



Perceived Importance and Bundles of Ecosystem Services in the Yangtze River Middle Reaches Megalopolis, China

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In this study, a survey with 4,580 residents in the Yangtze River Middle Reaches Megalopolis, central China, was conducted to assess the perceived importance of local ESs. Then, principal component analysis was used to identify their perceived coincidence (i.e., ES bundles), and an automatic linear model was used to reveal how the perceived ES importance and ES bundles were associated with socioenvironmental factors, including demographics, environmental awareness, and living environment. Our results showed that the provisioning ESs, especially water supply, had relatively higher perceived importance. There was no significant difference in perceived ES importance and ES bundles between experts and ordinary residents; thus, experts may recommend practices that meet the local residents' wishes in the YRMRM. In addition, we disclosed three bundles of perceived ES (i.e., green environment service bundle, ecological stability service bundle, and grain service bundle), which encompassed ES from different ES categories. Potential tradeoff existed in different ES bundles, mainly due to the divergent preferences of different residents. For example, residents with more bus services near the residence tended to perceive green environment service bundle as more important, but perceive ecological stability service bundle as less important. This study adds important first-hand empirical data to the field of the public preferences of local residents for a region of high economic and ecological importance in China, which could provide more information and scientific basis for socially just and sustainable region environmental planning and management.

Keywords: Yangtze River Middle Reaches Megalopolis, ecosystem services bundle, perceived importance, primary-school student in family, living environment

INTRODUCTION

Ecosystem service (ES), which refers to the benefit humans obtain from nature directly or indirectly, is fundamental to human survival, health, and well-being (Guerry, et al., 2015). The introduction of ES has provided a comprehensive perspective on the use and management of ecosystem and an important tool for quantifying the status of the human–nature relationship (Costanza, et al., 2014; Mikusiński and Niedziałkowski 2020). In recent years, ES research has become a central issue in the fields of sustainable development and natural-resource management (Sun, et al., 2020; Costanza,

et al., 2017). The establishment of many international initiatives such as the Millennium Ecosystem Assessment (MEA), the Economics of Ecosystems and Biodiversity (TEEB), and the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) has made a series of progress, greatly enriching the theory, concept, and application potential of ES (Costanza, et al., 2017; Díaz, et al., 2019). Many studies and uses of ES now focus on how nature benefits people directly as well as the supporting functions that enable those benefits (Wardropper, et al., 2020). These provide a solid scientific basis for the management, rational development, and utilization of natural resources.

How nature benefits people is not only influenced by the supply of ES but also driven by human needs and desires (Sun, et al., 2020). ES supply is the beneficial function supplied to the human society by ecosystems, while ES demand refers to the amount of service required by the human society, usually expressed through preferences, values, and direct use or consumption (Sun, et al., 2020; Wolff, et al., 2015). Although there are increasing calls in the scientific literature to develop comprehensive ES supply–demand frameworks for informing and supporting management decisions, most of the analytical efforts in ES research focus on ES supply (Lin, et al., 2019), economic valuation (Li, et al., 2016; Schild, et al., 2018), and identification/quantification of their impact factors such as land use/cover change (Zhang, et al., 2018; Zank, et al., 2016) and climate change (Underwood, et al., 2019; du Toit, et al., 2018). Limited studies have approached the demand side of ES (Chen, et al., 2018), leading to a mismatch in the considerable conceptual understanding of the ES concept for sustainable region environmental planning and management (Khosravi Mashizi and Sharafatmandrad 2021). Social demand for ESs varies among different groups of stakeholders (Bolaños-Valencia, et al., 2019). It can be regarded as the importance of certain ES to different stakeholders (Xu, et al., 2020) or the expectation and preference level of different stakeholders for certain ES (Villamagna, et al., 2013). For example, Xu et al. (2020) estimated the residents' demand for ESs by self-reported ratings on ESs' importance. How different stakeholder groups prioritize ESs is one of the core contents of ES demand investigation.

Several factors affect stakeholders' attitude toward the ES importance, related to 1) demographic profile (e.g., income, age, gender, and education) (Dou, et al., 2017; Graça, et al., 2018; Dou, et al., 2019; Garrido, et al., 2017), 2) environmental awareness (e.g., ecological worldview) (Wardropper, et al., 2020), and 3) living environment (e.g., living in periurban areas and proximity to forest) (Mikusiński and Niedziałkowski 2020; Riechers, et al., 2018). For instance, Lau et al. (2018) found that the wealthiest fishers would prioritize improvements in habitat ecosystem services and recreational benefits more than the others. Muhamad et al. (2014) found that living close to forests can enhance people's perception of ESs. However, those variables have different effects across different regions. Reasons for the differences may be related to the local sociocultural characteristics. The family-oriented concept is an important characteristic of socioculture in China. Primary-school

students may influence their parents' environmental behavior and had a positive impact on ES (Torkar and Krašovec 2019). The household variable such as a primary-school student in the family should be considered. In addition, living environment factors play an important role on perceived ES importance, which was related to the accessibility (Mikusiński and Niedziałkowski 2020). Therefore, consideration of living environment factors including traffic and land cover near residence can uncover the influence of geographical factors comprehensively. Furthermore, there may be differences in the attitudes of experts and ordinary residents toward the ESs. The unaccounted differences can lead to management problems, as experts may recommend practices that do not meet the laypersons' wishes (Riechers, et al., 2016; Karstens, et al., 2019; Schernewski, et al., 2018). Therefore, it is necessary to know whether there are differences in perceived ESs importance between experts and ordinary residents.

Understanding how people group, or “bundle,” diverse types of ES was also key to equitable policy and decision making around environment conservation (Wardropper, et al., 2020). ES bundle, defined as sets of consistently associated ES, draws attention to the complex associations among multiple services (Zoderer, et al., 2019; Liu, et al., 2019). Investigating a diversity of people who prioritize ESs and identifying ES bundles as perceived by residents can bolster the case for context-specific evaluations of social demand for ESs to inform planning and management. Zoderer et al. (2019) identified four main ES demand bundles by stakeholders' perception. The ES bundle analysis can identify and quantify ES associations across stakeholders (Wolff, et al., 2015). In addition, conflicts can emerge when stakeholders have different needs and priorities for ES bundle. Understanding the shape of ES bundles can provide a scientific basis for sustainable region planning and management.

The planers in the Yangtze River Middle Reaches Megalopolis (YRMRM), an important region in central China with rapid economic development and a high level of biodiversity, are facing challenges to balance economic development and environmental protection, as well as to guarantee the sustainability of ES provision and implementation of the ‘the Yangtze River Protection’ strategy. Previous studies have determined environmental performance and governance of Yangtze River urban agglomeration (Peng, et al., 2020; Peng, et al., 2019; Wang, et al., 2019; Odhiambo, et al., 2020; Huang, et al., 2021). Some studies also focused on agriculture for the estimation of resources, climatic, and institutional barriers in the land use (Peng, et al., 2020; Elahi, et al., 2018; Elahi, et al., 2020; Elahi, et al., 2019; Elahi, et al., 2021). However, limited studies focused on ecosystem services in the Yangtze River Middle Reaches Megalopolis, China. For example, the ES research in the YRMRM mainly focuses on the ES supply (Zhang, et al., 2018) and the reason for ES decrease (e.g., urbanization or land use change) (Zhang, et al., 2020; Zheng, et al., 2019). There are increasing calls for multiple perspectives of ES research (e.g., public preference and ES bundles) to provide more detailed information for regional environmental planning and management.

Therefore, the current study aimed to seek answers to the following three questions: 1) Are there any differences in attitude between experts and ordinary residents toward the importance of

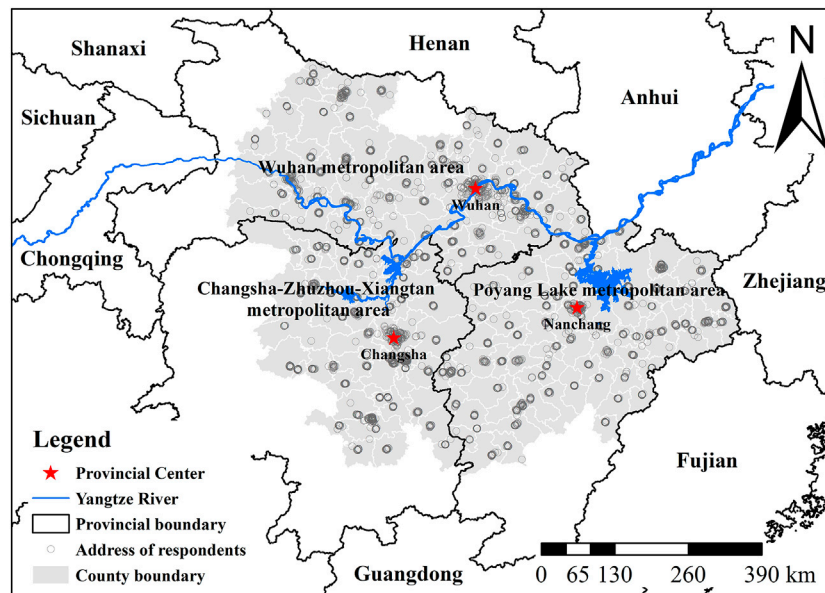


FIGURE 1 | Study area.

ESs? 2) What were the ES bundles as perceived by residents? 3) How were socioenvironmental factors (i.e., demographic, environmental awareness, and living environment factors) related to ES bundles? Here, we designed a questionnaire to assess the perceived importance of ESs in the YRMRM, identify the ES bundles as perceived by residents, and disclose the influence of demographics (e.g., a primary-school student in the family), environmental awareness (i.e., residents' environmental behavior), and living environment factors (e.g., the number of bus services and the extent of farmland, water, grassland, and forest near residence) on perceived ES importance and ES bundles. Our results enrich the understanding of how different local residents prioritize and group, or "bundle," diverse types of ES, which is conducive to sustainable region environmental planning and management in the YRMRM.

METHODS

Study Area

The Yangtze River Middle Reaches Megalopolis (YRMRM) in the central part of China consists of 229 counties in 31 prefecture-level cities in Hubei, Hunan, and Jiangxi provinces (Figure 1). In 2018, the extent of the YRMRM was about 326,100 km², with a total population of 133.4 million and a regional gross product of 8.50 trillion CNY (1.28 trillion USD with an exchange rate of 0.151 in 2018). It has created 9.4% of the overall economic output in China with 3.4% of the land area and 9.6% of the population in 2018. Furthermore, the State Council of China announced the guidance on September 25, 2014, which relies on the golden waterway (i.e., the Yangtze River) to promote the development of 'The Yangtze River Economic Zone' (Chen, et al., 2017). The YRMRM was ushered in a boom of development (Zhang, et al.,

2020). The YRMRM also showed an increasing population with a great variety of sociodemographic characteristics such as age, wealth, and migration background by urban growth (Zheng, et al., 2020; Tan, et al., 2014) and, thus, has resulted in a higher demand and value pluralism for ESs (Wardropper, et al., 2020; Zhang, et al., 2021). In addition, the YRMRM has rich biodiversity with subtropical monsoon climate. The research of local residents' attitude toward ESs in the YRMRM is of great importance since the results could provide a valuable reference for ecosystem management and prevention in other cities in China.

Survey Design and Implementation

A questionnaire was designed to explore residents' attitude toward ESs by asking participants to rate how important a certain type of ES is in the YRMRM. Following the work of Costanza et al. (2014) and Xie et al. (2017), 11 ecosystem services were chosen as our research objects (Table 1). ESs were categorized into four categories, namely, provisioning ES, regulating ES, supporting ES, and cultural ES (Xie, et al., 2017). The participants were asked 1) to rate on a scale of zero to five the importance of ESs (i.e., 0: not at all important; 1: slightly important; 2: important; 3: fairly important; 4: very important; and 5: extremely important) and 2) to provide individual information on gender, age, education, occupation, income, household composition, address, years of residence, and environmental awareness. The environmental awareness of residents was characterized by their environmental behavior: 1) Does their job involve environmental protection and management? 2) Are they educated or trained on environmental protection? 3) Are they volunteering for environmental protection causes? 4) Are they the member of a conservation organization? 5) The frequency of outdoor activities

TABLE 1 | Perceived importance of ESs (average, with SE); SE: standard error.

Category of ESs	ESs	Expert (n = 270)	Resident (n = 4,310)	All (n = 4,580)	
		Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Provisioning	Food supply	4.02 ± 0.07	4.06 ± 0.02	4.06 ± 0.02	3.97 ± 0.01
	Raw-material supply	3.59 ± 0.07	3.61 ± 0.02	3.60 ± 0.02	
	Water supply	4.23 ± 0.06	4.24 ± 0.01	4.24 ± 0.01	
Regulating	Air quality regulation	3.93 ± 0.06	3.84 ± 0.02	3.84 ± 0.02	3.68 ± 0.01
	Climate regulation	3.87 ± 0.06	3.89 ± 0.02	3.89 ± 0.01	
	Waste treatment	3.72 ± 0.06	3.80 ± 0.02	3.80 ± 0.01	
	Water flow regulation	3.76 ± 0.06	3.69 ± 0.02	3.70 ± 0.01	
	Erosion prevention	3.33 ± 0.05	3.33 ± 0.01	3.33 ± 0.01	
	Nutrient cycle maintenance	3.58 ± 0.06	3.52 ± 0.01	3.53 ± 0.01	
Supporting	Biodiversity	3.33 ± 0.05	3.31 ± 0.01	3.31 ± 0.01	3.31 ± 0.01
Cultural	Cultural service	3.31 ± 0.06	3.29 ± 0.02	3.29 ± 0.02	3.29 ± 0.02
Total		3.70 ± 0.03	3.69 ± 0.01	3.69 ± 0.01	3.69 ± 0.01

in green spaces (Potgieter, et al., 2019). The addresses of respondents are shown in **Figure 1**.

The questionnaire was conducted in July 2019 with final 4,580 samples. It was collected from 229 county-level divisions (municipal districts and counties) in the YRMRM with 20 per county. Data collection has collaborated with Suzhou Zhongyan Network Technology Co., Ltd., a professional online survey service provider maintaining a giant participant pool of around 45 million active web surfers, covering almost every county and municipal district in Mainland China (Tian, et al., 2020).

Data Analysis Steps

Obtaining Influence Factors

Experts (different from ordinary residents) were defined as those who have obtained relevant theoretical and practical experience with various issues of environmental protection and management through working as a manager, head, or technician in an organisation closely related to environmental protection and management (Riechers, et al., 2016; Zhang, et al., 2021). In this study, experts meet two aspects of occupation and environmental behavior: 1) they are the head of an organization, managers, experienced professionals, or technicians; 2) their job is directly involved in the environmental protection and management sector. As a result, 270 local experts were selected from 4,580 questionnaires (**Table 1**).

The influencing factors, including demographic, environmental awareness, and living environment, are summarized in **Supplementary Table S1**. The demographic and environmental awareness factors were descriptively summarized from 4,580 questionnaires. Living environment factors were characterized by public traffic (i.e., the number of bus services near residence) and land cover (i.e., farmland, water, grassland, and forest) near residence. The residential address was converted into longitude and latitude by geocoding and then

converted into a point as shown in **Figure 1**. Then, living environment factors were calculated by using a 1.5 km buffer region of address to count the corresponding land cover and bus services in ArcGIS software (version 10.5).

The land cover data covering the whole of the YRMRM for the year 2015 were purchased from the Data Centre for Resources and Environmental Sciences, Chinese Academy of Sciences (RESDC) (<http://www.resdc.cn>). These datasets were produced at 30 m resolution though expert knowledge-based interpretation of Landsat images (Liu, et al., 2005). The bus service data were downloaded from the RESDC (<http://www.resdc.cn>).

Statistical Analyses

We first applied a descriptive analysis to evaluate the perceived importance of ESs in SPSS 26 (IBM Deutschland GmbH, Ehningen, Germany). The differences in perceived ESs importance between experts and residents were also compared.

Second, associations between perceived ESs importance were examined using Pearson's correlation coefficient (Ko and Son 2018). The principal component analysis (PCA) was conducted to derive the sets of associated ES importance that were frequently perceived together (i.e., ES bundles) (Zoderer, et al., 2019). PCA studies how to reveal the internal structure of multiple variables through a few principal components, that is, to derive a few principal components from the original variables and make them retain as much information as possible. Variance was used to express the principal component; that is, the greater the variance, the more information the principal component contains.

Third, an automatic linear model (i.e., an advanced version of the multivariate linear regression method) was used to reveal the relationship between socioenvironmental factors and ES bundles in SPSS 26 (IBM Deutschland GmbH, Ehningen, Germany). The automatic linear model is a data mining approach similar to regression trees, which utilises machine learning to find the best predictive model by automatic variable selection and automatic data preparation (Panneerselvam, et al., 2021). The steps for the

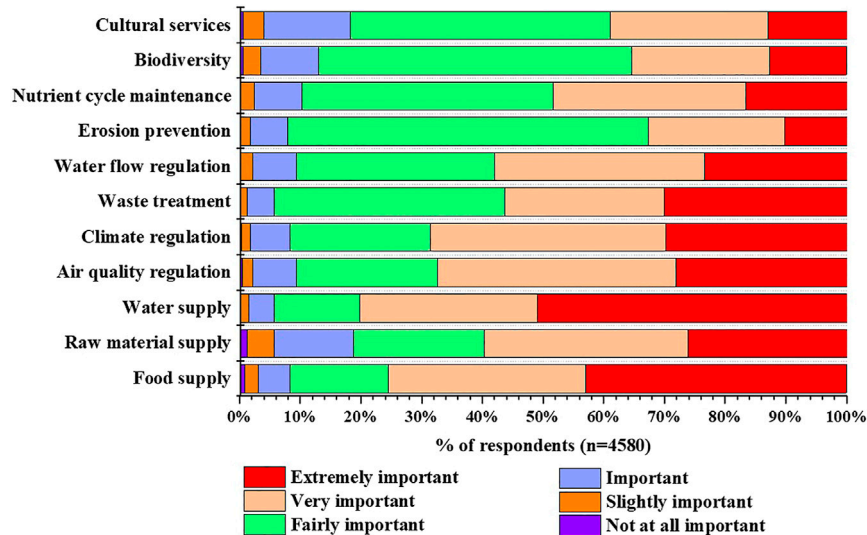


FIGURE 2 | Proportion of ESs perceived importance.

automatic linear model are as follows: 1) preliminary data processing; 2) replacing missing data values; 3) determining the quality predictor; 4) identifying outliers; and 5) calculation of the stepwise model and coefficient of determination (Panneerselvam, et al., 2021). Results of the model showed the effect coefficients and its variable importance. The important predictors were identified by the rank of variable importance. Similarly, the influence of socioenvironmental factors on perceived ES importance was also revealed by the automatic linear model, as shown in **Supplementary Table S3**. All categorical variables were converted into dummy variables before statistical analysis.

RESULTS

The Perceived Importance of Various Ecosystem Services in the YRMRM

There was no significant difference in averaged perceived ES importance between experts and ordinary residents in the YRMRM (**Table 1**). This showed that, on the whole, the attitude of experts and residents toward the ESs importance was consistent, while for the individual ES, experts' perceived importance of air quality regulation, water flow regulation, and nutrient cycle maintenance were larger than that of ordinary residents. Ordinary residents' perceived importance of waste treatment and food supply was larger than that of experts. Compared with experts' attitude toward ESs, ordinary residents prefer provisioning services (**Table 1**). This led to a slight difference in the ES importance ranking between experts and ordinary residents in the YRMRM.

For all respondents, the averaged perceived ES importance was greater than 3 (i.e., fairly important) (**Table 1**). Provisioning ESs (including food, raw material, and water supply) was rated the most important, followed by regulating ESs, supporting ESs, and

cultural ESs (**Table 1**). The averaged perceived ES importance (3.69) was greater than that of regulating, supporting, and cultural ESs. The ESs with the greatest perceived importance were water supply, food supply, and climate regulation, whereas cultural service, biodiversity, and erosion prevention were the lowest.

The 6-point scale distribution of perceived importance was different in 11 types of ESs (**Figure 2**). As a whole, 25.9% of the residents perceived ESs as extremely important. More specifically, most of the residents believed that food supply (42.9%) and water supply (51%) were extremely important. On average, 40% of the residents believed that provisioning ESs was extremely important, while 23.2% perceived regulating ESs as extremely important. In contrast, 0.4% of the residents perceived ESs as not at all important. For individual ES, 1.2% of the residents perceived raw material supply as not at all important, followed by food supply (0.8%) and cultural service (0.6%).

Ecosystem Service Bundles

Strong positive associations were observed between perceived importance within and across ES categories (**Supplementary Table S2**). For example, Pearson's coefficient between the perceived importance of food supply and raw material supply was 0.45 in provisioning ESs. Among regulating ESs, the perceived importance of air quality regulation, climate regulation, water flow regulation, and nutrient cycle maintenance had a strong correlation. In addition, perceived water supply importance was strongly positively correlated with the perceived importance of air quality regulation, climate regulation, water flow regulation, and nutrient cycle maintenance. This showed that when residents in the YRMRM perceived one ES as highly important, they would also tend to perceive other ESs as highly important.

By the use of principal component analysis (PCA), we were able to detect three bundles of perceived ESs: the green

TABLE 2 | Principal component analysis (PCA) of ES perceived importance.

	Green environment service bundle (component 1) 29.5%	Ecological stability service bundle (component 2) 12.9%	Grain service bundle (component 3) 10.5%
Food supply	0.158	0.18	0.765
Raw-material supply	0.14	0.104	0.831
Water supply	0.583	0.393	0.005
Air quality regulation	0.637	0.307	0.039
Climate regulation	0.627	0.315	0.071
Waste treatment	0.386	0.372	-0.13
Water flow regulation	0.676	0.029	0.147
Erosion prevention	0.001	0.782	0.119
Nutrient cycle maintenance	0.687	-0.233	0.264
Biodiversity	0.049	0.675	0.267
Cultural service	0.589	-0.192	0.194

ESs perceived importance with factor loadings above a value of 0.38 are shown in bold and further referred to as components of the ESs bundle.

TABLE 3 | Automatic linear model of ES bundles on socioenvironmental variables, showing standardized beta coefficients with significant levels (parsimonious models).

Socioenvironmental factors		Green environment service bundle		Ecological stability service bundle		Grain service bundle	
		Coefficient	Variable importance	Coefficient	Variable importance	Coefficient	Variable importance
Demographics	Male	0.06 ^a	0.04				
	Age			-0.01 ^b	0.08	0.01 ^b	0.10
	Education						
	Senior high school or below	0.08 ^a	0.04				
	Master's degree or above	-0.18 ^a	0.04				
	Occupation						
	II	-0.13 ^c	0.09				
	III					-0.15 ^b	0.09
	VI			-0.12 ^b	0.08		
	Income						
<3,000 yuan/month	-0.19 ^c	0.26					
3,000–10,000 yuan/month			-0.14 ^c	0.20			
Primary-school student in the family	0.06 ^a	0.03	-0.15 ^c	0.26	-0.15 ^c	0.33	
Years of residence					0.02 ^c	0.18	
Environmental awareness	Frequency						
	<3 times/month	0.30 ^c	0.22	0.09 ^b	0.11		
	1–5 times/week	0.14 ^a	0.05			-0.07 ^a	0.07
Living environment	Bus services near residence	0.08 ^c	0.24	-0.05 ^c	0.13		

^ap < 0.05.

^bp < 0.01.

^cp < 0.001. "II" = professional and technical personnel (science and engineering, medical, education, management, social sciences, etc.), "III" = civil servants (safety and fire, administrative affairs, people's police, etc.), "VI" = manufacturing and related personnel (processing of agricultural and sideline products, industrial production, etc.).

environment service bundle, the ecological stability service bundle, and the grain service bundle (Table 2). The green environment service bundle (explaining 29.5% of the total variance) was characterized by a high positive loading of water supply, air quality regulation, climate regulation, waste treatment, water flow regulation, nutrient cycle maintenance, and cultural service. The second component, the ecological stability service bundle, explained 12.9% of the total variance and was positively related to erosion prevention and biodiversity. The grain service bundle (accounting for 10.5% of the total variance) was characterized by the supply of food and raw material.

Generally, the green environment service bundle mainly consisted of a mix of regulating ESs and cultural service. Ecological stability service bundle mainly consisted of a mix of regulating ES (i.e., erosion prevention) and supporting ES. Grain service bundle mainly consisted of provisioning ESs.

Factors Influencing the Ecosystem Service Bundles

Demographics, environmental awareness, and living environment factors shaped ES bundles (Table 3). In the

demographic pattern, demographic factors influence the ES bundles differently. For example, a primary-school student in the family was found to be positively associated with the green environment service bundle, but negatively associated with the ecological stability service and grain service bundle. A male student was positively associated with the green environment service bundle, but had no effect on the ecological stability service and grain service bundle. In the environmental awareness pattern, a lower frequency of outdoor activities in green spaces was found to be positively associated with ES bundles. Other environmental awareness factors (e.g., the work related to environmental protection and management) had no effect on ES bundles. This showed that there was no difference in perceived ES bundles between experts and ordinary residents. In the living environment pattern, bus services near residence was positively associated with the green environment service bundle, but negatively associated with the ecological stability service bundle. The extent of farmland, forest, water, and grassland near residence had no effect on ES bundles, while for the perceived importance of individual ES, the influence of the extent of farmland, forest, water, and grassland near residence was significantly different (**Supplementary Table S3**). For example, the extent of forest near residence was positively associated with the perceived importance of erosion prevention and biodiversity. The extent of water and grassland near residence was negatively associated with the perceived importance of air quality regulation and water flow regulation, respectively.

The important predictor rankings based on the variable importance are also shown in **Table 3**. Income, a primary-school student in the family, frequency of outdoor activities in green spaces, and bus services near residence were found as the top important predictors of ES bundles. The group with higher income, a primary-school student in the family, lower engagement level of outdoor activities in green spaces, and more bus services near residence tended to perceive the green environment service bundle as more important. The group with no primary school student in the family, less bus services near residence, and lower engagement level of outdoor activities in green spaces tended to perceive the ecological stability service bundle as more important. The group with no primary school student in the family and more years of residence tended to perceive the grain service bundle as more important.

DISCUSSION

Identifying how different people groups value and prioritize ESs is a key step for equitable environmental management, which is not only morally imperative but also critical to the success of protection or management (Lau, et al., 2018; Aryal, et al., 2021; Guenat, et al., 2021). However, many conservation practices and ES studies assume that stakeholder groups are homogeneous, easy to identify, and only need to be classified (Lau, et al., 2018; Reed 2008). In this study, we assessed the perceived ES importance in the YRMRM by comparing the opinions of local experts ($n = 270$) and residents ($n = 4,310$) and identified the ES bundles. In addition, we paid specific attention on

the influence of demographic (e.g., a primary-school student in the family), environmental awareness (i.e., residents' environmental behavior), and living environment factors (e.g., the number of bus services and the extent of farmland, water, grassland, and forest near residence) on the perceived importance and bundles of ESs. Our results disclosed how different local residents prioritize and group, or "bundle," diverse types of ES in the YRMRM, which could provide a scientific basis for socially just and sustainable region environmental planning and management.

We found that there was no significant difference in averaged perceived ESs importance between experts and ordinary residents. This showed that experts may recommend practices that meet the local residents' wishes well in the YRMRM while a slight difference existed in the perceived importance of individual ES. For example, experts' perceived importance of regulating ESs was larger than that of ordinary residents. This may be because experts pay more attention to the stability of the ecosystem. In addition, our results showed a maximal perceived importance score on provisioning ESs, especially water supply, followed by regulating ESs, supporting ESs, and cultural ESs (**Table 1**), which showed similar results. For example, Mensah et al. (2017) found that supporting and provisioning ESs were rated the most important, followed by regulating and cultural ESs in local communities of South Africa. In most cases, supporting services are of priority (Lau, et al., 2019). The reasons for the differences may be related to the wide water area in the YRMRM (e.g., the Yangtze River, Dongting Lake, and Poyang Lake). Our previous study also showed that the land use with the highest per unit area ecosystem service value was the water area in the YRMRM (Zhang, et al., 2021).

The perceived ES importance refer to the resident's preference or need for ES, which is an important part of ES demand (including sociocultural and economic characteristic) (Castro, et al., 2014). A higher ES importance means a greater demand for ES (Xu, et al., 2020). A diversity of people who prioritize and group ESs differently can reflect the tradeoff of stakeholders in ES demand to a certain extent. In this study, we identified three ES bundles (i.e., green environment service, ecological stability service, and grain service bundle) as perceived by residents, which can be regarded as ES demand bundles to a certain extent. This was different from (Zoderer, et al., 2019) identifying four main ES demand bundles. Stakeholders differ in terms of their expressed demand for ES bundles (Zoderer, et al., 2019). The ES bundles identified by residents generally encompassed ES from different ES categories, as was particularly the case for the green environment service bundle, which consisted of a mix of provisioning ESs (i.e., water supply), regulating ESs (i.e., air quality regulation, climate regulation, waste treatment, water flow regulation, and nutrient cycle maintenance), and cultural service. Compared with ES categories, a deeper understanding of how ESs are bundled together can improve the ability to manage multiple ESs precisely (Shen, et al., 2020).

ES bundles were significantly linked to the respondents' sociodemographic background and environmental behaviour variables (Zoderer, et al., 2019). Here, factors of 'income, a primary-school student in the family, frequency of outdoor activities in green spaces, and bus services near residence' were identified as the top important predictors of ES bundles. For example, a primary-school student in the family was found to be

positively associated with the green environment service bundle. For individual ES, residents with a primary-school student in the family gave high score to the perceived importance of food supply, raw material supply, erosion prevention, and biodiversity (**Supplementary Table S3**). Primary-school students can influence their parents' environmental behavior and had a positive impact on ES (Torkar and Krašovec 2019). This may be the effect of 'small hand holding big hand.'

In addition, we also found that a potential tradeoff existed in different ES bundles, mainly due to the divergent preferences by different residents. More bus services near residence tended to perceive the green environment service bundle as more important, but perceive the ecological stability service bundle as less important. For the individual ES, residents with more bus services near residence gave high score to the perceived importance of water supply, climate regulation, water flow regulation, nutrient cycle maintenance, and cultural service (**Supplementary Table S3**). Convenient transportation improves the accessibility of residents, thus making it possible for residents to give ES high importance. Furthermore, we found that the extent of forest near residence was positively associated with the perceived importance of erosion prevention and biodiversity. Riechers, et al. (2018) also found positive correlations between cultural services and distance to urban green spaces. Living close to forests can enhance people's perception of ecosystem services (Muhamad, et al., 2014). For farmland, people with a larger extent of farmland near residence gave high score to the perceived importance of erosion prevention and biodiversity. The less the distance from the residence to the farmland, the more the effect of ecological environment improvements (e.g., erosion prevention and biodiversity) for them, which leads to an increase in their perceived importance. In this way, the spatial distributions of social groups and their perception of ES can be one way in which the urban development and landscape planning can be informed (Riechers, et al., 2018).

There are several limitations in this study, which could be improved in future studies. First, the survey respondents in this study were only adults (18–60 years old) and did not include children. The variable of a 'primary-school student in the family' indirectly rather than directly expresses the role of children in perceived ES importance. For more detailed cases, Torkar and Krašovec (Torkar and Krašovec 2019) found that female students expressed attitudes that are more positive toward forest-supporting ecosystem services than male students. Second, the contingent valuation technique using WTP and WTA remains a widely used approach to achieve a monetary estimation of ecosystem services (Xu, et al., 2020). Such an approach can be used to quantify the value of ES bundle from a monetary perspective, which is an important research field. Third, our results lack the spatial distribution of ES importance. Combined with spatial heterogeneity factors (Xie, et al., 2017), the spatial and temporal distribution of ES importance can be characterized. Fourth, ES demand can be regarded as 1) the importance of certain ES to different stakeholders (Xu, et al., 2020), 2) land development index (Zhai, et al., 2020), and 3) the amount of resource consumption (Cui, et al., 2019) for different

research purposes. An integrated method by engaging stakeholders for sociocultural assessment and including economic assessment and explicit recognition of spatial and temporal processes can improve existing methods for future evaluations of ES demand.

CONCLUSION

In this study, we assessed the perceived ES importance and ES bundles in the YRMRM and revealed their relationship with socioenvironmental factors, including demographics, environmental awareness, and living environment. ESs were perceived as more than 'fairly important,' and the water supply had the highest perceived importance. There were strong positive associations between ES perceived importance, and three ES bundles (i.e., green environment service, ecological stability service, and grain service bundle) were identified by the perception of residents. A tradeoff existed in different ES bundles due to the divergent preferences of different residents. Residents with higher income, a primary-school student in the family, lower engagement level of outdoor activities in green spaces, and more bus services near residence gave high score to the green environment service bundle. In addition, a primary-school student in the family was identified as the top important factor influencing both the perceived ES importance and ES bundles. This highlights the role of local sociocultural characteristic in evaluations of ES demand. Bus services near residence shaped the ES bundles, which was related to the accessibility. Our work further illustrates the need to incorporate living environment factors into the understanding of public preferences for sustainable regional management. Our main limitation was that the results lack the spatial distribution of ES importance. An integrated method by engaging public preferences and explicit recognition of spatial and temporal processes can improve existing methods for future ES evaluations.

IMPLICATIONS

This study has important implications for managers, policy makers, and other decision makers of regional sustainable development. First, although experts may recommend practices that meet the local residents' wishes in general, the slight difference in the attitude of experts and residents toward the perceived ES importance should be considered in decision making. Second, in the living environment pattern, bus services near residence were found as the important drivers of perceived ES importance and ES bundles. Developed public transport (i.e., bus) may also increase the frequency of green outdoor activities, which is conducive to improving the score of perceived ES importance and ES bundles. In addition, the extent of farmland, water, grassland, and forest near residence shaped the perceived importance of specific ES, respectively. This also provides some useful information for sustainable region environmental planning. Third, the green environment service bundle (explaining 29.5% of the total variance) was identified by

the perception of residents, which reflected people's demand direction to a certain extent. The construction of urban greening may help to improve the perceived importance of ES. Fourth, environmental protection education covering both adults and children may enhance the effect of 'small hand holding big hand' to improve perceived ES importance.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**; further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

GZ: conceptualization, methodology, data curation, software, and writing—original draft preparation; XZ: data curation,

investigation, and visualization; LX: data curation, investigation, and visualization; QZ: data curation and investigation; DL: data curation and investigation; HW: supervision; SL: supervision, conceptualization, methodology, and writing—reviewing and editing.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fenvs.2021.739876/full#supplementary-material>

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