Table 1). The respondents were given the options to decide on the given two policy programs (A and B) and a status quo (existing condition) with zero payment. The number of alternatives was same whereas the level of attributes was thoroughly different. The inclusion of status quo in the choice set was necessary because the welfare estimation without its presence would be biased and unreliable

Table 1
Ecological attributes and their levels in the choice set.

Evaluation indicators	Program 1 (status quo)	Program 2 (Improved 1)	Program 3 (Improved 2)
River water quality level	Level 2.5	Level 3	Level 2
Guarantee rate of farmland irrigation	60%	70%	60%
Sand storm frequency	44 Days	35 Days	30 Days
Area of east Juyan lake	40 km^2	50 km^2	60 km^2
Biodiversity	☆	☆☆☆	☆☆
Farmland landscape (Whether or not beautiful)	No	Yes	No
Leisure and entertainment conditions	55 km^2	130 km^2	105 km^2
Your family is willing to pay for this (Every Year)	0	RMB 150	RMB 100
Please select one of these	□	□	□

Description of the river attributes, environment changes in the attributes and selection in Heihe watershed.

1. River water quality: The average water quality of the watershed, providing a clean water source for the living and survival of the animals and plants. Water quality from 1 to 5 to reduce in turn, 2 level of water is cleaner, by conventional purification treatment can become potable water, 3-level water suitable for general fish reserves and swimming area. The status is 2.5 levels.
2. Guarantee rate of farmland irrigation: The actual irrigation water is the percentage of the irrigation amount, and the current situation is 60% to guarantee the agricultural production in Heihe basin.
3. Sand storm frequency: Ejina Qi (Dust Source) The annual number of days of Ascension is closely related to the air quality and the health of residents, and the current situation is 44 days.
4. Area of east Juyan Lake: East Juyan lake stable Water area, for the downstream provision of animal and plant habitats, regulating the basin climate, the status quo is 40km^2.
5. Biodiversity: Cultivated land provides suitable living space for animals and microorganisms, and rich biodiversity has positive significance for farmland and ecological environment.
6. Farmland Landscape: Reasonable planning of farmland structure, planting trees and grass, the establishment of forest belt to build field roads. Comfortable, beautiful farmland provides a space for residents to walk, relax and entertain.
7. Leisure and entertainment conditions: The area of Heihe Middle Swimming Wetland Park, providing eco-tourism, enjoy the scenery and other functions, protection of biodiversity in the watershed, has been built 55km^2.

with demand theory (Barreiro-Hurle et al., 2018). A choice set design with the insertion of status quo (current condition of the ecological attributes) permits proper investigation of welfare estimates; though if the choice was selected regularly, then the design would still permit for the comparative attraction of the ecological attributes. That enables the respondents to consider the alternative policy program options with progresses in the ecological attributes instead of current ecological conditions (status quo), hence inspiring the individuals to trade-offs and do not let them take an informal choice (Brazell et al., 2006). The Bayesian D-efficient design with preceding evidences regarding parameters was used for the creation of experimental designs (Yao et al., 2015). The order of ecological attributes was rotated in the different questionnaire versions.

In the choice set, all the selected attributes and their levels are demonstrated in a way that the policy alternative programs are put side wise. On the basis of pilot survey in the investigated area and relative importance of the attributes; a total of seven ecological attributes namely, river water quality, farmland irrigation, number of sandstorm day, increase in the east Juyan lake area, landscape, biodiversity and leisure & entertainment conditions were selected. The 1st column of the choice task represents all the selected ecological attributes which needs to be improved, whereas the corresponding rows identify their levels (see Table 1). The 2nd column represents the status quo (current condition) of the selected ecological attributes with zero payment. Similarly, the 3rd and 4th column indicates the alternative policy programs with the representation of improving the current conditions of ecological attributes along with voluntary payments. The levels of ecological attributes are different from each other in the alternative policy programs, which assists in the estimation of the utility parameters (Poder et al., 2016). The choice task presented in Table 1 enables each respondent to choose the most preferred alternative among the choice sets that gives maximum utility.

2.5. Data screening

Before analyzing the welfare estimation, by conducting follow-up questions, the disputed answers data having a real zero willingness to pay (WTP) was isolated and removed from the final data. After screening, 60 protest responses questionnaires (3% of the total questionnaires) were excluded and a total of 1621 questionnaires were selected for welfare estimation. The segment of legitimate zero WTP (status quo) responses was comparatively low in all three sub-basins. The conditional logit and mixed logit model was estimated through econometric softwere STATA 20.0. All the selected ecological attributes were allotted a random normal distribution, whereas a non-random distribution was allotted to the monetary attribute and alternative specific coefficient (ASC).

3. Results and discussion

3.1. Descriptive statistics

Fig. 2 represents the different demographic features of all the sampled household in the three sub-basins of Heihe River. Of the total respondents, females in upper sub-basin (USB), middle sub-basin (MSB) and lower sub-basin (LSB) were 44.2%, 46.1% and 48.0% respectively. Males in USB, MSB and LSB were 55.2%, 53.9% and 52.0% respectively. Likewise, the next portion represents the household size (HHS), HHS was divided into three categories i.e. 1–3 members, 4–7 members and 8–11 members. The results demonstrated that 42.8% of the respondents in the USB consisted of 1–3 households, while 53.5% respondents in MSB and 56.1% in LSB had 1–3 household size. Similarly, HHS of the 53.4% of the respondents in USB consisted of 4–7 members followed by 44.5% in MSB and 41.3% in LSB. The outcomes suggested that majority of the respondent's household size consisted of one to three members in all the sub basins.

The Fig. 2 also depicts the level of education of the respondents. As shown, 31% of the respondents had junior school education in the USB followed by 20% and 18.8% of the respondents in MSB and LSB respectively. Comparatively, a higher number of the respondents (27.8%) in the LSB had bachelor and above level of education followed by USB where 10.2% of the respondents had bachelor and above level of education. The study of Khan et al. (2019) also confirmed that majority of the respondents in HRB have low level of education. Moreover, 32.8% of the sampled respondents in the USB had an age between 40 and 50 years, in MSB 30.5% of the sampled respondents were between 30 and 40 years of age and 35.5% of the sampled respondents in the LSB had an age between 20 and 30 years. To account for household's annual income, the respondents were distributed in six groups on the basis of their income level. The Fig. 2 illustrates that 63.4% in USB, 62.8% in MSB and 68.1% in LSB of the respondents had an annual income of 0–0.5 million RMB. Household's annual income and education background are two important variables that are significantly related to household's WTP (Xiong et al., 2018) and have been assumed to effect the household's WTP (Balana et al., 2013).

3.2. Welfare estimation

Table 2 indicates the estimated results of the ecological attributes using conditional logit (CL) model. The results demonstrate that the coefficients of all ecological attributes along with monetary attribute (payment) and ASC were statistically significant and had a priori expected signs at 1, 5 & 10% risk levels except biodiversity attribute in MSB and LSB. The results also indicate that the coefficient of monetary attribute (payment) along with ASC was negative and highly significant in all three sub-basins, specifying a general preference to choose among alternative policy options (Chen et al., 2016). The understanding of the significant coefficients recommends that in all the three sub basins respondents got greater utility when confronted to better ecological conditions.

Table 3 demonstrates the estimated results of the ecological attributes by applying mixed logit model. The outcomes suggested that the coefficients of all the ecological attributes as well as coefficients of

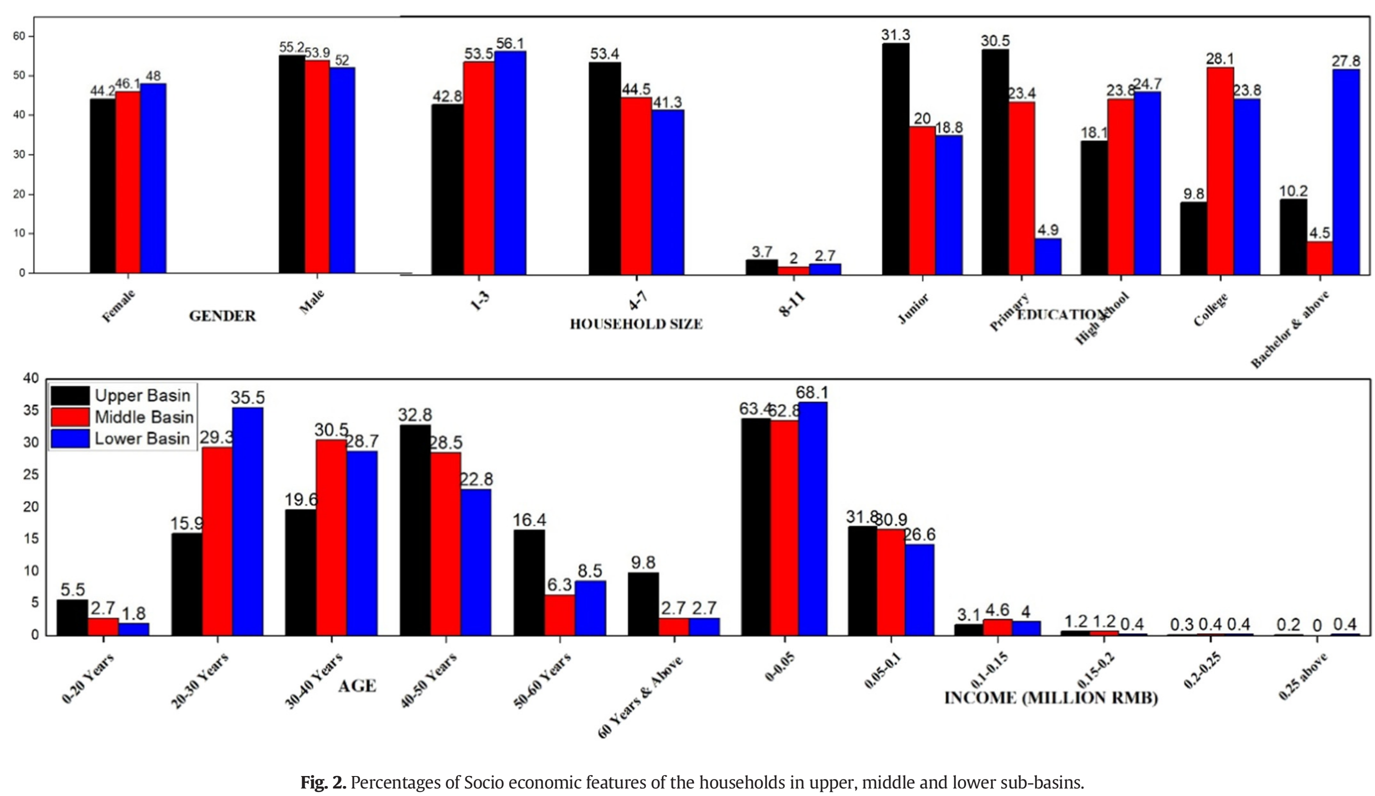

Fig. 2. Percentages of Socio economic features of the households in upper, middle and lower sub-basins.

Table 2
Estimated results for ecological attributes (Conditional logit model).

Choice	Upper Basin		Middle Basin		Lower Basin	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Payment	−0.006***	0.002	−0.005***	0.001	−0.006***	0.001
ASC	−1.347**	0.567	−0.442***	0.221	−2.131***	0.250
River water quality	−0.686***	0.196	−0.617***	0.076	−0.308**	0.144
Farmland irrigation	0.044***	0.022	0.035***	0.008	0.073***	0.012
Sandstorm	−0.053**	0.028	−0.028***	0.011	−0.038**	0.021
Area of east Juyan lake	0.032**	0.013	0.049***	0.005	0.037***	0.013
Biodiversity	0.040***	0.012	0.005	0.043	0.014	0.095
Landscape	0.026***	0.012	0.085**	0.044	0.065*	0.038
Leisure & entertainment	0.006**	0.003	0.005***	0.001	0.028***	0.003
Summary statistics						
No. of Obs	1791		11,520		1809	
LR chi^2(9)	194.19		692.08		196.57	
Log likelihood	−558.775		−3872.630		−564.1763	
Prob > chi^2	0.000		0.0000		0.0000	
Pseudo R^2	0.1480		0.0820		0.1484	

***, ** and * represent significance levels of 1%, 5% and 10% respectively.

payment and ASC attributes are statistically significant in all the three sub basins with the exception of farmland irrigation and area of east Juyan Lake in USB and farmland irrigation and sandstorm in MSB. The biodiversity and leisure & entertainment attributes however, were non-significant in LSB. The significant results for the scenario regarding improvements in the current conditions of the ecological attributes in all the three sub-basin were highly valued by respondents. The outcomes showed that the respondents have positive WTP for the protection and improvements of ecological attributes of river basin (Xiong et al., 2018). The ecological environment of HRB has been significantly worsened due to the overexploitation of groundwater resources (Qi and Luo, 2007). The significant coefficients of the ecological attributes also confirmed the respondent's preferences regarding ecological attributes. The statistically significant standard deviation (SD) of mean of all the random parameter confirms the existence of heterogeneity of preferences for ecological attributes in three sub-basins of Heihe River, which evaluated that inclusion of the random preference variation improved the model in all the three sub-basins. Though this directed to the decision of unsuitability of the conditional logit model for the estimation of current data. However, for the test of the alternate model for the estimation of benefit transfer, conditional logit model estimates are valuable.

Table 3
Estimated results for ecological attributes (Mixed logit).

Choice	Upper Basin		Middle Basin		Lower Basin	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Mean						
Payment	−0.012***	0.004	−0.013***	0.001	−0.010***	0.002
ASC	−3.222***	1.195	−2.266***	0.433	−3.566***	0.533
River water quality	−1.530***	0.502	−1.294***	0.183	−0.664**	0.315
Farmland irrigation	0.025	0.050	0.029	0.018	0.093***	0.025
Sandstorm	−0.124*	0.069	−0.002	0.024	0.076***	0.038
Area of east Juyan lake	0.046	0.029	0.029**	0.012	0.068***	0.023
Biodiversity	0.476**	0.025	0.323***	0.093	0.060	0.194
Landscape	0.052***	0.025	0.177*	0.098	0.381**	0.197
Leisure & entertainment	0.019**	0.009	0.060***	0.030	0.004	0.006
SD						
River water quality	1.739***	0.650	2.495***	0.274	1.842***	0.580
Farmland irrigation	0.240***	0.240	0.198***	0.015	0.178***	0.035
Sandstorm	−0.304***	0.061	0.203***	0.023	0.099**	0.058
Area of east Juyan lake	0.528***	0.054	0.157***	0.016	0.071**	0.034
Biodiversity	0.500***	0.091	0.925***	0.201	1.435***	0.390
Landscape	−0.835**	0.440	0.745***	0.324	1.129***	0.301
Leisure & entertainment	0.051***	0.013	0.048**	0.004	0.025***	0.007
Summary statistics						
No. of Obs	1791		11,520		1809	
LR chi^2(7)	146.46		958.36		57.72	
Log likelihood	−485.5478		−3393.448		−535.318	
Prob > chi^2	0.000		0.000		0.000	

***, ** and * represent significance levels of 1%, 5% and 10% respectively.

3.3. Willingness to pay (WTP) estimation

Due to the rapid economic development and urbanization in the past few decades, river network and its services have suffered extensive destruction in China (Li et al., 2014). Recognizing the public preferences and assessing the benefits from river ecosystems are crucial for sustainable river management and restoration (Khan and Zhao, 2019). Accordingly, Figs. 3 & 4 represents the willingness to pay (WTP) estimates that were calculated through Krinsky-Robb approach with 1000 Halton draws (Krinsky and Robb, 1990). The figures also show the overlapping of all the ecological attributes at 95% confidence intervals which implies the unequal willingness to pay for the improvements in the degraded ecological attributes in all three sub basins with the exception of irrigation in USB and MSB, lake area, landscape and leisure & entertainment in MSB and LSB. The highest WTP was estimated for improvements in the level of river water quality i.e. RMB 117.6, 113.7 and 55.3 in upper, middle and lower sub basins respectively. The previous literature discovered that river water quality is the most favored attribute for most river ecosystems in China (Shang et al., 2012; Zhang, 2012). The findings of Ma et al. (2009) showed that the river water quality at mountainous and piedmont sites are good enough, but due to rapid economic development and population growth, the river water quality has been deteriorated. Furthermore, estimated WTP for irrigation was RMB 2.4, 6.5 and 13.1 in upper, middle and lower sub basins respectively. Whereas, lowest WTP was estimated for improvements in the conditions of leisure & entertainment in all the three sub basin with an annual WTP of RMB 1.1, 0.9 and 4.9 respectively (Fig. 3). Hence, it would be worthy to not only improve ecological assets, but also develop leisure and entertainment conditions and ecotourism that involves collaboration with surrounding tourism sites (Park and Song, 2018).

Similarly, Fig. 4 also represents the WTP estimates using mixed logit model. The results indicated that the highest willingness to pay was assessed for improvements in the level of river water quality with an annual WTP of RMB 126.6 in upper sub-basin, 97.1 in MSB and 66.4 in LSB. While annual WTP for landscape attributes was RMB 38.1 in LSB, RMB 13.3 in MSB and RMB 4.3 in USB. The sub-basins were slightly different from each other in preferences of selected ecological attributes, which resulted in the different amount of WTP for improvement in the selected ecological attributes. The attitude of the individuals towards particular comforts and their WTP for selected ecological attributes contribute a vital part in the justification of dissimilarities in corresponding WTP quantities (Doran et al., 2015). Due to comparative significance of ecological attributes, there is fluctuation in the inhabitant's WTP for the improvements in ecological attributes (Khan et al., 2018). In our findings the estimated MWTP values are reasonable for ecological attributes or water quality improvements and in line with the findings of (Bliem et al., 2012; Doherty et al., 2014; Hanley et al., 2006).

3.4. Feasibility of value transfer between three sub-basins

It is frequently argued that the precise valuation of a giver transfer as the accurate assessment of the policy location is unidentified. Previous studies reported that valuation of the policy location by transfer validity can be revised by assessing the variation of transfer errors (TE). Even though the estimated values of WTP for various attributes vary, their

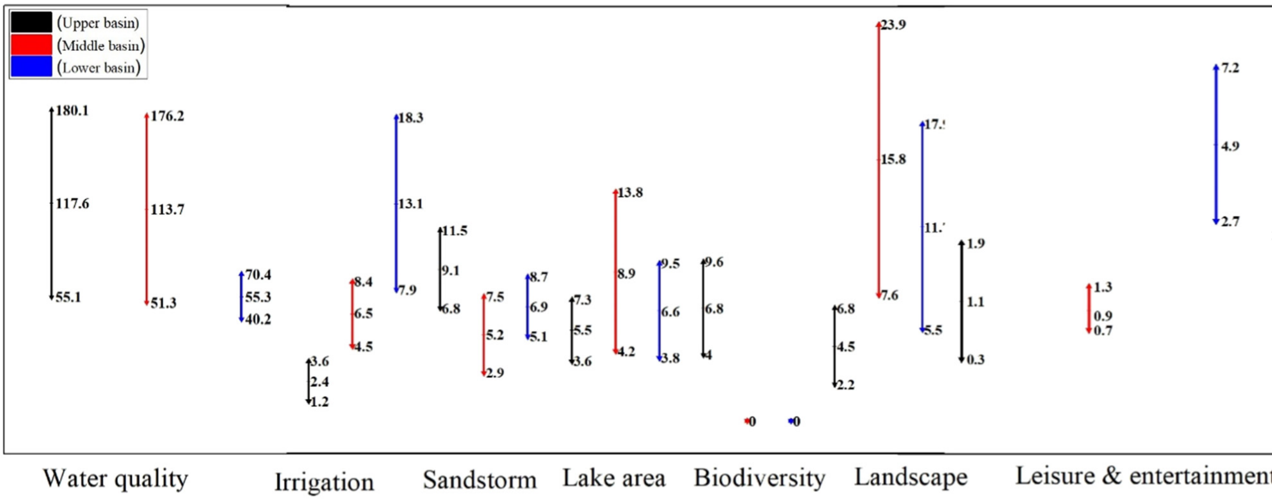

Fig. 3. Mean willingness to pay and upper & lower limit of 95% CI (conditional logit).

utility is dependent on the feasibility of the TE. The estimated results in Tables 2 & 3 portray the selected ecological attributes and alternative specific constant's feasibility and their benefit estimates. The resemblance among the study location and policy location is one of the key factors for shifting the benefits of one site to the other site. The ultimate principle for transferring benefits from study location to the policy location is the similarities among the sites in the context of policies and human population (Newbold et al., 2018). For the reason of similarities in the sites, the researchers mostly emphasize on the socio-economic features of the inhabitants, but on the other hand for transferring benefits, biophysical site features are also essentials (Boyle and Parmeter, 2017). This may be challenging for a researcher to set all the standards for transferring benefits, nevertheless, the benefit transfer (BT) is likely to be more valid if more closely criteria are encountered.

BT are the transfers of the simple mean value obtained from conditional logit and mixed logit models. The estimated results in Table 4 represent the transfer errors (TEs) associated to the benefits from the upgradations in a particular ecological attribute as well as the pairs of the different ecological attributes. In the context of magnitude of the average TEs among residents concerning the single particular attributes the highest mean TEs related to the BT was predicted in USB (54.5–93.9%) from the MSB and LSB followed by LSB (36.7–46.5%) from USB and MSB. Similarly, the lowest average TEs were recorded in LSB (10.2%) from USB and MSB followed by (13.2%) in the MSB from USB and LSB.

On the basis of findings, the range of estimated mean transfer errors is 10.2%–93.9%. The comparison of TEs in three sub basins argued that the differences in their magnitude are generally associated with the variations in the sites and population. It is evident from the findings that TEs of a single attribute or combinations of the attributes were relatively lower in the mixed logit model than the TEs estimated through conditional logit model. For instance, the TE calculated in USB for water quality in conditional logit model (CL) was 33% whereas in mixed logit model the TE was 23.4% from MSB followed by 53% in CL model and 47.6% in ML model from LSB. The reduced values of TEs in mixed logit model are due to the consideration of spatial preference heterogeneity, which confirms that with the insertion of taste heterogeneity TEs has been reduced. It may be due to the uneven distribution of respondents' preferences and welfare measures across areas, which exhibit significant spatial disparity (Logar and Brouwer, 2018). Moreover, in line with earlier outcomes (Brouwer et al., 2015), the inclusion of preference heterogeneity lesser the TEs, hence supporting the application of those models (mixed logit models/random parameter logit models) that account for preference heterogeneity. Similarly, the estimates of benefits for the combination of WQ + LS (water quality + landscape) in the USB, the TEs estimated through CL model were 45.1% and 20.2% in ML model from LSB. Whereas the TEs estimated for WQ + LS to LSB from USB through CL model were 82.3% in and 25.4% in ML model, which suggests that the TEs calculated through ML model were simultaneously reduced. Current applications of choice experiment in BT have found choice experiment appropriate for BT, precisely when the transfer implicates implicit prices (Glenk et al., 2015) or depending on the policy objectives and the framework (Jiang et al., 2005). Colombo et al. (2007) tested explicitly choice experiment for BT when taste

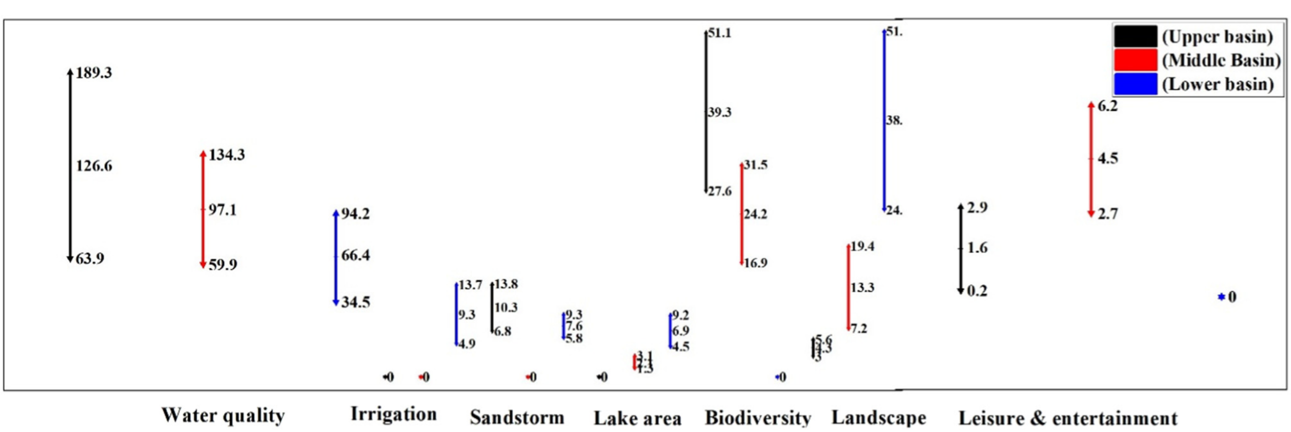

Fig. 4. Mean willingness to pay and upper & lower limit of 95% CI (mixed logit).

Table 4
Transfer error (%) of the willingness to pay for attributes and scenarios and mean transfer error by model.

	To USB				To MSB				To LSB			
	From MSB		From LSB		From USB		from LSB		from USB		from MSB	
	CL	ML	CL	ML	CL	ML	CL	ML	CL	ML	CL	ML
Water quality	33%	23.4%	53.0%	47.6%	34%	30.5%	51.4%	31.6%	112.9%	90.8%	105.9%	46.3%
Farmland irrigation	169.6%	NA	444.1%	NA	62.9%	NA	101%	NA	81.6%	NA	50.5%	NA
Sandstorm	43.0%	NA	24.4%	26.5%	75.5%	NA	32.7%	NA	32.3%	36.1%	24.6%	NA
Lake area	64.6%	NA	21.7%	NA	39.2%	NA	26.0%	215.4%	17.8%	NA	35.2%	68.3%
Biodiversity	NA	38.5%	NA	NA	NA	62.7%	NA	NA	NA	NA	NA	NA
Landscape	254.0%	208.3%	163.0%	782.7%	71.8%	67.6%	25.7%	186.3%	62.0%	88.7%	34.6%	65.1%
Leisure & ent	10.2%	185.6%	358.1%	NA	11.4%	65.0%	410%	NA	78.2%	NA	80.4%	NA
WQ + FLI	0.2%	NA	43.1%	NA	0.2%	NA	43.2%	NA	75.6	NA	76.0%	NA
WQ + SS	6.1%	NA	51.0%	46.0%	6.5%	NA	47.8%	NA	103.9%	85.2%	91.4%	NA
WQ + LA	0.3%	NA	49.7%	NA	0.3%	NA	49.6%	26.2%	98.8%	NA	98.3%	35.6%
WQ + BIO	NA	26.9%	NA	NA	NA	36.9%	NA	NA	NA	NA	NA	NA
WQ + LS	6.1%	15.7%	45.1%	20.2%	5.8%	18.6%	48.3%	5.4%	82.3%	25.4%	93.4%	5.7%
WQ + LE	3.3%	20.8%	49.3%	NA	3.5%	26.3%	47.5%	NA	97.1%	NA	90.5%	NA
FLI + SS	1.3%	NA	73.4%	NA	1.3%	NA	71.1%	NA	42.3%	NA	41.5%	NA
FLI + LA	96.7%	NA	150.9%	NA	49.2%	NA	27.6%	NA	60.1%	NA	21.6%	NA
FLI + BIO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FLI + LS	224.4%	NA	261.6%	NA	69.2%	NA	11.5%	NA	72.3%	NA	10.3%	NA
FLI + LE	113.6%	NA	417.3%	NA	53.2%	NA	142%	NA	80.7%	NA	58.7%	NA
SS + LA	2.7%	NA	7.1%	NA	2.8%	NA	4.5%	NA	7.7%	NA	4.7%	NA
SS + BIO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SS + LS	54.4%	NA	37.1%	NA	35.2%	NA	11.2%	NA	27.1%	68.0%	12.6%	NA
SS + LE	39.5%	NA	16.3%	NA	65.4%	NA	92.4%	NA	14.0%	NA	48.0%	NA
LA + BIO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
LA + LS	149.7%	NA	85.2%	NA	59.9%	NA	25.8%	190.4%	46.0%	NA	34.8%	65.6%
LA + LE	52.1%	NA	77.6%	NA	34.3%	NA	16.7%	NA	43.7%	NA	14.3%	NA
BIO + LS	NA	14.1%	NA	NA	NA	16.5%	NA	NA	NA	NA	NA	NA
BIO + LE	NA	29.9%	NA	NA	NA	42.7%	NA	NA	NA	NA	NA	NA
LS + LE	202.2%	202.3%	201.3%	NA	66.9%	66.9%	0.3%	NA	66.8%	NA	0.3%	NA
Mean	54.5%	27.3%	93.9%	40.6%	25.6%	13.2%	46.0%	23.4%	46.5%	14.1%	36.7%	10.2%

heterogeneity of respondents was considered. They found that model estimates were affected by permitting for preference heterogeneity and, significantly, decreased the TE between the study and policy sites. Heterogeneity of respondents, either by employing heterogeneity approach modelling (i.e., random parameter logit models) or involving the variables related to the social characteristics and attitude of respondents delivers an effective basis for value transfer, since it is an important key to the understanding of people preferences in terms of WTP (Brouwer, 2000).

The TEs acceptable range is described previously in many studies. For instance, the acceptable range of TEs in the study of Blamey et al. (2002) was 4–191%, 25% of TEs were found by Rozan (2004), 66% of TEs were estimated by Hanley (2007), and 15–95% range of TEs were measured by Colombo and Hanley (2008). Brouwer (2009) argued that all the TEs estimated through meta-analyses for wetlands were larger than 40%. Though another study Kristofersson and Navrud (2005) suggested the average TEs range for the valuation of environmental quality are less than 20%. In fact the range of acceptable TEs can vary significantly, from study to study, and from policy to policy. This can be determined by a number of attentions such as the effect of the decision, large versus small costs or benefits, the magnitude of net benefits (errors may requisite more careful attention when the margin of net benefit is small) or the context of decision making for example, more attention may be required when a huge number of people are affected by a public decision (Boyle and Parmeter, 2017). Furthermore, the outcomes of the current study showed that the range of estimated mean transfer errors is 10.2%–93.9%. The results also depicted the lesser TEs in mixed logit as compared to conditional logit model. The reason for these reduced TEs may be the inclusion of preference heterogeneity Colombo et al. (2007) because spatial heterogeneity is a key factor in benefit transfer analysis (Bateman et al., 2011b; Johnston and Duke, 2009; Plummer, 2009). The welfare estimates calculated from mixed logit and conditional logit model are presented in Table 5. As per the supply and consumption of ecosystem services at numerous spatial scales, the valuation of ecosystem services requires a careful assessment which could indicate how individuals are affected by particular flow of services at various geospatial scales (Escobedo et al., 2011; Turner et al., 2000).

4. Concluding remarks

The current study is an effort to estimate the welfare impacts of the degraded HRB and to assess their transferability among the three sub-basins (Upper, middle and lower). The results revealed the significant existence of spatial preference heterogeneity among the population in terms of WTP for the upgradation in the degraded ecological attributes and the projected benefits obtained from the upgradation of ecological attributes. The highest WTP was recorded for improvements in river water quality level in all the sub-basins i.e. RMB 126.6, 97.1 and 66.4 in USB, MSB and LSB respectively followed by improvements in landscape with an annual WTP of RMB 4.3, 13.3 and 38.1 in USB, MSB and LSB respectively, while the lowest willingness to pay i.e. RMB 1.1 in USB, 0.9 in MSB and 4.9 in LSB was recorded for the improvements in the conditions of leisure & entertainment. Based on the spatially explicit choice experiment, TEs were estimated to account for spatial heterogeneity in the valuation of ecological attributes in HRB. The expected benefits obtained from the improvements in the attributes also differed from one basin to other basin. For instance, benefits were larger in LSB than USB and MSB. Similarly, the spatial preference heterogeneity was also found in accordance with the relative importance of the ecological attributes, the inhabitants of USB paid more attention towards the improvements in water quality and biodiversity, whereas the inhabitants of MSB preferred large improvements in regard to decrease in the frequency of sandstorm days, biodiversity and landscape. Likewise the people of LSB valued increase in the guarantee rate of farmland irrigation, decrease sandstorm days and increase in the area of east Juyan lake area. Improvements in the level of river water quality were the highly valued attribute in all the three sub-basins followed by

Table 5
Welfare estimates from CL and ML models.

Attributes	Conditional logit						Mixed logit					
	USB		MSB		LSB		USB		MSB		LSB	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
WQ + FLI	120	47	120	44	68	17	NA	NA	NA	NA	76	23
WQ + SS	127	44	119	44	62	20	137	82	NA	NA	74	24
WQ + LA	123	46	123	43	62	20	NA	NA	99	39	73	24
WQ + BIO	124	45	NA	NA	NA	NA	166	62	121	30	NA	NA
WQ + LS	122	46	130	40	67	18	131	86	110	34	104	12
WQ + LE	119	48	115	46	60	21	128	88	102	38	NA	NA
FLI + SS	12	3	12	1	20	3	NA	NA	NA	NA	17	1
FLI + LA	8	1	15	1	20	3	NA	NA	NA	NA	16	1
FLI + BIO	9	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FLI + LS	7	1	22	4	25	1	NA	NA	NA	NA	47	12
FLI + LE	3	1	7	2	18	3	NA	NA	NA	NA	NA	NA
SS + LA	15	1	14	2	14	0	NA	NA	NA	NA	14	0
SS + BIO	16	1	NA	NA	NA	NA	50	21	NA	NA	NA	NA
SS + LS	14	2	21	4	19	2	15	4	NA	NA	46	12
SS + LE	10	3	6	2	12	1	12	6	NA	NA	NA	NA
LA + BIO	12	1	NA	NA	NA	NA	NA	NA	26	9	NA	NA
LA + LS	10	0	25	3	18	2	NA	NA	15	5	45	13
LA + LE	7	2	10	3	12	1	NA	NA	7	1	NA	NA
BIO + LS	11	1	NA	NA	NA	NA	44	25	38	4	NA	NA
BIO + LE	8	2	NA	NA	NA	NA	41	27	29	8	NA	NA
LS + LE	6	1	17	6	17	3	6	2	18	4	NA	NA

biodiversity and landscape. The comparison of magnitude of mean TEs from single sub-basin to the others revealed that this variation is mainly due to differences in the sites.

Based on current findings, some policy implications are suggested, such as the estimated significant WTP from a high number of the respondents specified that allocating funds for the restoration of river ecosystems is considerable and could help to direct policy professionals in policy-making on expansion and raising public awareness. Particularly, the government of China should take appropriate measures prioritizing the restoration and improvements of river ecosystems. In spite primary data collection is the major choice for evaluation of ecosystem services but due to resources scarcity, time and financial constraints, obtaining it is often limited. Therefore, BT is an alternate method for the valuation of ecosystem services. Nevertheless, before applying BT, the policy professionals and regulators requisite to make trade-off decisions to balance the cost-effectiveness and potential inaccuracy of the transfer results. The key drawback of applying unit value transfer method is that, unit value estimates could quickly become obsolete, therefore, different methods for benefit transfer may be applied in different context. Moreover, to strengthen and extend the range of the current study, additional research work is required in different river basins rather to consider sub-basins of a single river.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2019.05.049.

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