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Research Article

Residents' perceptions of ecosystem services in an urbanizing basin: A case study in the Guanting Reservoir basin, China

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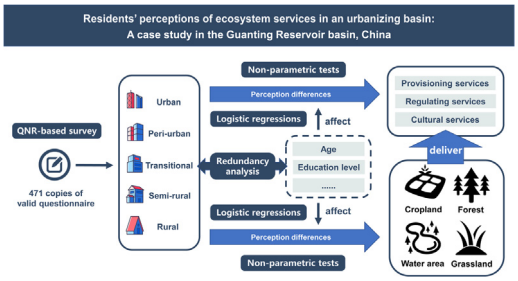
HIGHLIGHTS

- Differences in perceptions of ES along the urban-rural gradient were investigated.
- Local residents' socio-economic characteristics were used to delineate the gradient.
- Residents in urban-rural transitional areas showed unique perceptions.
- Variation in residents' perceptions of ES delivered by grassland was the greatest.
- Age and occupation were major factors affecting residents' perceptions.

GRAPHICAL ABSTRACT



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ABSTRACT

Understanding stakeholders' differences in perceptions of ecosystem services (ES) is crucial for guiding ecological conservation and planning. However, the variations of ES perception amongst different types of residents in urbanizing areas along an urban-rural gradient are still poorly understood. Combining a questionnaire-based survey, redundancy analysis, and statistical tests, we delineated the urban-rural gradient according to local residents' socio-economic characteristics, and investigated the differences in local residents' perceptions of ES and potential factors affecting them in the Guanting Reservoir basin, a rapidly urbanizing basin in China. The results showed that residents living in urban-rural transitional areas attached great importance to provisioning services of providing food and domestic water, regulating services of carbon sequestration and air purification, and cultural services of providing education and training, which were 0.7%–13.1%, 0.7%–9.1% and 2.5%–21.2% higher than that of residents in other areas, respectively. Age and occupation were major factors affecting residents' perceptions. In terms of land-use types that deliver ES, the difference in perceptions of ES delivered by grassland was the greatest amongst residents. Our results support recommendations for policymakers to take into account the stakeholders' diverse perceptions, thus promoting residents' sense of gain on ES.

1. Introduction

Ecosystem services (ES) underpin human well-being and are a cornerstone for socio-economic and eco-environmental policymaking (Costanza et al., 2017). Only on the premise of ecosystems being comprehensively and effectively conserved, could public policy better promote the well-being of residents and sustainable development paths (Pan et al., 2016; Riecheres et al., 2018; Shi et al., 2016; Y.C. Zhou et al., 2024). To achieve this objective, and to bridge the existing gap in the application of scientific knowledge into policy mak-

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ing practice, the implementation of advocacy planning and collaborative governance has been promoted at the global, continental, national and urban scales (IPBES, 2019; European Commission, 2021; Pahl-Wostl et al., 2023; Zheng et al., 2023). When promoting public participation in decision-making, understanding the multi-dimensional perceptions amongst stakeholders is fundamental. Stakeholders here include residents, tourists, governmental and non-governmental organizations. For perceptions, choice preferences, knowledge identification, valuation frameworks and socio-economic characteristics should be considered (Chan et al., 2012; Hansen et al., 2018; Resque et al., 2021; de Oliveira Rolo et al., 2022; He et al., 2019).

In an urbanizing world, it is crucially important to understand residents' perceptions of ES with different socio-economic backgrounds in rapidly urbanizing areas. Urbanization generates environmental gradients resulting from complex spatiotemporal changes which can greatly vary over relatively short distances (Lemoine-Rodríguez et al., 2020). The "gradient paradigm" not only lays a solid foundation for understanding the spatio-temporal pattern of ES, but provides a platform to deepen our comprehension of the interactive relationship between human society and natural processes (McDonnell and Pickett, 1990). As urban residents' perceptions of ES have an increasing impact on ecosystems (Seto et al., 2012), evaluating the differences between urban and rural residents' perceptions of ES will assist us to act proactively in designing new policies and adjusting existing ones.

Some studies have evaluated the differences in urban and rural residents' perceptions of ES (e.g., Riecheres et al., 2018; Aguado et al., 2018; Murali et al., 2019; Quevedo et al., 2021). However, previous studies mainly focused on the differences based upon a binary division, i.e., urban and rural places, while the understanding on an urban-rural gradient is largely lacking. In addition, previous research mostly used the administrative divisions to distinguish urban and rural areas. Such administrative-based division was largely determined on population density and the construction of public infrastructures (National Bureau of Statistics of China, 2008; European Commission et al., 2021; Uhl et al., 2023). While the process of urbanization not only implies an increase in population density and the improvement in infrastructure as people concentrated in urban areas, but also signifies the expansion of market economy, transformation of production and lifestyle, and evolution of social organizational forms, which specifically manifested in socio-economic backgrounds of residents, including their standards of living, structure of age, level of education, and choices of occupation (Ward and Shackleton, 2016; Christian et al., 2019; Ou et al., 2002; Kroll and Kabisch, 2012). Neglecting local residents' socio-economic characteristics and only adopting the administrative-based division may not accurately and comprehensively measure their positions within the complex urban-rural gradient. In a nutshell, we still lack an understanding of the differences in perception of ES in urbanizing areas along an urban-rural gradient.

Combining the method of questionnaire survey and redundancy analysis can provide an effective approach to recognize the differences amongst residents' perceptions of ES along the urban-rural gradient. First, individuals' perceptions of ES are diverse and affected by their own life experience (Ko and Son, 2018; Hou et al., 2015). Hence, conducting a questionnaire survey can quantitatively investigate the differences in residents' perceptions of ES and externalize the driving factors (e.g., Shi et al., 2016; Targetti et al., 2020; Lima and Bastos, 2019). Second, redundancy analysis can divide a region into some subregions by residents' different socio-economic backgrounds. Such division compensates for the limitation of using a binary urban-rural administrative division, i.e., a classification with only two categories and a lack of consideration of socio-economic changes brought by urbanization, thus enabling to demonstrate the spatial heterogeneity of perceptions of ES more comprehensively in a rapidly urbanizing area.

Taking the Guanting Reservoir basin as an example, we aimed to explore residents' perceptions of ES in a rapidly urbanizing basin. First, based on the Common International Classification of Ecosystem Services (CICES V5.1), we designed a questionnaire to investigate local residents' perceptions of the importance level of 14 types of ES and their cognition on the specific land-use types that can deliver them. Subsequently, we used stratified random sampling method to select sampling places and collect questionnaires. We then performed the redundancy analysis to delineate the urban-rural gradient according to residents' socio-economic conditions in our sampling places. At last, by using the non-parametric test methods, we analysed whether the differences in residents' perceptions and cognitions in the rapidly urbanizing basin were significant. With the help of logistic regressions, we explored the relationship between socio-economic characteristics of different types of respondents and their perceptions. By exploring residents' preferences of ES and factors, we can provide suggestions to the protection and application of ES at the basin scale.

Our study contributes to understanding the differences in perceptions of ES in urbanizing areas in the following three ways. First, we delineated the urban-rural gradient driven by the socio-economic characteristics of local residents rather than administrative divisions. Second, the data-driven urban-rural gradient can be used to explore residents' perceptions of ES and their dedicated differences, especially for areas located at the middle of the gradient. Third, we further distinguished the corresponding factors affecting perceptions of residents in each type within the gradient.

2. Materials and methods

2.1. Study area

The Guanting Reservoir basin (Fig. 1) is located in the northwest of Beijing, consisting of the Yongdinghe River subbasin, the Yanghe River subbasin and the Sangganhe River subbasin, with a total area of 46,790 km^2. The Guanting Reservoir basin covers 42 counties, districts, banners or county-level cities across Beijing, Hebei, Shanxi and Nei Mongol Zizhiqu. The basin is situated in the transitional zone between the North China Plain and the Inner Mongolia Plateau and is dominated by mountains and intermountain basins. With a temperate continental monsoon climate, the weather is hot and rainy in summer but cold and dry in winter, where the average annual temperature is 6–8 °C and mean annual precipitation is 409 mm, notably 60%–70% of which occurs in summer. Due to its special location in the upwind direction of winter prevailing winds and the upstream of main rivers running across Beijing, the basin serves as an important barrier for the capital's ecological security, and its ecological protection and water conservation functions have been highly valued (Meng et al., 2020; Y.H. Zhou et al., 2024). In 2017, the total population of the basin was 11.43 million, and GDP reached CNY 390.15 billion.

In the past three decades, the Guanting Reservoir basin has experienced a rapid process of urbanization. The urbanization levels amongst regions in the basin vary between 18.1% and 87.4% (National Bureau of Statistics of China, 2010). The urban land area in the basin has nearly doubled from 1992 to 2015 and is expected to continue to grow at a rate of 27.3–32.3 km^2 per year from 2015 to 2040 (Huang et al., 2019).

2.2. Data

We utilized three types of data: 1) on-site questionnaire, 2) socio-economic statistical data, and 3) basic geospatial data. The questionnaire aimed to reflect residents' perceptions of ES with different socio-economic backgrounds and was applied in August 2020. Socio-economic statistical data, including the urban-rural population distribution, sex ratio, age structure and disposable income of residents, were extracted from the 6th National Census, *Hebei Economic Yearbook 2019* (General Office of Hebei Provincial People's Government, 2019) and *Shanxi Statistical Yearbook 2019* (Statistics Bureau of Shanxi Province and Survey Office of the National Bureau of Statistics in Shanxi, 2019). Basic geospatial data such as the DEM data of the Guanting Reservoir

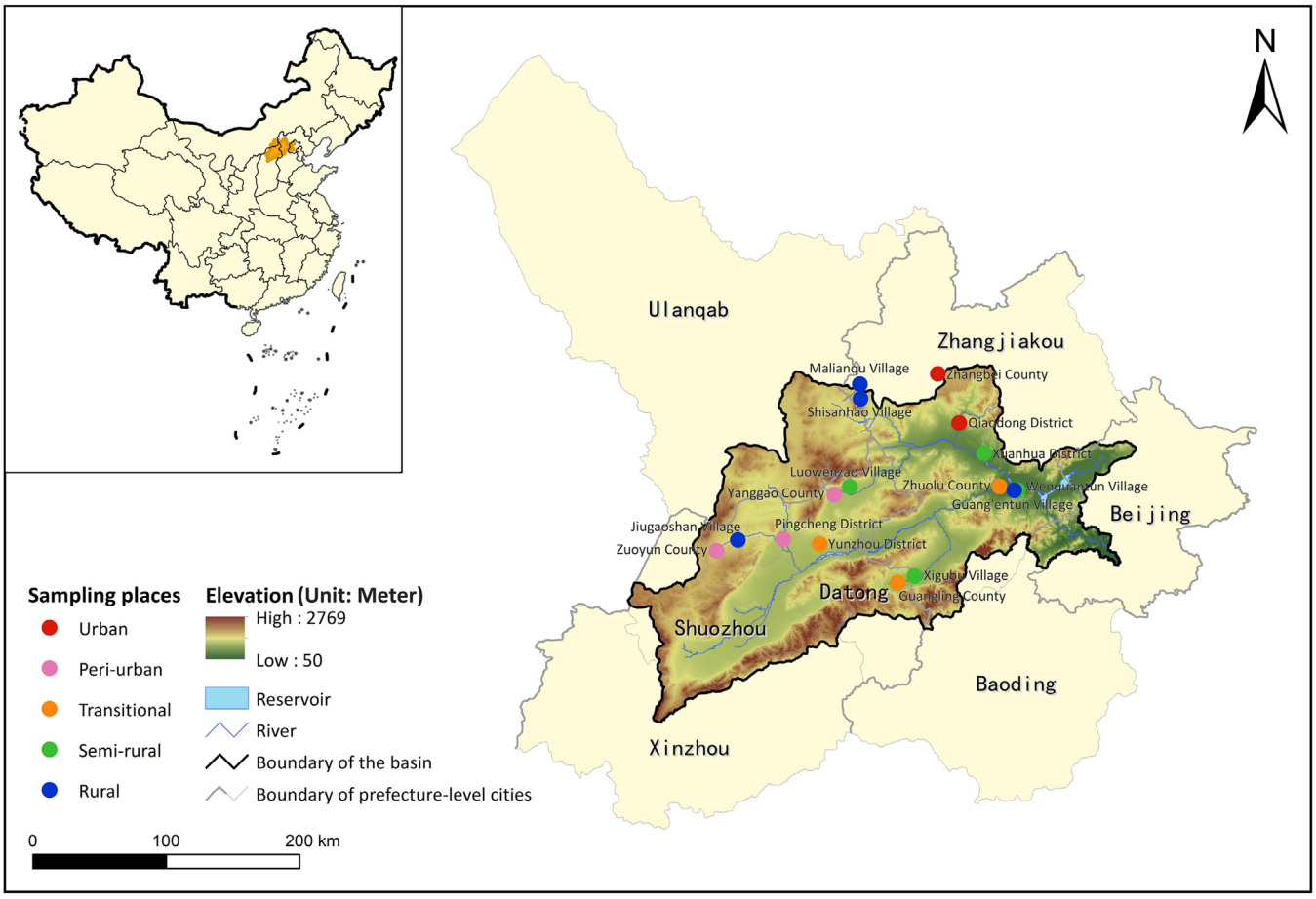

Fig. 1. The Guanting Reservoir basin.

basin, coordinates of sampling places, vector layers of rivers, lakes and boundaries were obtained from the National Geomatics Center of China and the National Platform for Common Geospatial Information Services.

2.3. Conducting questionnaire surveys

The questionnaire (see Appendix 1) was designed to capture the differences amongst residents' perceptions of ES. It consists of two parts: (1) the socio-economic background of the respondents (i.e., gender, age, time of residence, monthly income, occupation, education level and frequency of visiting natural amenities); (2) the respondents' perceptions of local 14 types of ES, including the importance of all types of ES and their cognition on land-use types that can deliver these services. Respondents were asked to select the land-use types that could deliver each of the 14 types of ES and rate the importance level of ES using the Likert scale method from 1 (least important) to 5 (most important) (Burkhard et al., 2012; Montoya-Tangarife et al., 2017).

To select local ES used in the questionnaire (Table 1), we considered the natural and cultural characteristics of the basin following the CICES V5.1 (Kumar and Kumar, 2008; FLARE Network, 2017). For provisioning services, we chose three types of ES concerning basic need of living. In the case of regulating services, we selected seven ES that were all related to local ecological conditions, so it would be easy for respondents to understand those services (Wu, 2017). As for cultural services, we chose four types of ES based on existing findings in our previous research (Meng et al., 2020).

As for land-use types, we referred to the first-level classification in Remote Sensing Monitoring Dataset of Land-Use and Land-Cover Change in China (Xu et al., 2018). This classification divides land-use and land-cover into six first-level types, i.e., cropland, forest, grassland, water area, built-up land, and unused land. Considering that built-up and unused land are not providing any of the selected ES (Lemoine-Rodríguez et al., 2020), only the remaining four land-use types (cropland, forest, grassland and water area) were retained in the survey.

To ensure that the sampled respondents are sufficient to represent the entire population in the basin, the number of questionnaires is determined by the formula proposed by Yamane (1967), which can be expressed as follows:

$$n = \frac{N}{1 + N(1-e)^2}$$

where n is the number of questionnaires to be distributed; N is the total population of the study area; and e represents the confidence level.

At 95% confidence level, at least 400 questionnaires should be collected in the studied region, while in practice we collected a total of 486 questionnaires, and 471 of which were valid, resulting an effective response rate of 96.9%. The reliability and validity of the questionnaires were examined using the Cronbach's α coefficient and KMO measure. Cronbach's α coefficient was above 0.8, which indicates a good internal consistency as the value was higher than 0.7 (Nunnally, 1978). The KMO measure was above 0.7, indicating a high internal validity (Ma et al., 2015).

The Kolmogorov-Smirnov test (K-S test) was used to check the data normality (Tao, 1994). In the K-S test, the data is considered to be consistent with normal distribution with the p value higher than 0.05. Yet, in our study, p values were all equal to 0.000, which suggests that the data were in a skewed distribution. Therefore, we used a non-parametric test for further analysis.

Table 1
ES used in the questionnaire.

Types of ecosystem services in the questionnaire (abbreviation)		Corresponding ecosystem services in CICES V5.1 (codes)
Provisioning services	Providing food (P1)	Cultivated terrestrial plants (including fungi, algae) grown for nutritional purposes (1.1.1.1)
		Cultivated plants grown for nutritional purposes by in-situ aquaculture (1.1.2.1)
		Animals reared to provide nutrition (1.1.3.1)
		Animals reared by in-situ aquaculture for nutritional purposes (1.1.4.1)
	Providing firewood (P2)	Cultivated plants (including fungi, algae) grown as a source of energy (1.1.1.3)
		Cultivated plants grown as a source of energy by in-situ aquaculture (1.1.2.3)
	Providing domestic water (P3)	Surface water for drinking (4.2.1.1)
		Ground water for drinking (4.2.2.1)
Regulating services	Carbon sequestration (R1)	Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals (2.1.1.2)
	Sustaining biological species (R2)	Maintaining nursery populations and habitats (including gene pool protection) (2.2.2.3)
	Flood control (R3)	Hydrological cycle and water flow regulation (including flood control) (2.2.1.3)
	Air purification (R4)	Regulation of chemical composition of atmosphere (2.2.6.1)
	Water purification (R5)	Regulation of the chemical condition of freshwaters by living processes (2.2.5.1)
	Wind-break and sand-fixation (R6)	Storm protection (2.2.1.4)
		Weathering processes and their effect on soil quality (2.2.4.1)
	Soil-water conservation (R7)	Control of erosion rates (2.2.1.1)
Cultural services	Providing outdoor entertainment (C1)	Elements of living systems used for entertainment or representation (3.2.1.3)
	Experiencing regional culture (C2)	Characteristics of living systems that are resonant in terms of culture or heritage (3.1.2.3)
	Providing education and training (C3)	Characteristics of living systems that enable education and training (3.1.2.2)
	Providing aesthetic experiences (C4)	Characteristics of living systems that enable aesthetic experiences (3.1.2.4)

2.4. Delineating the urban-rural gradient with socio-economic conditions

To compare differences in ES perception in an urbanizing region, we selected sampling places with different administrative levels, including city districts, counties, and villages. Our study region included Zhangjiakou and Datong, two major cities situated in the Guanting Reservoir basin. The total number of districts, counties, and villages are 10, 16, and 5,598, respectively. To ensure that the number of questionnaires can support subsequent analyses, we selected 16 sampling places using the stratified random sampling method by their administrative levels and population, i.e., four city districts, four counties and six villages. Considering that the number of residents varied, we distributed 40 copies of questionnaire in each city district, 30 copies in each county, and 20 copies in each village.

We used the redundancy analysis (RDA) to delineate the urban-rural gradient amongst the 16 sampling places. The RDA method allowed us to find gradients amongst samples with multiple socio-economic backgrounds that are characterized by environmental factors. This gradient analysis method combined correspondence analysis with multiple regressions to provide a detailed explanation of relationships amongst samples within the constraints of environmental factors, so that the ranking axes could reflect the environmental gradient (Braak and Milauer, 2012). Using the concept of ordination in community ecology, we saw the respondents as species, the sampling places as quadrats carrying species, and the respondents' seven socio-economic backgrounds (i.e., gender, age, time of residence, monthly income, occupation, education level and frequency of visiting natural amenities) as environmental factors affecting the distribution of species. The average values of coordinates on each ranking axis of all respondents in a place is the coordinate of that sampling place.

After the RDA, we performed the Kruskal-Wallis test (K-W test) and the Dunn's multiple comparison test to determine whether the distribution of coordinates representing sampling places on ranking axes were significantly different (Aguado et al., 2018). K-W test is a test of variability used amongst multiple independent samples (Gibbons, 1971). It could tell if there are differences amongst those coordinates. When $p < 0.05$, it can be assumed that there were significant differences amongst them. The Dunn's multiple comparison test is a post-hoc test conducted after K-W test to find out in which two coordinates existed the difference, enabling further refinements of the division. Again, the difference between two coordinates was considered to exist when $p < 0.05$. Based on differences found in K-W tests and Dunn's multiple comparison tests, sampling places could be divided in different types.

We settled different types of sampling places on the urban-rural gradient with the help of residents' socio-economic characteristics. Referring to existing research (Banerjee et al., 2014; Cattivelli, 2021), we chose age, occupation, education level, monthly income, and frequency of visiting natural amenities as factors determining the urbanization level of the sampling places and their position on the urban-rural gradient. Specifically, in terms of age, we focused on the proportion of residents under 60 years old. For occupation, the proportion of non-farmers was calculated. As for education level, we counted the proportion of people who had received a higher education. These indicators mentioned above are in line with previous research practices (Danielaini et al., 2018; Arif and Gupta, 2018; Mondal and Sen, 2020). Given that the annual per capita disposable income of urban households in Zhangjiakou and Datong in 2020 were CNY 35,595 and 36,685, respectively (Zhangjiakou Municipal Bureau of Statistics and Survey Office of the National Bureau of Statistics in Zhangjiakou, 2021; Datong Municipal Bureau of Statistics and Survey Office of the National Bureau of Statistics in Datong, 2021), we calculated the proportion of residents with monthly income over CNY 4,000. As regards to the frequency of visiting natural amenities, the proportion of people who visited over 10 times last year was recorded in accordance with field interviews. However, it is important to note that only socio-economic factors that had significant influence in the redundancy analysis were selected.

We assumed that the overall socio-economic backgrounds of local residents of a place can, to a certain extent, reflect the urbanization level of the place. For example, residents with higher levels of income and education, being younger, and having frequently visiting natural amenities, had a more urbanized way of life. Thus, the place where they live had a higher level of urbanization.

2.5. Comparing residents' perceptions of ES

After collecting residents' scores on the importance of each ES in the questionnaire, we used the K-W test to explore the differences amongst them. Statistically significant differences were considered to exist amongst the scores when p value was lower than 0.05, which meant that residents could be considered to have different perceptions to those ES.

In addition, we used the Chi square test to examine the potential differences in residents' cognition of the land-use types that can deliver ES

Table 2
Characteristics of the sampled respondents and residents of the basin from the census.

	The sampled respondents		Residents of the basin	
	Category	Amount (proportion)	Category	Amount (proportion)
Gender	Male	191 (40.6%)	Male	2615,554 (51.1%)
	Female	280 (59.4%)	Female	2507,588 (48.9%)
Age	≤ 19 years old	106 (22.5%)	≤ 14 years old	418,410 (8.2%)
	20–59 years old	327 (69.4%)	15–64 years old	4308,810 (84.1%)
	≥ 60 years old	38 (8.1%)	≥ 65 years old	395,922 (7.7%)
Monthly income (CNY)	<2,000	274 (58.2%)	Urban 2,550	
	2,000–4,000	111 (23.6%)		
	4,000–6,000	48 (10.2%)		
	6,000–8,000	13 (2.7%)	Rural 901	
	8,000–10,000	14 (3.0%)		
	>10,000	11 (2.3%)		
Education level	Primary school and below	53 (11.3%)	Primary school and below	1,646,065 (32.1%)
	Junior high	124 (26.3%)	Junior high	2,242,250 (43.8%)
	Senior high	157 (33.3%)	Senior high	835,806 (16.3%)
	College or above	137 (29.1%)	College or above	399,021 (7.8%)

following Shi et al. (2020). As the prediction frequency of some samples was less than 5, the Fisher's exact test method was then applied (Fisher, 1970). A p value lower than 0.05 indicates that differences existed.

2.6. Determining factors affecting ES perceptions

We used an ordered multinomial logit regression to determine the socio-economic factors affecting residents' perceptions of ES in each type of sampling places along the urban-rural gradient. Meanwhile, we used a binary logistic regression to determine corresponding factors affecting residents' perception that whether a certain land-use type could provide ES in different types of sampling places. First, by a Chi square test (Fisher's exact test method, $p < 0.05$), we selected socio-economic factors with statistically significant differences amongst residents showing distinct perceptions. Then, we applied a collinearity diagnostic. When the tolerance values are greater than 0.2 or values of variance inflation factor (VIF) are less than 5, we can believe that there was no collinearity amongst these factors (Akinwande et al., 2015).

After completing the above preparations, a binary logistic regression and an ordered multinomial logit regression were performed. The validity of model was judged by an Omnibus test. When $p < 0.05$, the model could be seen as valid. The fitting degree of model was judged by the result of Hosmer-Lemeshow test, which indicated a good fit when $p > 0.05$ (Ma et al., 2015). Due to the sample size, we considered factors to be significant when $p < 0.1$.

3. Results

3.1. Characteristics of the sampled respondents

Our sample represents the overall features of residents in the basin (Table 2). For age structure, as there were more older respondents (aged 60 and over) in villages, about 69.4% of the respondents were aged between 20 and 59 years old, which was smaller than the proportion of total residents in the basin of the corresponding age group (84.1%). For the same reason, the proportion of respondents aged below 19 (22.5%) was higher than the overall level of residents in the basin (8.2%). The monthly income was also generally in compliance with the statistical data, approximately 81.8% of the respondents earned less than CNY 4,000, amongst which 58.2% earned less than CNY 2,000.

In terms of gender, the proportion of female respondents was 10.5% higher than the average level in the basin. Since poorly-educated people may have difficulty understanding abstract concepts like ES, respondents with a higher education level were more likely to complete the questionnaire, which resulted a higher proportion of the sampled respondents graduated from senior high school or above (62.4%) than census value (24.1%).

3.2. Urban-rural gradient in sampling places

The selected 16 sampling places can be divided into five groups according to residents' socio-economic conditions there. Results of the K-W test showed that on the first RDA axis, there was a significant difference ($p < 0.01$) amongst coordinates representing sampling places (Fig. 2). Furthermore, according to results of Dunn's multiple comparison test, sampling places could be divided in five types ($p < 0.05$).

According to results of the redundancy analysis, six of residents' socio-economic backgrounds significantly affected the distribution of coordinates. Wherein, gender, age, frequency of visiting natural amenities and education level were significant at the level of $p < 0.001$, monthly income at the level of $p < 0.01$, and occupation at the level of $p < 0.1$.

For each type of the sampling places, we calculated the proportion of respondents who were under 60 years old, non-farmers, with a degree of higher education, had a monthly income of CNY 4,000 or above, and had visited natural amenities over 10 times last year. In combination with these socio-economic characteristics, we determined the distribution of the five types of sampling places and identified them as urban, peri-urban, transitional, semi-rural, and rural areas, with 77, 115, 111, 112 and 56 respondents, respectively.

From rural to urban areas, a gradual upward trend could be found amongst the proportions of respondents who were under 60 years old, non-farmers, and those with a degree of higher education (Table 3). The corresponding values rose from 64.3%, 60.7%, and 12.5% to 100.0%, 98.7%, and 57.1%, showing an increase of 35.7%, 38.0%, and 44.6%, respectively. Although the proportions of respondents who had monthly income of over CNY 4,000 and visited natural amenities over 10 times last year did not show the expected increasing trend with the increase in urbanization, the corresponding percentage values in urban and peri-urban areas were higher than those in transitional, semi-rural, and rural areas by 10.2%–24.7% and 3.5%–21.6%, respectively.

3.3. Perceptions of the importance of ES

At the significance level of $p < 0.05$, there were differences amongst residents' perceptions to all three provisioning services (Fig. 3). Residents in transitional areas attached the highest importance to services of providing food and domestic water, scoring 4.41 and 4.73 out of 5, respectively, which were 0.7%–13.1%, 2.4%–10.0% higher than those of the other four types of areas. In contrast, urban residents attached the lowest importance to the service of providing food, and rural residents gave it to the service of providing domestic water, scoring only

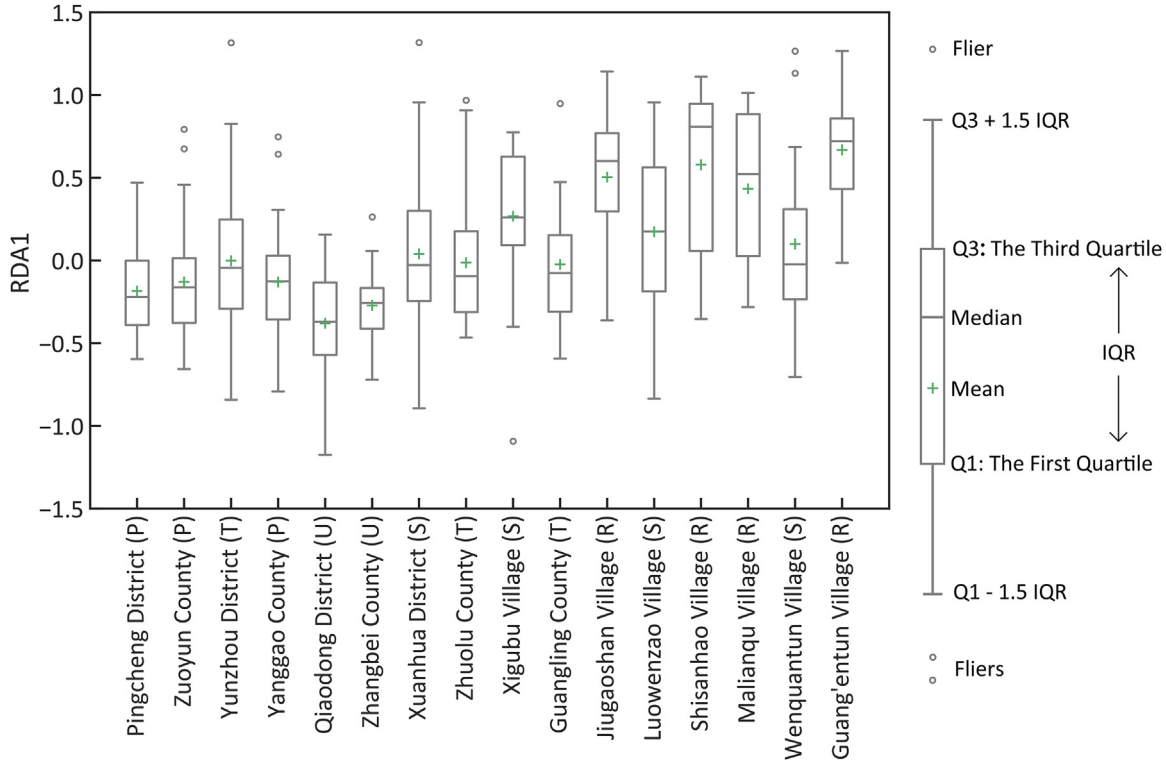

Fig. 2. Coordinates of sampling places in the first RDA axis.
Note: U, P, T, S or R in parentheses represents the category of corresponding sampling place, i.e., urban, peri-urban, transitional, semi-rural and rural areas, respectively.

Table 3
Socio-economic characteristics of respondents in each type of sampling places.

Proportion of respondents (%)	Urban	Peri-urban	Transitional	Semi-rural	Rural
Under 60 years old	100.0	98.3	97.3	88.4	64.3
Non-farmers	98.7	97.4	90.1	88.4	60.7
With a degree of higher education	57.1	33.0	25.2	17.9	12.5
With monthly income over CNY 4,000	33.7	23.5	11.7	13.3	9.0
Visited natural amenities over 10 times last year	26.0	28.7	22.5	21.4	7.1

3.90 and 4.30, respectively. As for the service of providing firewood, rural residents emphasized its importance (3.50), while residents in semi-rural areas paid the least attention (2.71), with the former being 1.29 times of the latter. In addition, residents in all types of areas gave the least importance to the service of providing firewood, with lowest scores (2.71–3.50).

Regulating services showed significant differences in the perceived importance to services of flood control and soil-water conservation amongst residents ($p < 0.05$). Specifically, residents in urban areas attached the most importance to the service of flood control and peri-urban areas to the service of soil-water conservation, scoring 3.94 and 4.62, respectively, which were 1.01–1.32 and 1.07–1.35 times of those given by residents in the other four areas. Rural residents placed the least importance to the above two services, with scores of 2.98 and 3.43, respectively, only 75.6% and 74.2% of the highest score. As for the other regulating services, residents in transitional areas valued the service of air purification most (4.58), while residents in semi-rural areas valued it the least (4.38), with the former being 4.6% higher than the latter. Peri-urban residents attached the highest importance to the remaining three services of sustaining biological species (4.26), water purification (4.60), and wind-break and sand-fixation (4.48). Whereas urban residents attached the lowest importance to the service of water purification (4.36), and rural residents to services of sustaining biological species (3.48) and wind-break and sand-fixation (3.75). In the horizontal comparison of seven regulating services, residents in five types of areas all considered the service of flood control to be the least important, scoring only between 2.98 and 3.94, with the highest and lowest scores 6.4%–14.7% and 13.2%–32.0% lower than those of the other services, respectively. Apart from residents in peri-urban areas considering the service of soil-water conservation (4.62) to be more important than wind-break and sand-fixation (4.48), services of air purification (4.38–4.58), water purification (4.36–4.60), and wind-break and sand-fixation (3.75–4.48) ranked amongst the top three most important regulating services by residents.

There were no significant differences amongst residents' perceptions of four cultural services. Generally, residents in areas with higher levels of urbanization placed higher value on cultural services than those in areas with relatively lower urbanization levels. To be specific, urban residents placed the greatest emphasis on the service of providing aesthetic experiences (3.91), while residents in semi-rural areas put the least importance to it (3.66), with the former being 6.8% higher than the latter. Residents in peri-urban areas attached the highest importance to services of providing outdoor entertainment (3.78) and experiencing regional culture (3.83), while residents in transitional areas attached the highest importance to the service of providing education and training (4.11). However, rural residents made light of the above three services, with scores at 3.33, 3.38, and 3.39, respectively, which corresponds to 11.9%, 11.7%, and 17.5% lower than above three scores. Five types of

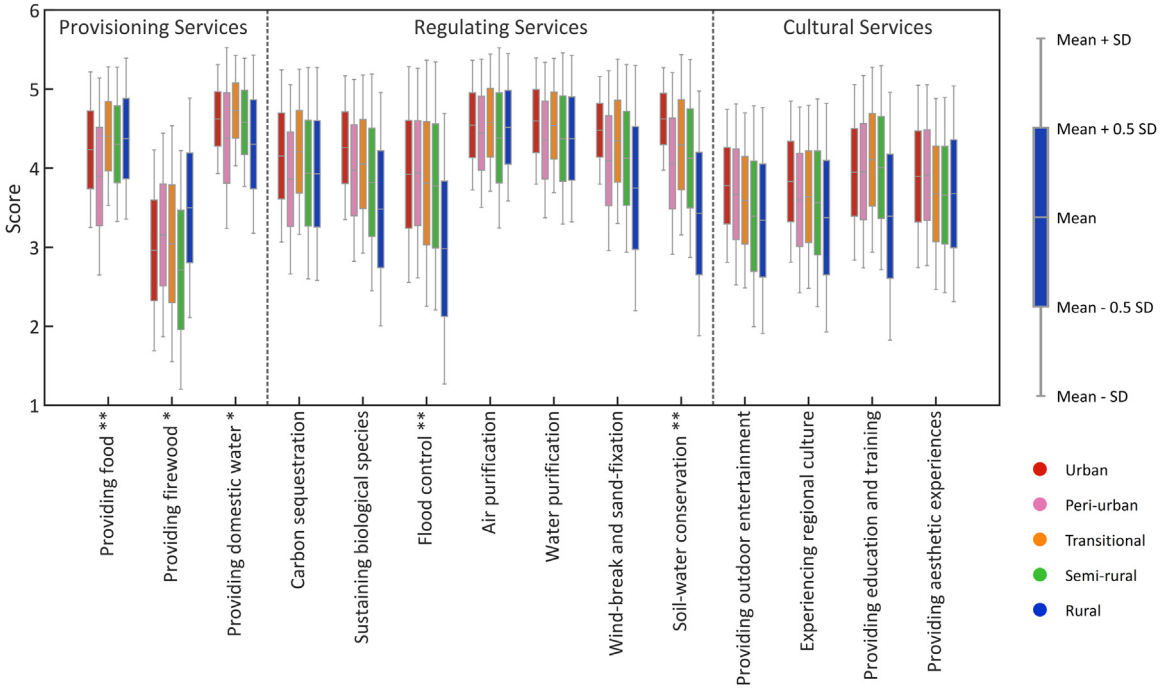

Fig. 3. Residents' perceptions of the importance of each ES.
Note: *, ** indicate significant differences amongst the five types of areas at $p < 0.05$ and $p < 0.01$, respectively, according to results of the K-W test.

residents all considered the service of providing outdoor entertainment to be the least important, with scores ranging only from 3.33 to 3.78. In the meantime, except rural residents, all the other four types of residents considered the service of providing education and training to be the most important, with scores ranging from 3.95 to 4.11, which were 16.5%–18.3% higher than the score placed by rural residents.

It is noteworthy that residents in peri-urban areas placed the highest importance on four out of seven regulating services (i.e., sustaining biological species, water purification, wind-break and sand-fixation and soil-water conservation) as well as two out of four cultural services (i.e., providing outdoor entertainment and experiencing regional culture). Furthermore, the standard deviations of scores given to those six services were also the smallest, indicating a general appreciation for these services amongst peri-urban residents. On the contrary, with the largest standard deviations, rural residents placed the least importance on four out of seven regulating services (i.e., sustaining biological species, flood control, wind-break and sand-fixation and soil-water conservation) and all four cultural services except the service of providing aesthetic experiences, showing a greater divergence compared to the other four types of residents.

3.4. Cognition of the land-use types providing certain ES

The greatest differences in cognition of what can provide ES amongst residents in different areas lay in grassland, which was reflected in five ES (Fig. 4). Differences in their cognition of water area were reflected in two ES. Besides, deviations in the cognition of forest were also reflected in two ES. Finally, residents showed no cognitive differences to all ES provided by cropland.

Cognitive differences in grassland focused on whether it could provide four regulating services and one cultural service ($p < 0.05$). Amongst residents from five different types of areas, the most substantial perceptual differences were observed in services of air purification and wind-break and sand-fixation ($p < 0.01$). In urban areas, the majority of residents, 62.3% and 44.2% respectively, recognized grassland' s potential to provide those two services. In stark contrast, rural areas exhibited the lowest recognition, only 25.9% and 37.7% respectively. The former were 2.4 and 1.2 times of the latter. Regarding the cultural service of providing outdoor entertainment, approximately 73.7% of urban residents acknowledged this service provided by grassland, whereas only 51.9% of residents in transitional areas concurred.

There were also evident cognitive differences in residents' attitudes towards services of sustaining biological species and water purification that could be provided by water area ($p < 0.05$). The findings indicated a gradient increase in positive attitudes from rural to urban residents. A significantly higher percentage of urban residents believed that water area could provide those two services, with proportions 15.8%–117.8% and 9.1%–77.0% higher than those of the other areas, respectively.

The cognition of ES provided by forest were significantly different only in services of providing food and soil-water conservation ($p < 0.05$). For urban residents, 26.0% believed that forest could provide food, a perception shared by only 10.8%–13.2% of residents in the other four areas. Conversely, compared to their counterparts in other areas (45.8%–61.7%), a higher percentage of rural residents (67.9%) recognized the role of forest in providing the service of soil-water conservation.

At the level of $p < 0.05$, there was no cognitive difference on ES that cropland could provide. Irrespective of area type, the majority of residents concurred that cropland could provide food, with the proportion varying from 73.0% to 85.6%.

3.5. Factors affecting residents' perceptions of ES

Age was the most important factor affecting perceptions of the importance of ES in urban, transitional and semi-rural areas. For these three types of areas, it affected five perceptions (i.e., the services of providing food, flood control, water purification, soil-water conservation, and providing education and training), three perceptions (i.e., sustaining biological species, wind-break and sand-fixation, soil-water conservation) and five perceptions (i.e., providing food, providing firewood, sustaining biological species, providing education and training, and providing aesthetic experiences) of the importance of ES, respectively ($p < 0.1$) (Table 4). Amongst them, for urban residents, age had the greatest impact on their perceptions of the service of providing food, with a regression coefficient of 20.97–22.58, which was 2.5–15.7 times that

Table 4
Socio-economic factors affecting residents' perceptions on the importance of ES.

		P1	P2	P3	R1	R2	R3	R4	R5	R6	R7	C1	C2	C3	C4
Gender	Male						−0.975(3)**		−0.448(4)**						
	Female						0		0						
Age (years old)	≤19	22.138(1)***	1.928(4)**	—		—	4.474(1)*		7.551(1)***	—	8.165(1)*** 5.603(3)**			−1.429(4)*	1.963(4)**
	20–29	22.302(1)***	1.540(4)**	—		2.753(3)**	5.308(1)**		7.237(1)***	1.996(3)**	8.181(1)*** 6.705(3)**			−1.811(4)**	—
	30–39	22.577(1)***	—	—		3.669(3)*** 0.797(4)*	5.592(1)**		7.271(1)***	1.945(3)**	8.207(1)*** 6.367(3)**			1.437(1)*	—
	40–49	1.699(4)**	—	—		3.468(3)***	4.858(1)*		7.603(1)***	1.927(3)**	7.982(1)*** 6.943(3)**			—	—
	50–59	20.974(1)***	—	1.994(5)***		3.573(3)***	—		7.556(1)***	2.170(3)**	8.261(1)*** 6.527(3)**			−1.797(4)**	—
	≥60	0	0	0		0	0		0	0	0			0	0
Time of residence (year)	<5					—	—			−1.239(2)***					
	5–15					−0.832(3)**	1.461(5)***			—					
	>15					0	0			0					
Frequency of visiting natural amenities	1–2 times	—	1.687(5)**		−3.271(1)** −2.238(2)**					−2.330(3)***	−1.545(3)**				
	3–5 times	—	1.552(5)*		1.070(1)** −1.444(2)**					−1.323(3)**	—				
	6–10 times	—	1.436(5)*		−1.881(2)***					−1.519(3)**	—				
	>10 times	−1.418(4)**	—	—	—					−1.443(3)**	−2.335(3)**				
	Not once	0	0	0	0					0	0				
Education level	PS and below	—				−1.780(4)**	−2.837(3)*						−4.934(3)**		
	Junior high	—				—	—						—		
	Senior high	−2.592(5)**				—	—						—		
	College	—				—	—						—		
	M.D. or above	0				0	0						0		
Occupation	Staffs	—	−2.678(2)***			−2.455(3)***			—	−3.083(1)**			−3.316(1)***		—
	Employees	−2.448(1)***	—			—			−1.626(1)*** −1.050(3)**	−1.268(2)**			—		—
	Individuals	1.089(1)*	—			—			—	—			—		—
	Farmers	—	0.836(4)*			−0.917(3)*			—	—			—		1.628(4)***
	Students	—	−1.386(2)*			—			−1.219(1)** −1.254(2)**	−0.997(2)*			−1.760(1)**		−1.218(4)*
	Retired	—	—			—			—	—			−4.928(1)*		1.509(4)**
	Others	0	0			0			0	0			0		0
Monthly income (CNY)	<2,000													−18.448(1)***	
	2,000–4,000													−17.190(1)***	
	4,000–6,000													−18.249(1)***	
	6,000–8,000													−18.072(1)***	
	8,000–10,000													—	
	>10,000													0	

Note: ***, ***, and * represent $p < 0.01$, $p < 0.05$, and $p < 0.1$, respectively. Numbers in the table represent coefficients of the ordered multinomial logit regression, and numbers in parentheses represented the urban-rural gradient (1-urban, 2-peri-urban, 3-transitional, 4-semi-rural, 5-rural). 0 indicated that this category was the control group of corresponding socio-economic factor. — indicated that there was no data or the p value of this data was over 0.1. Blank space in the table represented that this socio-economic factor had no significant effect on perceptions of ES ($p > 0.1$). The formulation of categories of some socio-economic factors was simplified in the table, with complete descriptions available in Appendix 1.

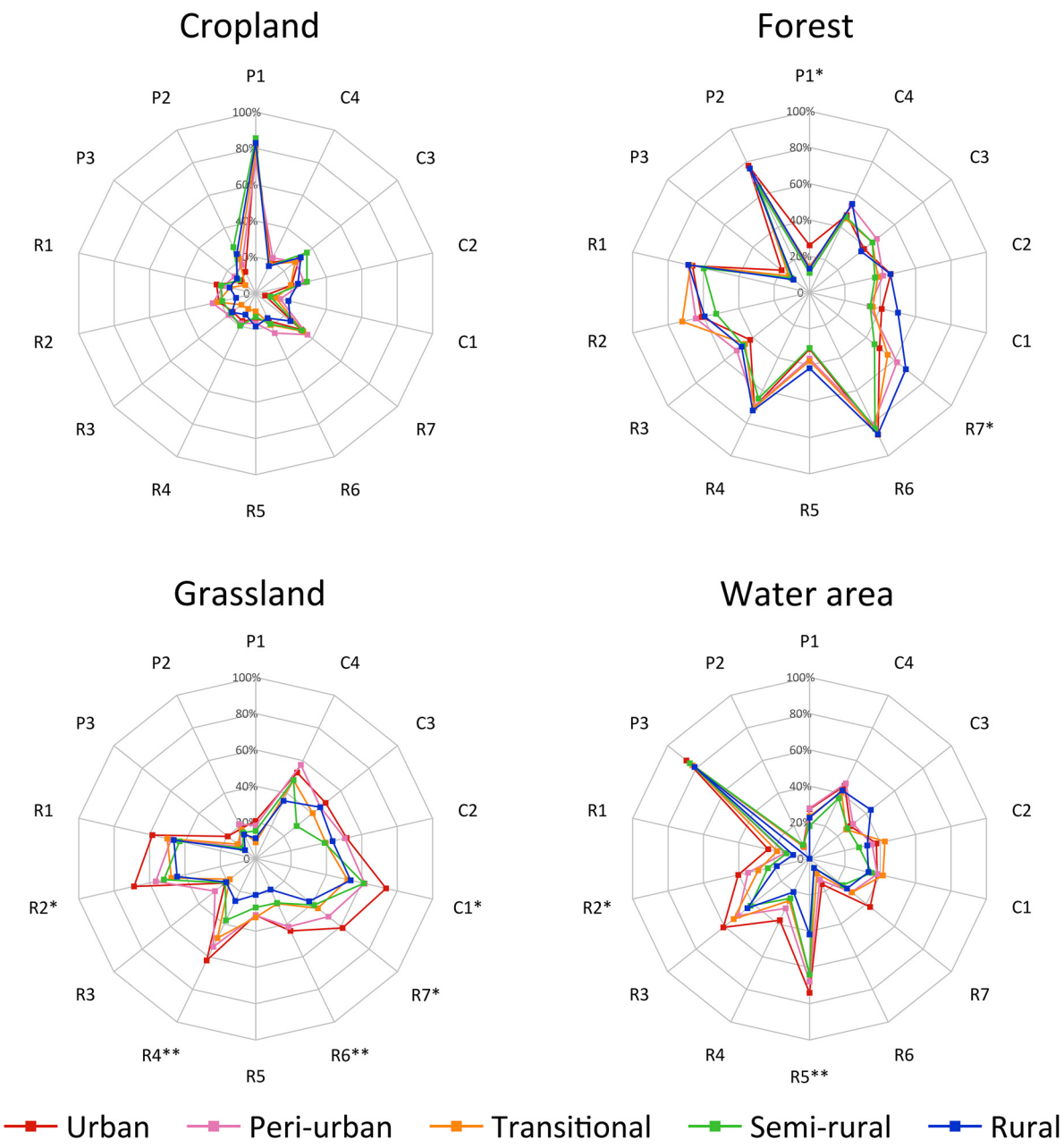

Fig. 4. Residents' cognition of the land-use types that can provide a certain ES.
Note: *, ** indicate significant differences amongst five types of areas at $p < 0.05$, $p < 0.01$, respectively, according to results of the K-W test. The abbreviation of ES refers to Table 1.

of the other four ES. In addition, apart from the negative regression coefficients of age on the service of providing education and training in semi-rural areas (−1.81– −1.43), regression results of age on other ES in three areas were all positive, indicating that compared to the residents over 60 years old, younger residents in these three areas increased their emphasis on relevant ES.

In peri-urban areas, occupation was the most important factor influencing residents' perceptions of ES, affecting the services of providing firewood, water purification, and wind-break and sand-fixation ($p < 0.1$). Specifically, compared to students (−1.39) and farmers (−0.92), staff of government and institutions attached less importance to the services of providing firewood (−2.68) and water purification (−2.46), with regression coefficients of the latter being 1.9 and 2.7 times of the former. Enterprise employees paid less importance to the service of wind-break and sand-fixation, with a regression coefficient of −1.05. Furthermore, occupation also significantly influenced residents' perceptions of four ES in urban areas, two ES in transitional and semi-rural areas, making it the second most important factor affecting the perceptions of ES in these three areas.

In rural areas, age, time of residence, frequency of visiting natural amenities, and education level respectively affected residents' perceptions of the services of providing domestic water, flood control, providing firewood, and providing food ($p < 0.1$). Of note, compared to residents who have lived for over 15 years, those who lived for 5–15 years paid more attention to the service of flood control, with a regression coefficient of 1.46. As the frequency of visiting natural amenities increased, the importance attached to the service of providing firewood steadily rose, but the regression coefficient decreased from 1.69 when visiting 1–2 times to 1.44 when visiting 6–10 times, indicating a gradually diminishing increase in the perception of importance.

Table 5
Socio-economic factors affecting residents' cognitions of land-use types.

		Cropland	Forest	Grassland	Water area
Gender	Urban	−1.219(C1)**		1.040(C1)***	
	Peri-urban				
	Transitional		−0.973(C2)**		
	Semi-rural			1.291(C1)***	
	Rural				
Age	Urban				
	Peri-urban	1.032(R5)**	−0.744(P2)***	0.803(P3)***	−0.802(P3)**
			−0.992(R6)**		0.953(R6)**
	Transitional				
	Semi-rural	0.483(C1)**	−0.488(R4)*		
	Rural			−0.575(P3)*	
Time of residence	Urban				−0.717(R7)**
	Peri-urban				
	Transitional				
	Semi-rural				
	Rural				−1.014(P1)**
Frequency of visiting natural amenities	Urban	−0.468(P2)**	0.343(P2)**		
	Peri-urban		1.001(R6)**		
	Transitional				
	Semi-rural	−0.445(R1)**	0.394(C3)***	0.348(C2)**	
	Rural	0.522(R5)**			
Education level	Urban	−1.006(P2)***	0.674(P2)**		
		−1.379(R5)***			
	Peri-urban		0.792(R1)**		
			0.654(R2)**		
	Transitional	1.098(R5)**	0.628(R2)**		0.937(P3)**
	Semi-rural		0.477(R2)*		
	Rural				
Occupation	Urban		2.312(R1)*		
			−3.871(C1)**		
	Peri-urban	−1.987(R7)*			−1.583(R6)*
	Transitional		−2.667(P3)**		3.637(P3)***
	Semi-rural		−1.902(R2)*		
	Rural				
Monthly income	Urban	0.681(R5)***	0.566(R5)***	0.726(R3)***	
		0.474(R6)***		0.448(R4)**	
	Peri-urban	0.428(R2)**	−0.672(R3)***		0.639(R3)***
	Transitional				
	Semi-rural				
	Rural				0.906(R3)**

Note: ***, **, and * represent $p < 0.01$, $p < 0.05$ and $p < 0.1$, respectively. Numbers in the table are coefficients of the binary logistic regression, and codes in parentheses represent certain ES affected by socio-economic factors.

3.6. Factors affecting residents' cognitions of land-use types

In urban areas, monthly income was the most important factor affecting residents' cognitions of land-use types delivering ES, reflected in whether cropland, forest and grassland could provide the regulating services of flood control, air purification, water purification, and wind-break and sand-fixation (Table 5). The regression coefficients ranged from 0.45 to 0.73, all of which were positively correlated.

Age was the greatest influencing factor on the cognition of land-use types delivering ES in peri-urban areas, involving all four land-use types whether could provide two provisioning services of providing firewood and domestic water, as well as two regulating services of water purification and wind-break and sand-fixation. Wherein, age had a positive correlation (0.80) with the cognitions of grassland' s ability to provide domestic water, but a negative one (−0.80) on water area providing this service. In addition, age also had a negative correlation (−0.99) with the cognition of forest providing the service of wind-break and sand-fixation, but a positive one (0.95) on water area providing it.

In transitional areas, education level was the most important factor positively affecting residents' cognitions of cropland providing the service of water purification, forest providing the service of sustaining biological species, and water area providing domestic water, with regression coefficients ranging from 0.63 to 1.10.

Frequency of visiting natural amenities was the most significant socio-economic factor in semi-rural areas. It negatively affected residents' cognitions of cropland providing the service of carbon sequestration (−0.45), positively affected residents' cognitions of forest providing education and training (0.39) and grassland providing the service of experiencing regional culture (0.35). As for rural areas, age, time of residence, frequency of visiting natural amenities, and monthly income, each had an impact on the cognitions of only one land-use type, respectively.

It is noteworthy that, with an increase in urbanization level, the influence of socio-economic factors could be changed. For example, from semi-rural areas to peri-urban areas, the regression coefficient of education level on the cognition of forest sustaining biological species increased from 0.48 to 0.65, a growth of 37.1%, indicating that its impact has gradually enhanced. For water area providing the service of flood control, compared to rural areas (0.91), the regression coefficient of monthly income in peri-urban areas reduced to 0.64, a decrease of 29.5%. As for age on the cognition of grassland providing drinking water, the regression coefficient changed from −0.58 to 0.80, which exhibited a correlation turning from negative to positive.

4. Discussion

4.1. Differences in perceptions of ES between urban and rural residents

There were structural differences in residents' perceptions of ES in the Guanting Reservoir basin. Generally, residents in urban and

peri-urban areas paid more attention to regulating services and cultural services. Our findings are consistent with the conclusions of previous studies conducted in different regions of the world, that regulating and cultural ES were more important to urban dwellers than to rural people, reflecting the homogeneous characteristics existing in global urbanizing regions (Casado-Arzuaga et al., 2013; Lemoine-Rodríguez et al., 2020; Kimpouni et al., 2021). For example, Casado-Arzuaga et al. (2013) analysed users' perception of ES in Bilbao Metropolitan Greenbelt, finding that 97.6% of respondents indicated cultural services as important ES, while only 52.2% selected provisioning services. Kimpouni et al. (2021) explored differences in local residents' perceptions of ES in Djoumouna Periurban Forest of Congo and found that regulating services were ranked ahead of cultural and provisioning services. However, our study provides three unique findings.

First, residents in urban areas placed greater emphasis on regulating service of flood control, and cultural service of providing aesthetic experiences, than residents in peri-urban areas. For five regulating services and three cultural services valued by urban and peri-urban residents, degrees of importance placed by peri-urban residents on these ES were 3.0%–13.8% higher than that of urban residents, with a standard deviation 13.6%–43.5% lower than that of urban residents as well. However, as for services of flood control and providing aesthetic experiences, urban residents' emphases (3.94, 3.91) exceeded those of peri-urban areas (3.92, 3.90), and standard deviations (1.33, 1.14) were also smaller than in peri-urban areas (1.37, 1.15), reflecting high and widespread attention paid by urban residents. With progressing urbanization, land cover, hydrological conditions and microclimate changed, increasing the risk of urban waterlogging due to the degradation of natural ecosystems and the growth of impervious surfaces. When climate change led to higher frequency and intensity of extreme weather events, urban infrastructures with low design standards were unable to cope (W. Liu et al., 2023; Yang et al., 2023).

Moreover, cities are the most concentrated areas for various elements, resources, and socio-economic activities. When cities acted as a disaster-bearing body, direct losses caused by flooding, indirect losses caused by interrupted economic activities, and even environmental losses of natural resources are high (K. Liu et al., 2023). In this study, urban residents have already noticed this and accordingly increased their level of concern. In addition, the focus given by urban residents to the service of providing aesthetic experiences could be explained through Maslow's hierarchy of human needs (Maslow, 1970; Wu, 2013). When urban residents could fulfil their physiological and safety needs as living standards continued to rise, and had the advantage of satisfying their belongingness, love and esteem needs through more fulfilling job opportunities and more diverse and inclusive communities in cities (De Vita and Oppido, 2016; Shen and Zhang, 2021), they had more opportunities to follow with aesthetic experiences which were situated at the higher level of the pyramid of needs.

Second, in comparison with other groups, residents in semi-rural and rural areas did not attach great importance to most types of ES, and their perceptions also varied greatly. Specifically, residents in semi-rural and rural areas marked the lowest scores to 11 out of 14 ES, and the standard deviations of 12 ES were the greatest. This reflects an emerging division amongst groups of rural residents in China. The market economy and the process of urbanization has provided opportunities for rural residents to leave their villages to earn money and engage in various types of off-farm jobs. However, due to restrictions of the household registration system and social security, rural residents still found it difficult to establish a permanent foothold in cities. Eventually, with the monetary capital gained by working outside and different ideologies been exposed to, some of them decided to return, creating a plurality of employment, assets, and values within villages (He and Tong, 2002). If policy-makers continue to regard people living in rural and semi-rural areas as a homogeneous group of farmers, such social stereotype could lead to inappropriate policies and regulations. Rural residents' diversified demands and perceptions of ES should be carefully considered in policy making.

Third, in regulating services, residents in five types of areas all attached great importance to services of air purification and water purification, regarding them as the top two of regulating services. This vividly illustrates that residents' perceptions of ES were influenced by their own experiences as well as mainstream views. Zhangjiakou and Datong were exposed to serious water shortages, with average per capita water resources less than 350 m^3 and 300 m^3, respectively, which were only 20% and 15% of the national average (Zhangjiakou Municipal Government, 2021; China Water Resources News, 2022). Under such natural condition, residents had to use water of poor quality to meet their needs. So, it was intuitive to attach importance to the service of water purification, which reflects that ES perception was directly affected by local environmental characteristics and personal experience (Gonzalez et al. 2009). This is in line with the fact that ES are always context-specific. However, compared with other cities in North China that had suffered from air pollution (Rohde and Muller, 2015; Cheng et al., 2013), air quality of Zhangjiakou and Datong was maintained at a good level due to large coverage of forests and locating upwind of this basin (Xu et al., 2017). Residents also paid high attention to the service of air purification, which may be related to media coverage and publicity (Hartter, 2010). In other words, residents' perceptions were deeply affected by the mainstream views of society as well (Lamarque et al., 2011).

4.2. Residents' unique perceptions of ES in transitional areas

Different from existing research focusing on the urban-rural duality (Aguado et al., 2018), we paid additional attention to residents' perceptions of ES in areas with a medium level of urbanization along the urban-rural gradient, i.e., the transitional areas.

For provisioning services, residents in transitional areas attached a great importance to providing food and domestic water, with a higher emphasis (0.7%–13.1% and 2.4%–10.0%, respectively) compared to the other four types of areas. It reflected the adaptation of residents to the changes in production mode and life style brought by urbanization. After rural residents moved to counties in transitional areas, their dependence on natural elements such as land for their livelihood diminished, and their direct contact with natural resources also decreased (Martín-López et al., 2012; López-Santiago et al., 2014). They needed to acquire food and drinking water, which had become market commodities or government services, by purchasing with money. After taking the first step towards urbanization, when residents in transitional areas no longer obtained food by ploughing and sowing, and the source of drinking water was no longer as visible as it used to be in rural areas, they found it difficult to adapt to this change and reflect their emphasis on relevant services (Zhang et al., 2020; Cui, 2014; Yang, 2011). As the level of urbanization continued to rise, residents gradually fitted in with new livelihood strategies. At the time they realized that obtaining food and water of better quality through market was viable and did not lower their standard of living (Cumming et al., 2014), their emphasis on these two services would correspondingly decrease to the original level or even below.

For regulating services, residents in transitional areas attached a significant importance to the service of carbon sequestration and air purification, scoring 4.21 and 4.58 respectively, which were 1.2%–9.1%, 0.7%–4.6% higher than those in the other four types of areas, correspondingly. This reflected residents' concerns about the environmental issues brought by rapid industrial development and large-scale urban construction in transitional areas. In 2020, the urbanization rates of Yunzhou District, Guangling County, and Zhuolu County in transitional areas were 31.9%, 42.3%, and 46.9%, respectively. According to the S-shape curve of urbanization levels proposed by Northam (1979), transitional areas were experiencing accelerated urbanization. Industrial activities and the expansion of built-up areas not only resulted in the increased discharge of industrial waste, but carbon emissions as well, leading to increasing environmental pressure (Xu et al., 2023; Ding et al.,

2019). Compared to wastewater and waste residue, the impact of air pollution caused by waste gas was more tangible on daily life (Xu et al., 2020; Tang and Hu, 2023), so residents paid more attention to the service of air purification. As an intangible ES, the service of carbon sequestration still drew significant attention from residents in transitional areas, indicating their awareness of the intensive energy and resource usage in the process of urbanization. Although the new-type of industrialization and urbanization were highly advocated in China (Bai et al., 2014), not every place possessed the foundation of industrial structure and technological innovation, required for achieving green development and industrial structure transition, leaving traditional industries still playing an important role in the process of development (Shao and Wang, 2023; He et al., 2023; Ren and Yu, 2021).

In terms of cultural services, we found that residents in transitional areas paid greater attention to the service of providing education and training. They marked 4.11 points to the service, reaching up 1.2 times of those marked by residents in other areas. It suggested that counties in transitional areas were important carriers of the in-situ urbanization of rural residents. To acquire urban public services and educational resources, rural residents had a strong incentive to move to counties for children' s education (He, 2021). On the one hand, local government promoted the Movement of School Closure and Merger to concentrate students who were previously studying in rural schools to county schools, which increased the migration probability of rural residents (Cai and Kong, 2014; Liu and Xing, 2016). Furthermore, the intense competition caused by the concentration of students increased residents' emphasis on education. On the other hand, due to the convenience of transportation and the accessibility of information, residents in transitional areas once again turned their attention to those prestigious schools in urban areas under the influence of Halo Effect (Lin, 2023). Capitalizing on the high willingness of families to pay for their children' s education, prestigious schools in urban areas were extending their operations to counties, competing for talent students with the schools with limited local educational resources (Lei, 2021; Liu and Zhang, 2021). In summary, residents in transitional areas not only faced the educational dilemma coming from urban and rural areas, but also became involved in the competition between public and private schools within the place, all of which heightened residents' concern to the importance of education and the potential for ES to provide education and training.

4.3. Policy implications

The differences in residents' perceptions of ES and the related socio-economic factors in the Guanting Reservoir basin highlight the necessity of adapting policies on the sustainable development to local conditions. First, due to changes of land-use and land-cover in urbanizing areas, the supply of ES, particularly regulating services, has been decreasing (Long et al., 2014). The expansion of urban parks and green spaces could help reversing this trend. In addition, the needs of peri-urban and urban residents for cultural life continue to rise, so it is imperative to improve the accessibility to cultural services and its implementation in urban planning (Daniel et al., 2012; La Rosa et al., 2016). Second, as one of the crucial components of China' s administrative system, counties in transitional areas play an indispensable role in the process of in-situ urbanization of rural residents (National Development and Reform Commission of China, 2020). However, at present, counties are unable to provide services for all the newly immigrant population, and often struggle to meet people's demands for a better life, especially demands for better environment and cultural activities. In other words, such shortages in the accessibility of regulating and cultural services in counties should be substantially improved.

Urban and rural residents' different preferences and demands for ES can be coordinated using payment for ES amongst the upper, middle and lower reaches of the basin (Liu et al., 2011). In terms of the preservation of regulating services, rural areas in the upper reach of the basin invest much capital into the process of ecological rehabilitation and pollution mitigation, which sacrifices their financial profits but aims at long-term rewards for the whole area. Therefore, to safeguard the sustainable development of the basin, urban residents who benefit from these services in the lower reach might compensate for the loss that rural areas suffered (Yu and Ren, 2007).

ES play an important role in poverty alleviation (Fisher et al., 2014; Yin et al., 2022). In the context of promoting the connection between poverty alleviation and rural revitalization recently initiated in China , the diversity of rural residents in poverty should be considered to design targeted policies. For example, to the impoverished people, provisioning services play an important role in earning the living (Barrett et al., 2011), so their effect on enhancing social security guarantees in poverty alleviation should be brought into full play. As a decline in regulating services has a significant negative impact on farmers' poverty alleviation (McDermott and Schreckenberg, 2009), policy-makers should be concerned about its impact on households who cannot shake off poverty steadily and avoid them from returning to poverty due to disasters. For farmers with alternative livelihood strategies, they already had certain economic and social capital, so their ability to use cultural services to improve their own well-being should be enhanced (Yang et al., 2013).

Extra and consistent attention should be paid to services of air purification and water purification in the basin, which are widely valued by residents in areas with all levels of urbanization. To improve air quality, Datong Municipal Government and Zhangjiakou Municipal Government have both formulated action plans to consolidate the achievements in preventing and controlling air pollution (e.g., the implementation of the Air Quality Improvement Plan of Zhangjiakou, Action Plan (2018) for Preventing and Controlling Air Pollution of Datong), aiming to increase residents' sense of gain to ES. In 2019, the Air Quality Comprehensive Index, the annual average $PM_{2.5}$ concentration and the proportion of days with good air quality of Datong all ranked first in Shanxi province. The annual average $PM_{2.5}$ concentration in Zhangjiakou decreased from 35 $\mu g/m^3$ in 2014 to 25 $\mu g/m^3$ in 2019, reaching the air quality improvement target of 2022 Winter Olympic Games two years ahead of schedule (Datong Municipal Government, 2020; Zhangjiakou Municipal Government, 2020).

In terms of improving the quality of water resources in our study area, Zhangjiakou and Datong both have made sustained efforts in preventing water pollution as well as ensuring water security for rural residents, with the latter being regarded as one of the core indicators identified by the Chinese government for poverty alleviation (The State Council Information Office of PRC, 2020). As a result, the quality of drinking water in the study area has been significantly improved. By 2020, the qualified rate of centralized drinking water source in Zhangjiakou reached 100%. In 2021, the quality of urban water supply in Datong was ranked excellent throughout the year (Zhangjiakou Daily, 2021; Datong Daily, 2021).

4.4. Limitations

Based on the classification of ES by the CICES, we designed a questionnaire to investigate residents' perceptions of ES in a rapidly urbanizing basin. We revealed the differences in residents' preferences for 14 types of ES, their cognitions of four land-use types that can provide ES, and socio-economic factors affecting above perceptions. The results could be beneficial for the protection and application of ES in the basin. However, our study has three limitations to acknowledge. First, the expansion of the sample size and its diversity was required, so as to ensure the accuracy of our research, as the results of redundancy analysis are highly dependant on sample size. Second, we did not consider the influence of timing on residents' perceptions of ES in the field research since an abrupt environmental incident may temporarily change them. For example, after experiencing a severe sandstorm in spring, residents may attach more importance to services of air purification and wind-break and sand-fixation. Third, due to the characteristics implicit in the questionnaire design, the results in this study are mainly based upon qualita-

tive and semi-quantitative data. Consequently, in-depth interviews with residents in areas along the urban-rural gradient can be conducted in the future to enrich our understanding of perceptual differences in ES.

5. Conclusions

By combining the method of questionnaire survey and redundancy analysis, we delineated the urban-rural gradient in the Guanting Reservoir basin according to local residents' socio-economic characteristics. Substantial differences were found amongst residents' perceptions of ES. Generally, residents in urban and peri-urban areas paid more attention to regulating and cultural services than in transitional, semi-rural and rural areas. On the contrary, in semi-rural and rural areas, residents did not attach great importance to most types of ES, and their perceptions varied greatly. Residents in transitional areas attached great importance to provisioning services of providing food and domestic water, regulating services of carbon sequestration and air purification, and cultural service of providing education and training. Age and occupation were important factors affecting them. Along the urban-rural gradient, residents had a divergent perception of ES that can be provided by grassland.

Our findings suggest that the formulation of socio-economic policies should be not only foresighted, but also adapting to local conditions. In urbanizing areas, it is necessary to increase the supply of regulating and cultural services as residents will attach more importance to them. In urban-rural transitional areas, the environmental, educational and social issues brought by rapid urbanization have led to special needs for corresponding ES, which should be paid special attention. Regarding rural areas, policies should be appropriately applied to the practical situations of different types of households so as to implement precise support policy.

Ethical statement

Ethical approval was not required for this study since human participants were ensured following local legislation and institutional requirements. All proceeds of this research were carried out following the Helsinki Declaration principles of human subject investigation. Participation in this survey was anonymous and voluntary, assuring consent of prospective respondents before participation. Data accumulated for this research was treated confidentially.

Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Yansong Bai: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. **Qingxu Huang:** Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing. **Luis Inostroza:** Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Haoran Xu:** Data curation, Investigation, Writing – original draft. **Dan Yin:** Data curation, Investigation, Resources. **Ziwen Liu:** Data curation, Investigation, Resources. **Ling Zhang:** Data curation, Investigation, Resources. **Fangjin Xu:** Data curation, Investigation, Resources.

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Supplementary materials

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