



# Ecological degradation of an inland river basin and an evaluation of the spatial and distance effect on willingness to pay for its improvement

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## Abstract

Improvements in the ecological attributes of inland rivers have been projected to provide considerable non-market benefits, and the monetary valuation of these attributes has steadily increased over the past several decades. The present study addresses the spatial heterogeneity of the public's preference for ecological attributes and the distance-decay effect of willingness to pay (WTP) to improve various attributes of the river basin. The results revealed that spatial heterogeneity exists among the individuals; for example, the respondents of Liangzhou County prefer a large improvement in the natural landscape, forest coverage, and eco-tourism and are willing to pay 491.89, 369.32, and 338.37 yuan per year, respectively, for one unit improvement in these ecological attributes. Similarly, the respondents of Jinchang County value and are willing to pay 447.60, 431.81, and 318.18 yuan for one unit improvement in tourism, forest coverage, and natural landscape, respectively. Furthermore, the results from the random parameter logit model show a significant distance-decay effect of the household WTP for ecological attributes. For example, the respondents living within 5 km of the river are willing to pay more money, that is, 832.61, 365.62, and 353.05 yuan per year for improving the natural landscape, water quantity, and grass cover, respectively. As the distance from the river increases, the corresponding WTP decreases, meaning that the respondents (users) living near the Shiyang River Basin are willing to pay more for ecological attribute improvement than those living far away from the river.

**Keywords** Willingness to pay (WTP) · River ecosystems · Mixed logit model · Distance decay · Spatial heterogeneity

## Introduction

Spatial heterogeneity is a situation generally ascribed to a landscape or a population that refers to the uneven distribution

### Highlights

- The spatial heterogeneity of respondents' preferences and willingness to pay is investigated by using choice experiment method.
- Spatial heterogeneity of preferences exists among respondents living in different localities of the Shiyang River.
- Taste variation, attachment to the site, income, and education level influence the respondent's willingness to pay (WTP) for ecosystem services improvements.
- Significant distance-decay effect of willingness to pay was found in the study area.

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characteristics, events, or relationship across a region (Anselin 2010). Spatial heterogeneity in willingness to pay (WTP) is often modeled as a function of the one-dimensional distance between households and the adjacent point of the affected resources (Johnston et al. 2015; Schaafsma 2015). It is generally thought that WTP diminishes as a continuous function of this distance, leading to traditional distance-decay analysis. For example, for river restoration, a distance decay of WTP may compute the logical relationship between households' willingness to pay for river improvement and their distances from the nearest point of the affected river (Hanley et al. 2003). In different regions of China, the existing natural resources provide various ecosystem services and function depending on the nature of localities. The quality and type of ecosystem services provided to the human wellbeing vary widely across the earth landscape and ultimately influence the public's WTP for improvements in these services (Zhou et al. 2015; Liu and Huang 2017).

The river basin provides a wide range of ecosystem services that are the source of various economic benefits (Groot

et al. 2002; Sarukhan et al. 2005; Rouquette et al. 2011; Knüppe and Knieper 2016). Despite these benefits to society, many rivers have undergone increasing degradation and over-exploitation, which results in reducing their capacity to provide key environmental services. Globally, most of the rivers in the biosphere have been altered or nearly destroyed due to human activities and destruction (Yuan et al. 2005; Khan and Zhao 2018; Mauerhofer et al. 2018), which is now a major issue and has become a focus of attention (Karr 1991; Allan et al. 1997; Hong et al. 2009). If these estuaries are altered or significantly degraded by human activities, many of these ecosystem services and their benefits can be lost (Jadhav et al. 2017). Although certain practices of resource exploitation and pollution may have been for society's best interests, often the resource vanishes due to activities with limited benefits for society, and sometimes this loss entails high costs (Turner 2004).

Aggregating the individual benefits, the choices made by researchers can significantly influence the estimates that are readily available for cost–benefit analysis (Morrison 2000). Aggregating environmental values generally depends on sample mean values of individual benefits. Nonetheless, in relation to impact sites (proximity), individuals' locations may influence valuation, and therefore, it is necessary to first account for spatial heterogeneity in an assessment of aggregate benefits (Bateman et al. 2006). Analysis of how values differ spatially within the population being aggregated can mitigate bias by identifying values conditional on spatially related variables that are hypothesized to influence individual preferences.

Many stated preferences (SP) studies encompass spatial choices among ecological improvements at different localities in a confined geographical area. The characteristics of the spatial context of the ecosystem service undervaluation, notably the location providing the service, the availability of possible substitute sites, and the distance from the services to the population of beneficiaries, are all likely to affect the value attached to the ecosystem service (Schaafsma et al. 2013). Distance and substitutes may considerably influence willingness to pay (WTP), especially for water quality improvements in areas encompassing a large number of water bodies, such as rivers, creeks, or lakes (Johnston et al. 2002). For many environmental goods, the number of available substitutes increases with distance from the site, thereby contributing to distance-decay effects. The distance between the respondents in an SP survey and the locations providing the ecosystem services affects the substitutability of these services. Therefore, distance and substitution effects are interdependent in spatial choice studies.

According to the distance-decay effect, as the distance between the household and the location of the recreational site or non-market good increases, the household's WTP for that site or good tends to decrease. Similarly, the household's WTP for certain sites, goods, or attributes of those goods decreases when the distance between an individual's household and a

water recreational site or other substitute increases (Schaafsma et al. 2013). Approximately 50% of the water users live near the river due to a highly significant distance-decay effect (Bateman et al. 2006).

Thus, based on responses related to current ecological and economic conditions, the present study determines the welfare impacts of improving ecological attributes of an inland river basin, and the corresponding impacts of spatial heterogeneity and distances on household willingness to pay for improvements in river basin ecosystems. Although a watershed provides various benefits and services to society, to narrow our study down to a few ecosystem benefits, we selected the ten most important attributes that were the most likely to affect those living in the Shiyang River Basin and the immediate future of the study area. The aim of this study is to estimate the non-market benefits from restoring an ecologically degraded inland river basin and to forward some policy recommendations based on the findings. The remainder of the paper is organized in the following manner: Second section represents the research methodology and study areas; Third section addresses the results and discussion; Fourth section highlights the concluding remarks and policy recommendations.

## Methodology

### Selection of the study sites

Globally, the demand for scarce water has been intense, and due to the scarcity of water resources, many rivers cannot fulfill all the demands of the public or reach the terminal lakes or seas (Seth 2003; Liu and Xia 2004). Due to its geographical and geomorphological importance, the Shiyang River Basin was selected for the current study (Fig. 1). The Shiyang River has gained public attention due to the increasing stresses being placed on its water resources and the resulting environmental degradation (Ma et al. 2009; Khan et al. 2018). Shiyang is an inland river basin that is located in the northwestern part of China, in Gansu Province; the river originates in the Qilian Mountain and flows approximately 300 km to the northeast with an area of approximately 41,600 km. The Shiyang River Basin is the most developed and populated region, with the highest level of water use in the province and a rural population of 1.34 million and a total population of 2.27 million (Wang et al. 2009). Industrial sewage and upstream household discharges pollute the river (Li et al. 2013) and result in over-exploitation of surface and groundwater. In addition to agricultural practices, the non-point pollution sources include dry deposition, nitrogen dissolved in precipitation, and irrigation return flows (Almasri and Kaluarachchi 2004). Recently, the provincial government and regional water resource bureaus have proposed several IRBMs to address the water crises in

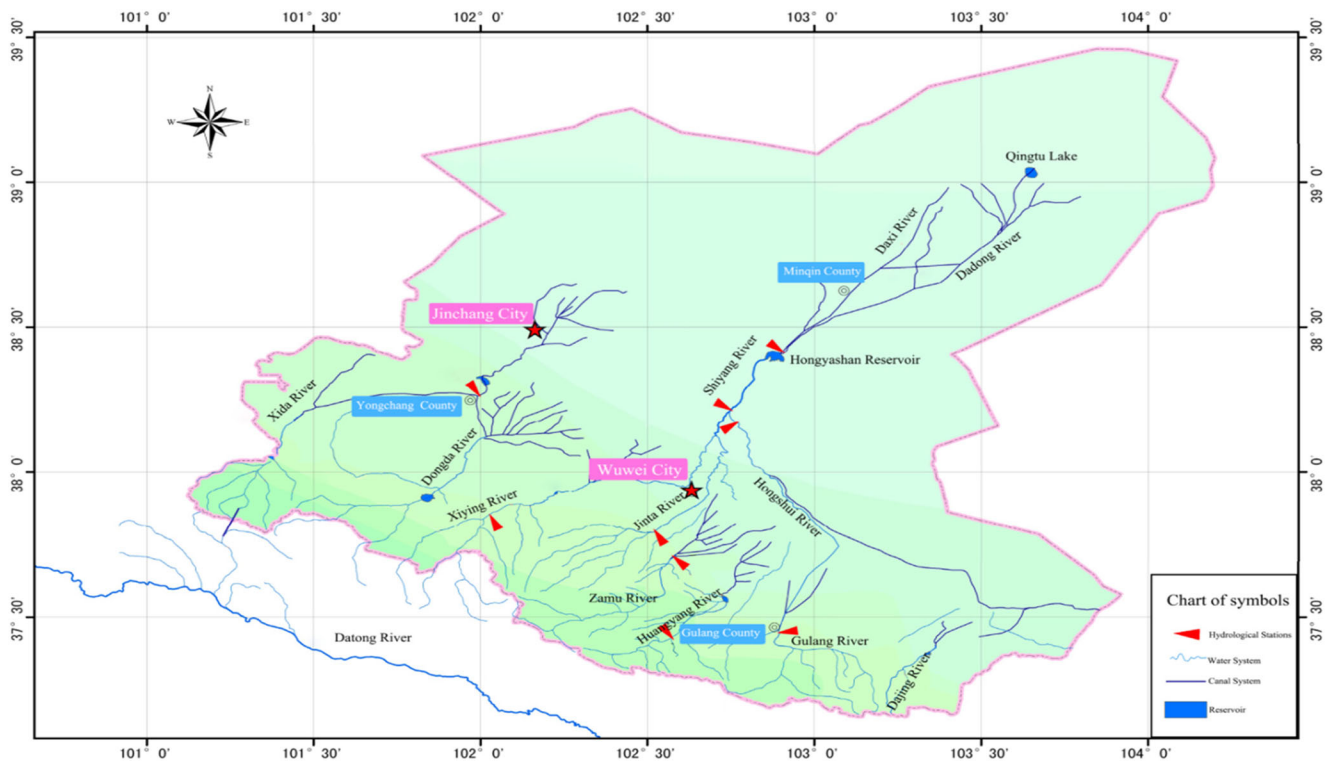


Fig. 1 Shiyang River Basin (ArcGIS 10.3)

the basin and safeguard against ecological deterioration (Wang et al. 2009; Yue et al. 2014).

### Choice experiment

Public preferences for improving ecological services and attaining better ecological conditions by 2020 in the Shiyang River Basin were assessed using the CE method. A stated preferences method, choice experiment (CE), estimated public preferences for non-market goods/services in a hypothetical market to value that good/service. Individuals are asked to select a preferred choice among the given choice set. Based on Lancaster's consumer theory, CE applies the characteristic theory of value, which reveals that the utility is attained from the characteristics of the good consumed rather than the good itself (Lancaster 1966). Generally, in the hypothetical choice tasks of the CE surveys, individuals often compared the associated payments collected from households for the improvement of ecological attributes and the alternative states of the ecological attributes.

The CE used in the assessment of environmental goods is based on an explicit utility theory (Louviere 2001), which is generally based on random utility maximization (RUM). According to RUM, the rational respondent only chose the alternative  $j$  in each task that yielded the maximum utility  $U$ , and the utility ( $U_{ij}$ ) received by individual  $i$  from choosing an alternative  $j$  consists of two components, i.e., the deterministic component is observable, and the stochastic component is

random and unobservable. The utility function can be computed as follows:

$$U_{ij} = V(Z_{ij}, X_i) + \varepsilon_{ij} \quad (1)$$

where  $X_i$  represents socioeconomic characteristics of an individual  $i$ , and  $Z_{ij}$  denotes the attributes of alternative  $j$ . Different individuals may correspond differently to the attributes  $Z_{ij}$  and vary along with alternatives having various attribute levels, whereas for an individual,  $X_i$  remains constant over alternatives. An individual  $i$  prefers and selects an alternative  $j$  over  $k$  if and only if the utility derived from alternative  $j$  is superior to that of alternative  $k$ , i.e.,  $j > U_{ik}$ .

$$\text{Prob}(j/J) = \text{Prob}\{V_{ij+\varepsilon_{ik}} \text{ for all } j \in J\} \quad (2)$$

where  $J$  is a complete set comprising all alternatives in each choice set. To estimate Eq. 2, the distribution of the error term is presumed to be random and normally distributed.

### Random parameter logit (RPL) model

The mixed logit or random parameter logit (RPL) model relaxes the three assumptions of the conditional logit model and assumes that unobserved factors can also influence the utility. The RPL model is more flexible and allows for preference heterogeneity, substitution, and correlation in unobserved factors. In addition to

the random approach, preference heterogeneity can be tested by the interaction of a respondent’s specific characteristics  $C_n$  with attributes  $x_{nj_k}$  or alternative specific constant  $ASC_j$ , with  $\gamma_{nk}$  and  $\varepsilon_{nj}$  as the associated constants (Bennett et al. 2001; Train 2009). An additional stochastic element,  $\eta_{ij}$ , in the RPL model will take into account autocorrelation and heterogeneity across alternatives, where  $\varepsilon_{ij}$  is independently and identically distributed with a type 1 extreme value. In the case of the RPL model, the utility function can be computed as follows:

$$U_{ij} = V(Z_{ij}, X_i; \beta_i) + \eta_{ij} + \varepsilon_{ij} \tag{3}$$

**Welfare measures**

The estimated coefficients ( $\beta$ ) are used to assess the marginal willingness to pay (MWTP) estimates of the attributes. For an increase in the quality of an attribute  $Z_k$ , the marginal willingness to pay (MWTP) can be determined as follows:

$$\partial P / \partial Z_k = MWTP_k = -B_k / \beta_p \tag{4}$$

To estimate the confidence interval of the MWTP, the identification of the WTP distribution is preliminary. Two methods, the delta method and the Krinsky–Robb method, can be used to estimate the confidence interval of the MWTP. In the case of the delta method, the WTP values are normally distributed, and by taking first-order Taylor expansion around the average values of the variables, the variance can be computed. The confidence interval (CI) can be computed as follows:

$$W\hat{T}P_k \pm z_{\alpha/2} \sqrt{\text{var}(W\hat{T}P_k)} \tag{5}$$

where  $Z/2$  is the inverse of the cumulative normal distribution and the confidence level is  $100(1 - )\%$ . If the WTP distribution is not normal, the delta method may be inappropriate because it will not divulge the skewness of the WTP distribution. In such circumstances, the non-parametric Krinsky–Robb method can be used, which does not presume any distribution regarding the confidence interval of the WTP.

**Coefficient distribution**

A random normal distribution was assigned to all the ecological attributes, while the price attribute was assigned non-random distributions. To minimize the instability of the random parameter logit model, the price coefficient was kept fixed. When distributions of all coefficients are allowed to vary, the RPL model will experience instability (Ruud 1996). The WTP is hard to evaluate if the distribution of price is allowed to vary, and the choices regarding the distribution of the price coefficient are problematic. The identification is empirically difficult when all attributes are allowed to vary in

a random parameter logit model (Ruud 1996). By letting non-price coefficients be independently normally distributed and keeping the price coefficient fixed, Revelt and Train (1998) assessed the public preferences for appliance efficiency levels. Revelt and Train (2000) assumed price coefficients to be fixed and applied normal and log-normal distribution to the non-price attribute in different models interchangeably.

**Data collection and survey**

To collect the data for the current study, a survey was conducted, and a well-designed and pretested questionnaire was administered to a sample taken from the population of the major cities and counties within the whole Shiyang River Basin. The four main counties, Gulang, Liangzhou, Jinchang, and Minqin, along with their major cities, were selected for the current study. To consider the typical ecological and economic characteristics of the reference cities, rural surroundings were selected. Furthermore, following the equidistance principle from the pre-selected urban center, a stratified random sampling procedure was applied to select the townships and villages. Three to seven townships were randomly selected from each county, one to seven villages were selected from each township, and finally, using the proportional allocation technique, 9–29 households were selected from each village.

The preliminary interviews with both environmental authorities and respondents were aimed at attaining an appropriate and reasonable description of the undervaluation issues.

**Table 1** Attributes and levels in the choice tasks

Attributes	Levels
Natural landscape (%)	No change, increased by 5, 10, and 20
Tourist amenity (%)	No change, increased by 5, 10, 15, and 20
Sandstorm frequency (number of days per year)	139, 55, 40, 35, 20
Forest coverage area (%)	No change, increased by 3.7, 16.7, and 20.7
Grass coverage area (%)	No change, increased by 5
Xerophytes (10,000 mu)	No change, increased by 5.25 (10 <sup>4</sup> mu), 9.3 (10 <sup>4</sup> mu)
Average water quantity (100 million m <sup>3</sup> )	No change, increased by 10 mm <sup>3</sup> , 40 mm <sup>3</sup>
Water quality (category)	V, IV, II
Ecological security (level)	3.5, 3, 2.5, 2
Voluntary payment (yuan per year)	0, 50, 100, 150, 200, 250, 300, 350, 400, 450, 500

Water quality levels: II—clean and with conventional purification can be used for drinking; III—not suitable for drinking without advanced purification but appropriate for fishing and swimming; IV—only suitable for industrial and agricultural uses; V—is not suitable for any use without purification. 15 mu = 1 ha

The attributes and their levels employed in our choice experiment are selected on the basis of previous literature and through scientists' discussions with local residents. Table 1 presents a payment attribute and nine river ecological attributes that reflect these undervaluation issues: the natural landscape of the entire river basin, the wetland and forest park tourism conditions in the basin, the reduction in dust and sandstorm days per year, forest coverage in the upper basin, grass coverage in the middle basin, the presence of suitable areas for xerophytes in the lower basin, the water quantity (annual inflow into the lower basin reservoir), the quality of the underground water and reservoir water in the lower basin, and the ecological security of the basins.

As ecosystem goods and services are naturally interconnected, it is difficult to find a set of attributes that are not causally related to each other. The causal relationship may influence a respondent's WTP estimates by altering the weights of the attributes, but the inclusion of causal prior attributes reallocates the values between the attributes rather than the biases of the estimates (Blamey et al. 2002; Hanley 2010; Yu et al. 2014). In our study, causality denotes the effect of water quality improvement and the protection of the natural landscape on other ecological attributes. A voluntary amount of payment is specified by the respondents for the restoration policy, and this attribute facilitates the estimation of a monetary valuation for ecological attributes.

Table 2 illustrates the attributes and their levels, where the alternatives are presented side by side. Our choice experiment comprises a household payment and nine ecological attributes of various levels. Each choice set has three alternatives, one status quo and two policy alternatives. Considering the status-quo alternative in the choice set improves the effectiveness of the experimental choice set design (Louviere et al. 2000). The alternatives were equivalent, while the attributes were systematically varied across the alternatives such that information related to the preference parameters of an indirect utility function

could be inferred (Carson et al. 2010). A consumer's welfare estimation would be misleading and inconsistent with the economic theory if only the policy options (without a status quo option) were introduced in the choice tasks (Hanley et al. 2001). This illustration of choice format with the inclusion of a status quo option allows the appropriate welfare estimation; however, if the status quo option were chosen frequently, then the format still would allow for the relative attractiveness of the ecological attributes. The format encourages the respondents to pay more consideration to the policy scenarios than to the current state of attribute levels by motivating the respondents to make trade-offs and not just make an easy decision (Brazell et al. 2006). The parameter estimates with the given information were used in a Bayesian D-efficient design to create the experimental design. The attribute orders and levels were changed among the questionnaire versions.

## Results and discussion

### Sample characteristics

The data were screened before estimating the model, and the protest responses, choice task simplifications, and analysis non-attendance (ANA) were removed from the data. After data cleaning, the analysis was based on a total of 900 completed questionnaires. Compared to the sample size, the choice experiment structure gives a higher number of observations. For example, there are three choice sets in one questionnaire, and each choice set further has three alternatives (one status quo and two policy alternatives). Consequently, each individual respondent has 9 observations (3 choice sets  $\times$  3 alternatives); therefore, the total sample size is multiplied by 9. After screening and dropping the incomplete questionnaires and missing variables, we have a total of 8100 observations for estimating the basic models. We obtained 1575, 2466, 1674, and 2385

**Table 2** Examples of the choice tasks

Attributes	Status quo	Alternative 1	Alternative 2
Natural landscape (%)	10	10	30
Eco-tourism and forest parks (%)	30	45	40
Sandstorms frequency (number of days per year)	139	40	55
Forest coverage area in upper basin (%)	46.3	50	63
Grass coverage area in middle basin (%)	55	60	55
Xerophytes in lower basin (10,000 mu)	0	0	9.3
Average annual water inflow into the reservoir (100 million m <sup>3</sup> )	250 (10 <sup>6</sup> m <sup>3</sup> )	260 (10 <sup>6</sup> m <sup>3</sup> )	250 (10 <sup>6</sup> m <sup>3</sup> )
Water quality (lower basin reservoir and underground water)	Category V	Category IV	Category II
Ecological security (level)	Level 3.5	Level 3	Level 2
Household payment (yuan/year)	0	100	350

15 mu = 1 ha

observations from Gulang, Liangzhou, Jinchang, and Minqin Counties, respectively, of the Shiyang River Basin.

Figure 2 shows the various socioeconomic characteristics of the respondents for the four major counties of the Shiyang River. The age group shows that the majority of the respondents, i.e., 30.3% in Gulang County, belong to the age group of 40–50 years. In Liangzhou County, 30.3% of respondents were in the age group of 30–40 years, 34.9% of the respondents in Jinchang County are in the age group of 40–50 years, and 47.9% of the respondents in Minqin County belong to the age group of 40–50 years. The education group shows that most of the interviewed respondents, i.e., 29.1, 28.1, 36.0, and 30.9%, belong to the low education group (5–8 years of education) in Gulang, Liangzhou, Jinchang, and Minqin Counties, respectively. The respondents with more than 16 years of education accounted for 17.7, 20.1, 22.0, and 17.7% of all the interviewed respondents in Gulang, Liangzhou, Jinchang, and Minqin Counties, respectively. The sex group of the interviewed respondents revealed that majority of the respondents in all four counties of the Shiyang River were male who were willing to pay for improvements in river ecosystem services. The finding demonstrates that the male respondents in Minqin, Jinchang, Liangzhou, and

Gulang Counties accounted for 69.4, 65.1, 61.3, and 60%, respectively (Fig. 2). This demonstrates that in our study area, males were more concerned and cared more about ecosystem services than females. Similarly, in terms of the income levels of the interviewed respondents in Gulang, Liangzhou, Jinchang, and Minqin Counties, the respondents were distributed into 12 groups based on their income levels. Figure 2 shows that 17.8% of the respondents in Gulang County belonged to the income level between 20,000 and 30,000 yuan per year; in Liangzhou County, 18.6% had incomes between 40,000 and 50,000 yuan per year; in Jinchang County, 18.8% had incomes less than 10,000 yuan per year; and in Minqin County, 23.0% had incomes less than 10,000 yuan per year.

Table 2 presents the levels of the ecological attributes under the status quo option, i.e., at the reference level with no change. Compared to the current or status quo situation, columns II and III (alternative 1 and 2) show the slight and substantial changes in the ecological attributes of the basin. Table 3 shows that the coefficients of the monetary and ecological attributes, except for eco-tourism and ecological safety in Gulang and Minqin Counties, were statistically significant at the 1 and 5% levels of significance and had the expected signs. Similarly, in the case of Liangzhou County, the monetary and ecological attributes

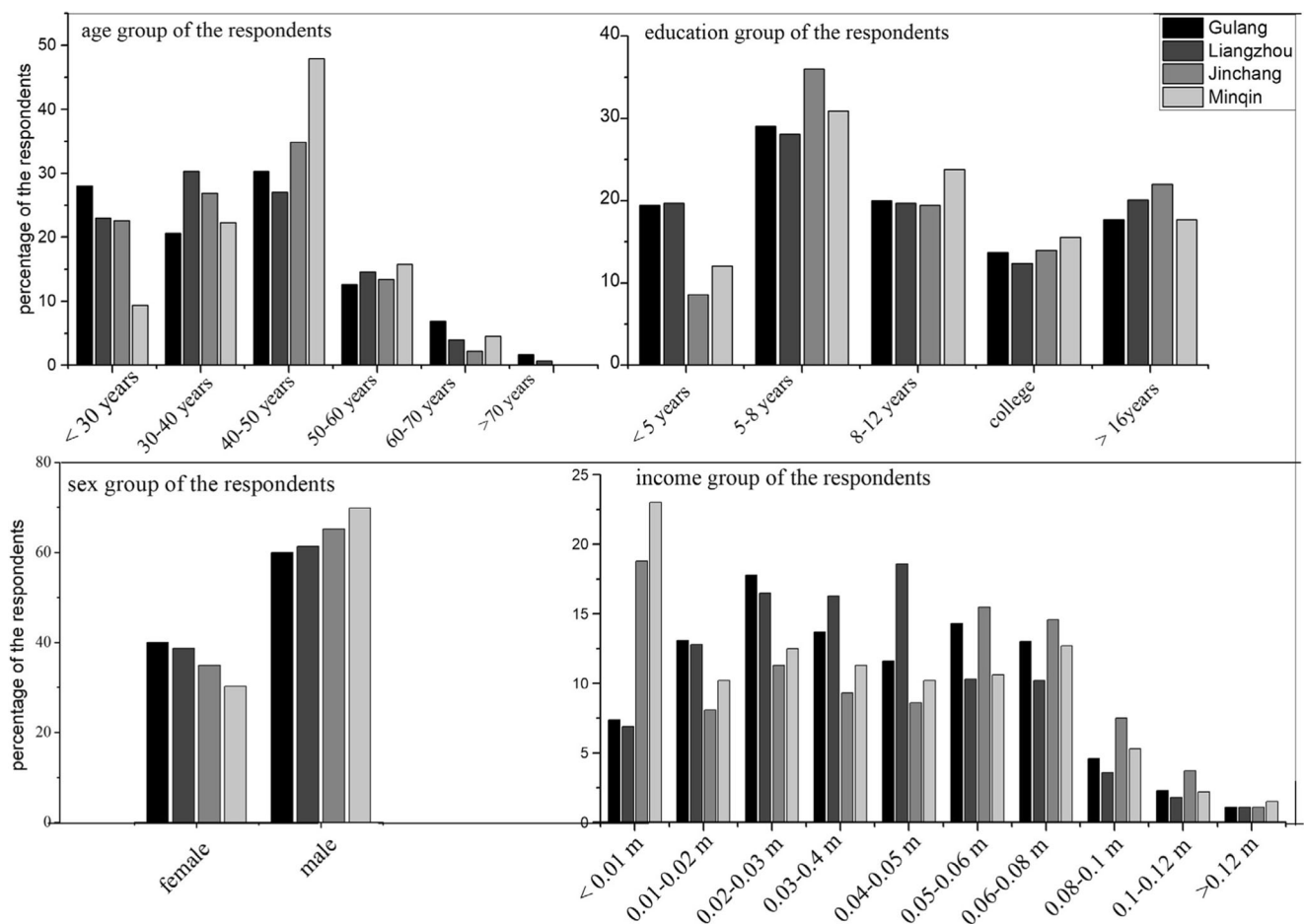


Fig. 2 Socioeconomic characteristic of the respondents in four different counties (spatial effect)

**Table 3** Random parameter logit model estimates (spatial heterogeneity)

Variables	Gulang		Liangzhou		Jinchang		Minqin	
	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
<b>Means</b>								
Payment	−0.02***	0.01	−0.02***	0.01	−0.02***	0.00	−0.02***	0.00
Landscape	7.40**	3.03	10.33***	3.21	7.45***	2.21	7.74***	1.72
Tourism	2.88	2.83	7.11***	2.68	9.06***	2.83	0.42	1.68
Sandstorm	−0.02***	0.01	−0.02***	0.01	−0.02***	0.00	−0.02***	0.00
Forest	7.25**	3.07	7.76***	2.75	8.74***	2.38	5.49***	1.45
Grass	5.53**	2.82	5.19***	2.27	6.36***	1.98	4.32***	1.48
Xerophytes	0.17***	0.06	0.22***	0.08	0.13***	0.04	0.16***	0.03
Quantity	4.60***	1.64	5.90***	2.17	3.66***	1.00	4.60***	0.97
Quality	0.73***	0.23	0.86***	0.28	1.27***	0.24	0.71***	0.13
Safety	1.33	1.27	3.50***	1.32	0.90	0.93	0.70	0.73
<b>Standard deviation of means</b>								
Landscape	−11.30**	5.47	14.12***	7.12	8.46***	2.80	5.63	3.88
Tourism	2.22	4.26	9.15*	5.55	19.34***	4.52	6.67***	3.04
Sandstorm	−0.03***	0.01	−0.04***	0.01	0.01***	0.00	−0.03***	0.01
Forest	−11.25**	4.56	−19.94***	6.21	−6.51	6.11	−5.55	3.79
Grass	−17.66***	5.60	13.37***	4.00	−2.57	5.48	−4.20*	2.36
Xerophytes	0.26***	0.08	0.31***	0.13	−0.07	0.06	0.17***	0.04
Quantity	−6.20**	2.50	−4.49***	1.90	−1.93	3.50	3.32*	1.85
Quality	0.82***	0.31	0.81***	0.25	1.07***	0.29	0.60***	0.19
Safety	5.47***	1.28	6.45***	2.08	−2.46***	0.56	3.68***	0.65
Number of observations		1575		2466		1674		2385
Log-likelihood		455.30		705.88		430.52		677.29
LR $\chi^2$ (9)		174.75		307.61		123.06		207.23
Probability		0.000		0.000		0.000		0.000

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

were of the expected signs and statistically significant. Moreover, Table 3 also reveals that all the monetary attributes and all the ecological attributes except for ecological safety were statistically significant in Jinchang County.

The random parameters with highly significant standard deviations of the means ensure the presence of the heterogeneity of preferences for all the ecological attributes except for tourism in Gulang and Liangzhou Counties; for the protection of the natural landscape, eco-tourism, reduction in sandstorm days per year, water quality and safety in Jinchang County; and for eco-tourism, reduction in sandstorm days per year, xerophytes, water quality, and safety in Minqin County (Table 3).

The willingness-to-pay estimates for all attribute levels, calculated with the Krinsky–Robb procedure (Krinsky and Robb 1990) with 1000 draws, are presented in Table 4. The results show that the 95% confidence intervals overlap among all the ecological attributes except for sandstorm frequency in all major counties of the Shiyang River basin, suggesting that WTP estimates are non-equal in the basins (Kosenius and Markku 2015). Based on the relative importance of the ecological attributes, the counties somewhat differ from each

other, and thus, the WTP differs among the counties (Khan and Zhao 2018; Khan et al. 2018). A respondent's attitude toward the specific amenities and his/her willingness to pay for improving the ecological attributes play an important role in the explanation of the differences in stated WTP amounts (Brouwer and Spaninks 1999). In addition to the

**Table 4** Marginal willingness-to-pay (WTP) estimates for four major counties

Variables	Gulang	Liangzhou	Jinchang	Minqin	Pooled data
Landscape	390.26	491.89	368.18	487.57	360.24
Tourism	151.63	338.37	447.60	26.58	282.64
Sandstorm	−1.10	−0.82	−1.04	−1.46	−1.01
Forest	382.39	369.32	431.81	345.51	371.42
Grass	291.67	247.15	314.36	272.19	308.46
Xerophytes	8.86	10.57	6.46	10.16	8.09
Quantity	242.71	280.73	180.88	289.94	186.28
Quality	38.51	41.03	62.70	44.88	43.50
Safety	70.06	166.55	44.65	43.83	25.73

socioeconomic characteristics of individuals and their attitudes toward the environmental quality of goods/services, the type of population (rural/urban) and the location play vital roles in the assessment of WTP for environmental quality. The individuals living in different locations and communities value environmental amenities differently (Rolfe et al. 2000). The individuals in all four counties have the highest WTP for landscape, forest cover, and grass cover, representing the relative importance of these attributes, while all the counties also share a low WTP for sandstorm frequency reduction. Ecological management and restoration of the degraded ecosystem not only lead to the economic development and survival of the valley but also an improvement to the ecological environment of northwestern China. Therefore, understanding the existing ecosystem issues, restoration of the degraded ecosystem, and social and ecological environments of the river basin is of great importance (Li et al. 2013).

Table 5 shows the estimates of the random parameter logit model and the impact of distances on the public WTP for ecological attribute improvement. The results obtained from the interaction of distances with the ecological attributes are statistically significant at both the 5 and 1% levels of significance and of the expected signs, meaning that the distances have a significant impact on these attributes and thus influence the public willingness to pay for improving these attributes. Moreover, all the ecological attributes except ecological safety are of the expected signs and are highly significant. The highly statistically significant standard deviation parameter for all attributes suggests that substantial taste heterogeneity exists for these attributes.

One of the ultimate objectives of any valuation technique is to estimate the societal welfare change associated with a change in the environmental attributes. Accordingly, Table 6 presents the marginal willingness to pay or implicit price for one unit change in the attributes. By applying the delta method, the implicit price for an attribute can be computed as the ratio of its mean coefficient to the coefficient of the cost attribute (Hanemann 1984). Since the mixed logit model fits the data more than the multi-multinomial logit model, the analysis of WTP is performed based on the mixed logit model results given in Table 5. The MWTP or implicit price is per percentile increment for the given ecological attributes. It is the maximum amount of money an average respondent is willing to pay for an additional one unit/% improvement in these attributes at ceteris paribus. For instance, according to the estimation result in Table 6, an average respondent is willing to pay approximately 380.39, 339.62, and 326.15 yuan for a 1% improvement in forest cover, landscape scenery, and grass cover, respectively.

On the basis of spatial characteristics such as distance and location, spatial heterogeneity analyzed the public’s preferences for non-market goods and services. These analyses are most common in the valuation of non-market goods and services such as rivers and water recreational sites. To measure the spatial heterogeneity of people’s preferences, the distance-decay effect is executed in the present study. Accordingly, as the distance between the household and the location of the recreational site or non-market good increases, the corresponding WTP for that site, good, or attribute of that good decreases (Bhattarai 2015).

**Table 5** Interaction of distances with the attributes (pooled data)

Variables	Coefficient	SE	Probability	LL	UL
<b>Means</b>					
Distance × payment	−0.002	0.000	0.000	−0.002	−0.001
Distance × landscape	0.510	0.079	0.000	0.356	0.664
Distance × tourism	0.330	0.073	0.000	0.187	0.473
Distance × sandstorm	−0.002	0.000	0.000	−0.002	−0.001
Distance × forest	0.571	0.069	0.000	0.436	0.707
Distance × grass	0.490	0.069	0.000	0.354	0.625
Distance × xerophytes	0.012	0.001	0.000	0.009	0.015
Distance × quantity	0.287	0.037	0.000	0.214	0.360
Distance × quality	0.063	0.006	0.000	0.052	0.074
Distance × safety	0.046	0.030	0.128	−0.013	0.106
<b>Standard deviation of means</b>					
Distance × landscape	0.683	0.099	0.000	0.489	0.878
Distance × tourism	0.612	0.081	0.000	0.454	0.770
Distance × sandstorm	0.002	0.000	0.000	0.002	0.003
Distance × forest	0.924	0.110	0.000	0.708	1.140
Distance × grass	−0.822	0.095	0.000	−1.009	−0.635
Distance × xerophytes	−0.008	0.001	0.000	−0.011	−0.005
Distance × quantity	0.364	0.041	0.000	0.283	0.444
Distance × quality	0.059	0.006	0.000	0.046	0.071
Distance × safety	0.410	0.036	0.000	0.340	0.481
Number of observations		8100			
Log-likelihood		2462.49			
LR $\chi^2$ (9)		670.82			
Probability		0.000			



**Table 6** Marginal willingness-to-pay (MWTP) estimates for ecological attributes (pooled data)

Variables	MWTP	Lower bound 95% CI	Upper bound 95% CI
Distance × landscape	339.62	198.35	548.78
Distance × tourism	220.01	104.57	390.94
Distance × sandstorm	-1.06	-1.06	-1.07
Distance × forest	380.39	242.98	583.83
Distance × grass	326.15	197.67	516.37
Distance × xerophytes	8.11	5.26	12.34
Distance × quantity	191.20	119.42	297.46
Distance × quality	42.00	29.01	61.23
Distance × safety	30.81	0.26	-1.43

In the available literature, the use of calculated areas within distances is common in several forms of welfare analysis, including the analysis of hedonic pricing that enumerates the impacts of surrounding attributes on housing prices (Johnston et al. 2001; Bateman et al. 2002; Paterson and Boyle 2002).

However, in the case of stated preference WTP to confirm spatial heterogeneity, such approaches have rarely been used and, even then, only using pre-selected, ad hoc distance bands. For instance, Yao et al. (2014) calculated the quantity of woodland within ad hoc distance bands of 10, 10–50, and 50–100 km from each respondent's household. These ad hoc band areas are used as independent variables to explain the heterogeneity in WTP for forest improvements. Using this approach of ad hoc distance bands, the surveyed respondents were redistributed into five distance band groups, i.e., ≤ 5 km, ≤ 10 km, ≤ 20 km, ≤ 30 km, and > 30 km. Table 7 demonstrates the results of the random parameter logit model for the given ad hoc base sample respondents. The estimated results show that all the ecological attributes are of the expected signs, consistent with economic theory and highly statistically significant.

To illustrate the distance-decay effect, Table 8, based on the random parameter logit model, demonstrates the marginal willingness to pay for ecological attributes in different ad hoc distance bands. As expected, all the estimated results are consistent with economic theory and statistically significant.

**Table 7** Random parameter logit (RPL) model for ad hoc distance bands (distance decay effect)

Variables	≤ 5 km		≤ 10 km		≤ 20 km		≤ 30 km		> 30 km	
	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
<b>Means</b>										
Payment	-0.02***	0.01	-0.02***	0.00	-0.02***	0.00	-0.02***	0.00	-0.02***	0.00
Landscape	16.19***	4.48	8.16***	2.03	8.34***	1.51	11.10***	2.19	6.27***	1.56
Tourism	4.42	3.06	3.18*	1.87	2.67**	1.36	2.60	1.48	4.71***	1.56
Sandstorm	-0.03***	0.01	-0.01***	0.00	-0.02***	0.00	-0.02***	0.00	-0.02***	0.00
Forest	5.29**	2.74	8.26***	1.91	6.85***	1.22	6.72	1.46	7.20***	1.62
Grass	6.86***	2.82	4.84***	1.68	5.00***	1.26	5.77	1.47	5.22***	1.44
Xerophytes	0.13***	0.05	0.18***	0.04	0.15***	0.03	0.18***	0.03	0.14***	0.03
Quantity	7.11***	1.89	3.25***	0.89	3.68***	0.70	4.70***	0.86	4.37***	0.84
Quality	1.14***	0.30	0.66***	0.14	0.78***	0.11	0.87	0.14	0.93***	0.13
Safety	2.28*	1.27	2.07**	0.87	1.54***	0.62	1.66	0.63	0.84***	0.68
<b>Standard deviation of means</b>										
Landscape	2.16	4.15	8.34*	4.82	-9.72***	3.89	-13.70***	3.35	5.72*	3.42
Tourism	17.64***	5.36	3.33	3.44	-8.41***	2.51	-13.27***	2.98	-8.19***	2.77
Sandstorm	0.06***	0.01	-0.03***	0.01	0.03***	0.00	-0.04***	0.01	0.02***	0.00
Forest	16.54***	5.64	-1.93	4.12	0.55	3.09	11.99***	2.66	10.81***	2.55
Grass	5.18	3.39	-9.28***	3.51	-8.52***	2.35	-12.26***	2.60	8.41***	2.55
Xerophytes	-0.29***	0.08	0.21*	0.06	0.21***	0.04	0.22***	0.04	-0.12**	0.05
Quantity	5.07**	2.65	-1.89	2.10	-4.11***	1.30	1.32	1.35	2.18*	1.30
Quality	0.76***	0.31	0.96***	0.18	0.58***	0.15	0.64***	0.24	0.92***	0.20
Safety	7.45***	1.91	3.33***	0.74	4.44***	0.57	-4.72***	0.66	4.00***	0.56
Number of observations	1764		2286		4617		4995		3105	
Log-likelihood	-490.28		-666.28		-1347.38		-1460.81		-871.498	
LR $\chi^2$ (9)	224.81		224.95		494.53		521.88		269.68	
Probability	0.000		0.000		0.000		0.000		0.000	

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

**Table 8** MWTP estimates for ecological attributes (ad hoc distance bands)

Variables	≤ 5 km	≤ 10 km	≤ 20 km	≤ 30 km	> 30 km
Landscape	832.61	620.49	500.47	486.68	348.7205
Tourism	227.10	203.47	160.48	139.18	261.9203
Sandstorm	-1.64	-1.25	-1.12	-1.07	-1.10396
Forest	272.00	383.50	411.49	359.67	400.667
Grass	353.05	295.91	300.34	308.83	290.2992
Xerophytes	6.78	10.39	9.12	9.63	7.953576
Quantity	365.62	300.71	221.18	251.14	242.9169
Quality	58.41	54.41	46.98	46.30	51.99784
Safety	117.22	135.25	92.42	89.00	46.51773

According to the results presented in Table 8, the people living near the river are willing to pay more for improvements in ecological attributes than those who are living far away from the river (Schaafsma et al. 2013), which ensures the distance-decay effect of their respective WTP for ecological attribute improvement. For example, the individuals living within 5 km of the Shiyang River are willing to pay 832.61, 365.62, and 353.05 yuan per year for one unit improvement in natural landscape, water quantity, and grass cover, respectively, which is higher than the amounts for those who are living within 10, 20, or 30 km from the given river. WTP often declines as the distance increases between a respondent's place of residence and the site providing ecosystem services (Schaafsma et al. 2013). According to Beckmann (1999), as the distance from a specific site increases, public awareness and knowledge regarding that site decreases, which in turn influences the public's preferences and WTP for those attributes or sites. Similarly, the average value should decrease with an increase in the distance, as the number of users of the site declines with distance (Bateman et al. 2006). Generally, it is presumed that WTP for goods or services declines with distance (Hanley et al. 2003). However, in several situations, the people living near the environmental amenity, such as a national park, may value the good less than those who live further away (Imber et al. 1991; Espey and Owusu-Edusei 2001); this might be the only reason that in the case of forest cover, the marginal willingness to pay increases along with distance. In some cases, the WTP may be the same across different distances from the river if the goods or services are scarce in nature (Clawson and Knetsch 1966).

To better understand the implications of adopting alternative investment strategies, the given information permits the decision-makers to favor either ecological or recreational improvements or a mix of benefits.

## Conclusions

In the present study, an attempt was made to investigate public WTP for different restoration attributes of the Shiyang River

Basin and to determine the prevailing spatial heterogeneity and distance effect of WTP for ecosystem services and for significantly improving degraded river stretches. To determine the spatial heterogeneity, a choice experiment method was used to collect the data from four main counties along with their major cities and adjacent villages. The result shows that the public on average receives high utility from undergoing restorations. Furthermore, the results revealed that respondents living in different locations of the Shiyang River Basin value the ecological attributes differently. For example, the people living in Liangzhou County prefer a large improvement in the natural landscape, forest coverage, and tourism and are willing to pay 491.89, 369.32, and 338.37 yuan per year, respectively, for one unit improvement in these ecological attributes. Similarly, the respondents in Jinchang County value and are willing to pay 447.60, 431.81, and 318.18 yuan for one unit improvement in tourism, forest coverage, and natural landscape, respectively. To determine the distance-decay effect of WTP, the data set was redistributed into five main groups on the basis of ad hoc distance bands. The results from the random parameter logit model show a significant distance-decay effect of the household WTP for ecological attributes. The estimated results demonstrate that the respondents (users) living near the Shiyang River Basin are willing to pay more for ecological attribute improvement than those living far away from the river.

Based on the findings, some key policy implications emerged. Specifically, the government of China should make improvements in river ecosystems on priority basis and implement policies to improve these attributes. The findings provided guidance, policy recommendations, and a reference for researchers to improve and enhance current river water services in the future. Moreover, to investigate and expand the scope of the current study, further studies are required to consider the beneficiaries of a specific area in comparison to the spatial heterogeneity and distance-decay effect between, rather than within, river basins. We recommend that future valuation studies of spatially defined environmental goods test for and, where necessary, take this spatial variation into account in the specification of distance-decay functions to produce more reliable WTP results and market delineation procedures.

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