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Milder, wilder, drier: Understanding preferences for urban nature-based solutions in China

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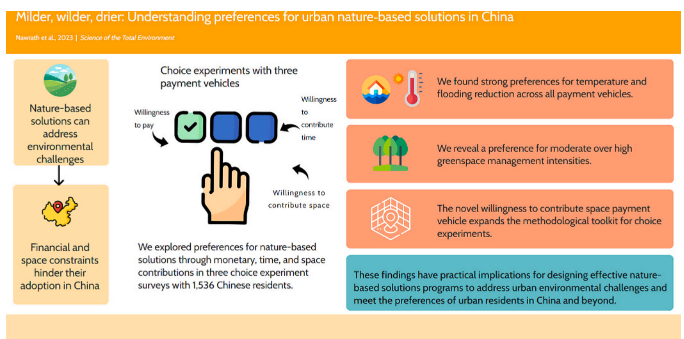
HIGHLIGHTS

- Strong preferences for temperature and flood reduction through nature-based solutions in China
- Novel approach capturing individuals' willingness to contribute privately owned space for implementing nature-based solutions
- Willingness to contribute space payment vehicle expands methodological toolkit for choice experiments
- Chinese public is willing to accept lower greenspace management intensities
- Potential for biodiversity benefits through lower greenspace management intensities

GRAPHICAL ABSTRACT



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ABSTRACT

Nature-based solutions have gained recognition for their potential to address urban environmental challenges, particularly in rapidly urbanising countries such as China. However, financial and spatial constraints hinder their widespread adoption. Here we explore urban residents' preferences for nature-based solutions targeting stormwater management, urban heat island reduction, and biodiversity support through monetary, time, and space contributions. We carried out three choice experiment surveys with 1536 Chinese respondents, employing three payment vehicles: willingness to pay (WTP), willingness to contribute time (WTCT), and a novel metric, willingness to contribute space (WTCS). The WTCS metric assesses individuals' willingness to voluntarily convert sealed surfaces on private land into greenspace. We found strong preferences for temperature and flooding reduction across all payment vehicles, reflecting substantial challenges of urban heat islands and flooding in China. Additionally, we reveal a preference for moderate greenspace management intensity, highlighting the potential for biodiversity benefits through reduced management intensities. The introduction of the WTCS payment vehicle expands the methodological toolkit for choice experiments and offers a novel approach to assess citizen support for nature-based solutions. These findings have practical implications for designing effective nature-based solutions programs to address urban environmental challenges and meet the preferences of urban residents in China and beyond.

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1. Introduction

With more than half of the world's population living in cities, urban areas are major contributors to sustainability challenges. Current urban growth and densification, and the associated increase in impervious surfaces increasingly strain existing stormwater systems, yielding high flood rates, exacerbating the urban heat island effect, and degrading urban habitats with negative implications for biodiversity (Yeakley et al., 2014). Nature-based solutions are increasingly being embraced as one route towards simultaneously addressing these urban environmental challenges (Nesshöver et al., 2017) which are rapidly rising to the top of the sustainable urban development agenda (Cousins, 2021). Nature-based solutions have been defined as "actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services and resilience and biodiversity benefits (UNEP, 2022). Nature-based solutions in cities include ecosystem restoration, the greening of grey surfaces, and integrated climate change mitigation measures such as afforestation, natural flood control, or constructing wetlands (European Commission, 2015; van den Bosch and Sang, 2017). Nature-based solutions act as an umbrella concept, incorporating concepts such as blue-green infrastructure and ecosystem services (Cohen-Shacham et al., 2016). There is evidence of nature-based solutions across a broad range of typologies supporting benefits in multiple ecosystem functions, including stormwater management, water quality mitigation, urban heat island reduction and biodiversity support (Jones et al., 2022). It is common to achieve secondary/non-target benefits alongside improvements in the primary intended target; for example, nature-based solution establishment to reduce flooding will typically also benefit water quality and aquatic ecology. Cities worldwide are using nature-based solutions as part of urban greening interventions such as parks, municipal or community gardens, rain gardens and bioswales, green roofs and walls, green streets, and restored waterways. In general, such greening interventions involve the restoration or clean-up of degraded, abandoned, or underused urban landscapes (i.e. public or private urban land) and their transformation into greening projects that redefine an area (Anguelovski et al., 2018; Wachsmuth and Angelo, 2018). The implementation of nature-based solutions in urban areas is further supported by many policy and research schemes such as the US Environmental Agency's Green infrastructure program, the 2013 European Union Strategy on Green Infrastructure, or the United Nation's Sustainable Development Goal 11 (to make cites, inclusive, safe, resilient, and sustainable; Anguelovski et al., 2020), and China's Sponge city Programme (Chan et al., 2022a).

Rapidly urbanising countries such as China are particularly affected by these urban challenges (National Bureau of Statistics of China, 2014). China's large-scale urbanisation started in the 1980s with a rapid increase in the urban population from 19 % in 1980 to 64 % in 2022 (World Bank, 2023). Moreover, China's built-up area increased nearly five-fold from 1981 to 2011 (National Bureau of Statistics of China, 2014). Combined with the effects of climate change, this trend has resulted in many Chinese cities facing urban sustainability challenges, including stormwater flooding, a high frequency of extreme weather events, water quality deterioration, increased urban heat island effect, and negative impacts on urban biodiversity (Chen et al., 2016; Ding et al., 2022). Among these, urban flooding is one of the most frequent and hazardous challenges with severe economic, environmental, and social costs (Chang et al., 2013; Zevenbergen et al., 2008; Zhou et al., 2012). Survey data indicate that 62 % of Chinese cities experienced flooding during the last decade, and direct economic losses amounted to up to US$ 100 billion between 2011 and 2014 (National Bureau of Statistics of China, 2014). For example, in 2021 devastating floods in Zhengzhou, a city with a population of 12 million, caused an estimated direct economic loss of more than ¥ 65.5 billion (~ € 8.3 billion) and substantial loss of life (Fu et al., 2023). Similarly, the capital city Beijing was overwhelmed by floods in 2023 with devastating economic and human losses (Al Jazeera, 2023). Nature-based solutions can play a significant role in mitigating the risk of flooding (Lallemant et al., 2021; Zimmermann et al., 2016), offering a promising pathway towards reducing the effects of projected future climate and land-use changes in countries such as China (CRED, 2015).

The urban heat island, referred to as the phenomenon that urban areas tend to have higher temperatures than surrounding areas (Zhou et al., 2015), can have negative impacts on water and air quality, microclimatology, vegetation growth (Dixon and Mote, 2003; Grimm et al., 2008; Shepherd, 2005) and human health (e.g. increased morbidity and mortality, risk of preterm birth; Grimm et al., 2008; O'Loughlin et al., 2012; Patz et al., 2005; Ren et al., 2023; Wu et al., 2012). China's urban areas have been expanding at a rate of 13.3 % annually (Zhang and Su, 2016). Moreover, temperatures in China are rising due to climate change. For instance, in 2023 a new extreme weather record of over 52 °C measured in northwestern China has been reported (Reuters, 2023). Therefore, urban heat island intensity has increased substantially in Chinese cities over the last decades (Lee et al., 2019), posing immense challenges to ecosystems and human health. Nature-based solutions have been shown to mitigate urban heat islands, thereby improving the health and well-being of urban residents (Liu et al., 2022).

China is one of the most biodiverse countries in the world (Güneralp et al., 2015). Land changes associated with China's large-scale urbanisation fragment or destroy habitats (McKinney, 2006), thus adversely impacting urban biodiversity (He et al., 2014). Moreover, evidence suggests that most provinces in China are expected to experience urban expansion either near protected areas or within biodiversity hotspots, making biodiversity conservation a pressing issue in contemporary Chinese cities (Güneralp et al., 2015). Further, as Chinese cities become more human-dominated and denser, residents are increasingly disconnected from biodiverse nature in their daily lives, threatening people's physical and mental health (He et al., 2023; Yuan, 2021). The management of urban greenspaces has been recognised as a critical component for enhancing urban biodiversity (Aronson et al., 2017; Müller et al., 2010). While biodiversity can exist in highly managed greenspaces, evidence suggests that reduced management intensities can support higher levels of biodiversity (Müller et al., 2018; Rudolph et al., 2017; Watson et al., 2020). Indeed, societal interest in reduced greenspace management intensities has been growing for a range of practical and normative reasons (Buck, 2015), such as reducing management costs and halting biodiversity losses. However, prioritising biodiversity through reducing management intensities may compromise the perceived appropriateness of greenspaces for recreation (Fischer et al., 2020). Studies on the perception of different degrees of greenspace management have found a preference for manicured grass over unkept greenery (Hwang et al., 2019; Poškus and Poškienė, 2015). Unkept greenery can also be associated with negative impacts such as fear of danger and crime (Lyytimäki et al., 2008; Skår, 2010) or discomfort (Bixler and Floyd, 1997; Hwang et al., 2019). This can create conflicts between biodiversity conservation and recreation amenity provision (Kowarik and Körner, 2005; Qiu et al., 2013). This may be particularly relevant in Chinese cities, where evidence indicates that the public prefers highly managed greenspaces over more biodiverse, less managed spaces (Hu et al., 2022). Nevertheless, biodiversity enhancement is increasingly being seen as a priority for greenspace design and management by landscape designers (Hu et al., 2022).

To address these urban sustainability challenges, China has become a leading advocate of the nature-based solutions concept, increasingly describing a host of domestic policies as nature-based solutions (Qi and Dauvergne, 2022). For instance, the Chinese government developed and launched the national Sponge City Programme (SCP) in 2014, with a total of CNY 177 billion (~US$ 28 billion) invested in 30 pilot cities (Fu et al., 2023; Li et al., 2017). The sponge city concept entails sustainable urban development practices including flood control, water conservation, water quality improvement, and ecosystem protection (Li et al., 2017). It envisions cities with water systems operating like a sponge to absorb, store, infiltrate, and purify rainwater and release it for reuse when needed through the targeted use of blue-green infrastructure (Fu et al., 2023; Li et al., 2017).

Despite evidence for the multiple benefits nature-based solutions can provide and initiatives such as the Sponge City Programme, a key barrier to their widespread adoption in rapidly urbanising countries such as China is a lack of knowledge over their financing (Brears, 2022). While the central government allocated US$ 60–90 million start-up financial support to each participating city for the first three years of the programme, financial responsibility for the implementation of the Sponge City Programme rested on the pilot cities themselves, and they were encouraged to raise funds through public-private partnerships, among other financing approaches (Chan et al., 2022b). In many cases, insufficient financial resources are available for the implementation and maintenance of such solutions (Kabisch et al., 2017). High maintenance costs of established nature-based solutions may be a barrier to upscaling. A central issue in this context is the structure of municipal revenues, which stem from either municipal tax revenue, fees for municipal services, or fiscal transfers from other government levels (Kabisch et al., 2017).

One possible approach for complementing municipal funding for nature-based solutions are direct financial contributions from citizens. Citizens might pay a tax or fee for the supply of urban ecosystem services (Tasca et al., 2018). For instance, in North America, Europe and Australia, stormwater fees have been implemented in a range of cities to finance sustainable stormwater measures (Zhao et al., 2019). However, we still know little about the willingness to pay (WTP) of urban residents in rapidly urbanising countries such as China for the supply of different ecosystem services.

Further, voluntary time contributions to greenspace management have been identified as a promising approach to reducing the financial needs of nature-based solutions (Hagedoorn et al., 2021a). Citizens' time contributions to nature-based solutions may serve as a suitable complementary source for nature-based solutions finance, particularly in low- and middle-income countries where public finance availability is generally lower (Hagedoorn et al., 2021b). To enable the implementation of time contributions to nature-based solutions in rapidly urbanising countries, we still lack a clear understanding of the factors that determine the willingness to contribute time (WTCT).

Another key barrier is the challenge of retrofitting nature-based solutions at scale into established urban environments, where public space is often highly contested (Croeser et al., 2022). Creating new greenspace will require cities to target existing land uses to be systematically replaced (Croeser et al., 2022). However, urban land is expensive and subject to various competing land uses, particularly in dense residential and commercial areas (Furchtlehner et al., 2022; Phelan et al., 2019). One approach to address the scarcity of urban land, therefore, is that private landowners voluntarily transform privately owned space in nature-based solutions such as green roofs or rain gardens (Furuseth et al., 2021). China has the world's highest homeownership rate of about 90 % (Huang et al., 2021). Land in China is state-owned and leased to homeowners for periods of up to 70 years (World Bank, 2014). Despite the complexities of urban land use rights in China, homeowners have substantial rights to use, benefit from, and transact their land use rights within stipulated guidelines.

Addressing the scarcity and competition for urban land, especially in China with its high homeownership rate and unique land lease system, poses a significant challenge for the implementation of nature-based solutions. However, currently, there is no metric available to measure residents' willingness to contribute space. Therefore, here we introduce the novel metric "willingness to contribute space" (WTCS), which can be used in choice experiments to assess individuals' willingness to convert sealed surfaces on private properties into greenspace. This metric is particularly pertinent in contexts where traditional land use is being reconsidered for ecological benefits. Unlike traditional choice experiment attributes that focus on monetary costs or benefits, WTCS captures individuals' non-monetary preferences related to land use. By measuring individuals' willingness to allocate space on their properties for greenspace, WTCS allows us to better understand the importance individuals place on enhancing ecosystem services. It may support understanding the willingness of individuals to actively contribute to urban sustainability efforts by allocating physical space for nature-based solutions. Similar to WTCT, WTCS expands the scope of choice experiments beyond monetary valuation, allowing us to capture non-market values and land-use preferences.

Further, given global urbanisation trends (Chen et al., 2014), it is important to understand how urban greenspaces can be managed for greater biodiversity benefits (Müller et al., 2018). Little is known about people's preferences for biodiversity and greenspace management intensities in China, since previous studies reported ambiguous results (Chen et al., 2018; Jim and Chen, 2006; Yang, 2021; Zhang et al., 2020). Understanding to what extent Chinese urban residents would accept reduced greenspace management intensities is highly relevant since such lower management intensities can support higher levels of biodiversity, particularly invertebrate and plant diversity (Müller et al., 2018; Rudolph et al., 2017; Watson et al., 2020). This may ultimately contribute to biodiversity conservation in China while simultaneously enabling management cost savings and reducing carbon emissions (Watson et al., 2020).

Thus, there is a need to better understand public preferences for ecosystem services provided by nature-based solutions in Chinese cities. Here, we contribute to informing urban environmental policy by using a choice experiment survey to estimate residents' willingness to pay (WTP), willingness to contribute time (WTCT), and the novel metric of willingness to contribute space (WTCS) to support nature-based solutions programs that improve the supply of ecosystem services related to stormwater management, urban heat island reduction, ecological water channel status and biodiversity support in Chinese cities.

2. Methods

2.1. Setting

Data were collected across urban areas in China (Fig. A1), an upper-middle-income country with the largest urban population of 758 million globally, accounting for 20 % of the global total (United Nations, 2018). China's urban areas have been growing rapidly since the 1980s (National Bureau of Statistics of China, 2014), but the growth rate has been declining to 3.1 % in 2010–15 (United Nations, 2018). The climate in China is highly diverse, ranging from tropical in the far south to subarctic in the far north and alpine in the higher elevations of the Tibetan plateau in the southwest (Li et al., 2017). Precipitation is distributed unevenly in time and space (Li et al., 2017). Temporally, it is almost invariably concentrated in the warmer months, and spatially, it increases from the northwest inland to the southeast coast, with the annual totals ranging from <20 mm in northwestern regions to exceeding 2000 mm on the southern coast (Li et al., 2017).

2.2. Choice experiment

We employed a choice experiment to estimate public preferences for ecosystem services in Chinese cities using three different payment vehicles. A choice experiment is a stated-preference method that allows the valuation of goods and services that are not traded in formal markets by eliciting survey respondents' preferences for characteristics (attributes) of these potential goods and services (Bateman et al., 2002; Hensher et al., 2005; Holmes et al., 2017). In choice experiments, public preferences for specific attributes are estimated as marginal utilities, which are used to estimate the public's willingness to pay (WTP) and willingness to contribute time (WTCT) (Jaung et al., 2020). In this study we introduced a new payment vehicle, willingness to contribute space (WTCS), a metric capturing property owners' willingness to convert sealed surfaces on private land into greenspace.

We followed a standard practice in choice modelling experimental design with the attributes and levels allocated to *non-status-quo* options in choice questions according to a mixed orthogonal fractional factorial design (Holmes et al., 2017) generated through the R-package 'support. CEs' (Aizaki, 2012). The initial generated full factorial design included 80 choice sets. The final fractional factorial design consisted of nine choice sets for each of the three payment vehicles (Tables A1, 2, 3). The three distinct versions of the survey were presented to respondents in randomised order. This process continued until we achieved our target sample size, with respondents being evenly allocated across the three versions to maintain equal representation in each sample group. Data from all choice questions were used for analysis.

To test our hypotheses, we used a multinomial logit model (MNL), which allows for the estimation of respondents' preferences for different attributes of the nature-based solutions programs. In the MNL model, the utility that an individual i derives from choosing alternative j is modelled as a linear combination of the attribute levels (Section 2.5). The utility function can be represented as:

$$\begin{aligned} U_{ij} = {} & ASC_j + \beta_{Water\_25} \text{ x } Water\_25_{ij} + \beta_{Water\_50} \text{ x } Water\_50_{ij} \\ & + \beta_{Temp\_2} \text{ x } Temp\_2_{ij} + \beta_{Temp\_4} \text{ x } Temp\_4_{ij} + \beta_{Veg\_knee} \text{ x } Veg\_Knee_{ij} \\ & + \beta_{Veg\_hip} \text{ x } Veg\_hip_{ij} + \beta_{Partly\_nat} \text{ x } Partly\_nat_{ij} + \beta_{Nearly\_nat} \text{ x } Nearly\_nat_{ij} \\ & + \beta_{Fee} \text{ x } Fee_{ij} \end{aligned}$$

where ASC_j is the alternative specific constant for alternative j (alternatives A, B, and status quo options). The $\beta_{attribute}$ are the coefficients representing the marginal utilities of the respective attributes, and $Attribute_{ij}$ represents the attribute levels for each alternative for individual i. Please note that the utility function detailed above is tailored for the WTP payment vehicle. For estimating WTCT and WTCS, we employed the same utility function but replaced the fee attribute with time and space attributes, respectively. The choice probability for individual i choosing alternative j was then calculated as the ratio of the exponentiated utility of alterative j to the sum of the exponentiated utilities of all alternatives:

$$P_{ij} = \frac{e^{U_{ij}}}{\sum_k e^{U_{ik}}}$$

where P_{ij} is the probability of individual i choosing alternative j, and the denominator is the sum of exponentiated utilities for all alternatives available to individual i. This MNL model allows for the estimation of how different attributes of the nature-based solution programs influence the choice probabilities of respondents. The coefficients β provide insights into the relative importance and impact of each attribute on the respondents' choice. We estimated the MNL models in the preference space to determine WTP, WTCT and WTCS for different attributes of the 'nature-based solutions program'. We used the delta method to estimate marginal willingness to pay (MWTP), marginal willingness to contribute time (MWTCT), and marginal willingness to contribute space (MWTCS) based on this formula:

$$MWTP_{attribute} = \frac{-\beta_{attribute}}{\beta_{fee}}$$

where MWTP for an attribute is calculated as the negative ratio of the attribute's coefficient to the fee/time coefficient. The negative sign is used because a higher cost (fee/time) typically reduces utility, so the MWTP represents how much a respondent is willing to pay to obtain a unit increase in the attribute's utility. We removed the negative sign for the MWTCS calculation to provide a more direct interpretation of the results, where positive values directly indicate a respondents' increased willingness to contribute space for specific attributes. The delta method considers the covariance matrix of the estimated parameters from the MNL model to estimate the standard errors of the MWTP values, which estimates the value that respondents place on changes in each attribute. The analyses were carried out using the R-package Apollo (Hess and Palma, 2019). We included the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) to assess the goodness-of-fit of the models.

For each payment vehicle, we started with a MNL model that only included the choice experiment variables, followed by a second MNL model including interactions with sociodemographic variables. These variables were included as direct effects to assess their independent influence on the utility derived from each alternative.

2.3. Sample population and sampling design

We carried out an online survey to investigate three options of citizen support to public greenspace management by comparing three payment vehicles in choice experiments in a Chinese sample. The sample was recruited by an online survey company, aiming to obtain a diversity of backgrounds and perspectives. Our sample quotas were: a balance of gender across people who identify as male or female; age balance across three brackets (18–29 years; 30–59 years; 60+ years old); a mix of ethnicities; a mix of individuals from different socio-economic groups (higher income; lower income); a diversity of people resident in different urban regions in China (Orme, 2010). The questionnaire was translated from English to Chinese by a bilingual researcher. We administered the survey online in Chinese in April and May 2023 using a survey platform provided by the survey company. To ensure participation exclusively from urban residents, the survey company limited the survey distribution on IP addresses within urban areas. We also included a pre-screening question to further confirm urban residency of respondents.

2.4. Survey

The questionnaire was developed in collaboration with an environmental economist from China, including the choice questions, attributes, and levels. Further, we pre-tested the survey with students from Duke Kunshan University ($n = 12$) to validate the survey design, ensure clarity and cultural appropriateness. Based on the feedback, we streamlined the introductory text to be more concise, thus mitigating the risk of respondent fatigue. We also refined the wording of the income level question for greater clarity and cultural relevance.

The first part of the survey briefly described the intent of the survey and asked the respondents to confirm their consent in participating (Section A3). This was followed by questions on socio-demographic variables, including age, gender, education level, income, employment status, and household size. Further, we asked for membership in environmental organisations to assess the respondents' environmental attitudes and for the mode of residence (owning/renting place of residence) to control for the respondents' ability to convert space on their property into greenspace such as green roofs or rain beds, among others.

For some of the variables, we created dummy variables, which are a way of incorporating qualitative information into regression models. For gender, we created the dummy variable *female*, for education the dummy *university degree* (respondents who have a university degree), for employment the dummy *full-time work* (respondents in full-time work), for income the dummy *high income* (respondents with household income above ¥ 40,000 per month), for mode of residence *owning property* (respondents who own the property they live in), and for membership in environmental organisations the dummy *environm. org. membership* (respondents who are members in environmental organisations).

We asked a series of questions to assess the respondents' perception and use of urban greenspaces, including frequency of greenspace use, time spent in greenspaces, perceived ecosystem service benefits of greenspaces, perceived importance of mitigating ecosystem disservices of greenspaces, and their willingness to contribute to greenspace management. We placed these attitudinal questions before the valuation section to make the respondents think carefully about the topic before answering the choice questions (Mariel et al., 2021).

Then, we introduced the choice experiment attributes and corresponding levels through a series of questions. We asked for the respondents' perception of flooding issues in their city, their perceived need for flooding reduction and heat reduction in summer, their perception of the level of greenspace management intensity, and their perception of the ecological state of water channels.

In the following section, the respondents were provided with a description of a hypothetical market situation in which the government of their city is planning to improve the management of urban greenspaces starting from 2023 to support China's central government's policies the "2030 Agenda for Sustainable Development" and "the Sponge City Initiative". It was stated that the city strategically plans to develop greenspaces to improve urban liveability through the "Urban Greenspace Program", initially running for a duration of ten years with measures being implemented continuously. We described that the program would aim to reduce flooding, reduce hot summer temperatures, change the greenspace vegetation management regime, and improve the ecological status of water channels. In the WTP sample, we stated that changes would need to be paid for through an increase in respondents' monthly water fee for a period of ten years. In the WTCT sample, we posed that changes would need to be supported through voluntary greenspace management work. In the WTCS sample, we indicated that changes would need to be supported through the conversion of sealed surfaces on the respondents' property into greenspace.

2.5. Attribute definition

Through a literature review, we identified and incorporated four key attributes into the 'urban greenspace programme' (Table 1) that signify their potential to deliver ecosystem services (Fig. 1). These attributes address critical issues such as stormwater flooding frequency, urban heat island mitigation, greenspace management intensity, and ecological quality of water channels. Stormwater flooding is a prevalent concern in Chinese cities (Chang et al., 2013; Zevenbergen et al., 2008; Zhou et al., 2012), and urban greenspaces as part of nature-based solutions have proven effective in reducing flood frequency and intensity by enhancing infiltration capacity (Galli et al., 2021; Zimmermann et al., 2016). In our choice experiment, we defined the *status quo* option as no reduction in flooding, while attribute levels ranged from 25 % to 50 % reduction. To combat the urban heat island effect, greenspaces can contribute to cooling temperatures through shading and evapotranspiration (Liu et al., 2022). Accordingly, we included an attribute with two levels representing temperature reductions of 2 °C to 4 °C. The management intensity of greenspaces directly influences biodiversity levels (Müller et al., 2018; Rudolph et al., 2017). To capture this variation, we introduced attribute levels indicating knee-high and hip-high vegetation along roads and building blocks, with short-cut vegetation serving as the *status quo* option. Enhancing the ecological quality of urban water channels can offer additional ecosystem services for urban residents (Cooper et al., 2023). Thus, we integrated an attribute representing different levels of channel ecological status. Following the water quality ladder framework (Hime et al., 2009), we defined the status quo option as the lowest ladder stage, while the first attribute level (partly natural) corresponded to the next higher stage, and the second attribute level (nearly natural) reflected the subsequent stage. For further details regarding attribute definitions and their corresponding levels, please refer to section A1.

2.6. Payment vehicles

We tested three different payment vehicles. More information on the payment vehicle attribute levels is included in the section A1.5–1.7. The first payment vehicle involved evaluating a monetary individual cost attribute. Specifically, we examined respondents' WTP for an increase in their monthly water fees over a ten-year period. By incorporating this cost attribute, we aimed to quantify the monetary value individuals placed on the enhanced ecosystem services that would result from the proposed changes. This approach allowed us to capture the monetary dimension of respondents' preferences and provided insights into the economic feasibility and perceived value of ecosystem service enhancements within the context of nature-based solutions.

In the second payment vehicle, we introduced a time cost attribute to evaluate the willingness to contribute time (WTCT) (Hagedoorn et al., 2021a). WTCT is particularly relevant in low- and middle-income countries (LMICs), where factors such as informal employment, less robust labour markets, and higher unemployment rates create a context where households might be 'income-poor but labour-abundant' (Tilahun et al., 2015). In such settings, WTCT offers a more inclusive and equitable method to estimate non-market values, avoiding the bias towards higher-income households often seen in WTP surveys. This is crucial as households in LMICs often prefer to contribute time over money (Ison et al., 2018; O'Garra, 2009). We defined WTCT as the time a respondent would spend on volunteer activities such as vegetation management, wildlife surveying, or litter collection in green spaces, with tasks tailored

Table 1
Attributes and levels of the discrete choice experiment for the three payment vehicles willingness to pay (WTP), willingness to contribute time (WTCT), and willingness to contribute space (WTCS).

Attribute	Attribute level	Description
Flood regulation	No change	No change of water ponding (baseline)
	25 % reduction	25 % reduction of water ponding
	50 % reduction	50 % reduction of water ponding
Temperature reduction	No change	No change in temperature (baseline)
	2 °C Celsius reduction	Decrease of 2 °C
	4 °C Celsius reduction	Decrease of 4 °C
Greenspace management intensity	No change	Short-cut vegetation (baseline)
	Knee-high vegetation	Vegetation growing up to knee-height
	Hip-high vegetation	Vegetation growing up to hip-height
Water channel status	No change	Hardly natural water channel (baseline)
	Partly natural	Partly natural water channel
	Nearly natural	Nearly natural water channel
WTP sample:	No change	No additional fee
Increase in monthly water fee	10 CYN	Additional fee of 10 CYN
	20 CYN	Additional fee of 20 CYN
	50 CYN	Additional fee of 50 CYN
	100 CYN	Additional fee of 100 CYN
	150 CYN	Additional fee of 150 CYN
WTCT sample:	No change	No voluntary work
Voluntary work in greenspaces	0.5 h	0.5 h per week
	1 h	1 h per week
	2 h	2 h per week
	3 h	3 h per week
	4 h	4 h per week
WTCS sample:	No change	No conversion of space
Conversion of sealed surfaces on private property into greenspace	3 m^2	Conversion of 3 m^2
	5 m^2	Conversion of 5 m^2
	10 m^2	Conversion of 10 m^2
	15 m^2	Conversion of 15 m^2
	20 m^2	Conversion of 20 m^2

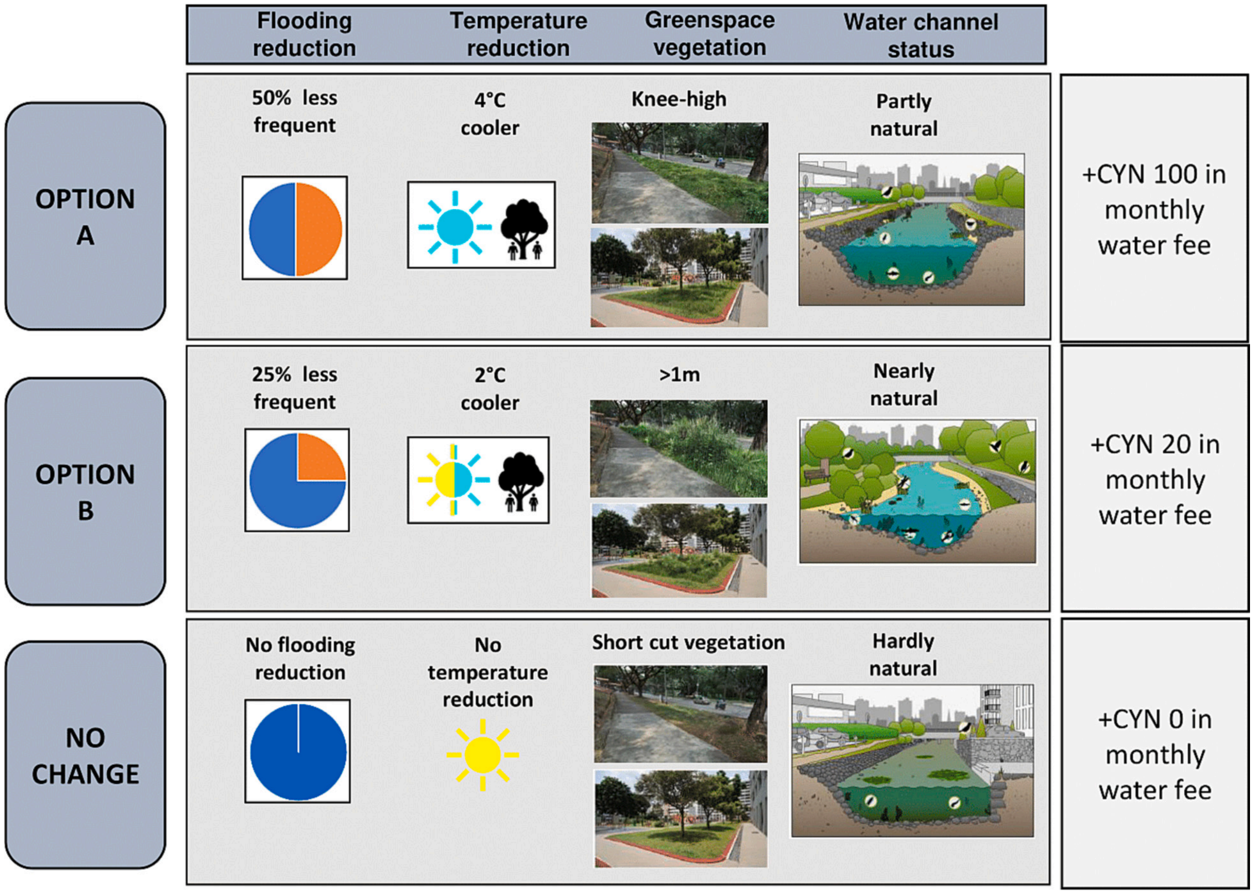

Fig. 1. Example choice set for the payment vehicle monthly water fee (WTP) including two 'urban greenspace programme' alternatives alongside a *no change* option, and the four attributes flooding reduction, temperature reduction, greenspace management intensity, and ecological quality of water channels, with two levels each. We established a total of nine choice sets for each payment vehicle.

to each individual's physical ability. However, it's important to note that describing time contribution as voluntary could lead to overestimation, as such commitments are not perceived as binding (Ando et al., 2020; Carson and Groves, 2007). In the third payment vehicle, we introduced a novel approach to measure respondents' willingness to voluntarily convert sealed surfaces on their properties into greenspace. This was evaluated by introducing the "Willingness to Contribute Space" (WTCS) metric. The concept of WTCS captures individuals' willingness to allocate a portion of their property, which is covered by impermeable surfaces such as concrete or asphalt, to be transformed into greenspace. By incorporating WTCS into our study, we aimed to explore the extent to which respondents would be willing to voluntarily dedicate an area within their property to be used for nature-based solutions.

To mitigate hypothetical bias (Mariel et al., 2021), we clearly described the different payment vehicle scenarios as well as how to choose between two alternatives for greenspace management and a *no change* option, for which no additional costs (WTP), no voluntary work for greenspace management (WTCT), and no conversion of space on the property (WTCS) would be required. Moreover, we presented an example choice set to allow respondents to familiarise themselves with the concepts.

To detect protest responses, we added a question to appear if respondents chose the *no change* option in all choice tasks. Protest responses are those in which respondents reject a part or the whole concept of the proposed choice questions (Meyerhoff and Liebe, 2006), and such responses should be identified and handled appropriately (Meyerhoff and Liebe, 2010). Therefore, we asked respondents to select from a list of reasons why they selected the *no change* option in every choice set.

3. Results

The sample consisted of 1536 respondents ($N = 517$ for the WTP sample, $N = 505$ for the WTCT sample, $N = 514$ for the WTCS sample) who provided information on sociodemographic characteristics and their perceptions and use of urban greenspaces (Table 2). The descriptive statistics were closely matched across the three payment vehicle samples. The mean age of the respondents was below the national average in China at 22.7 years. Approximately half of the respondents identified as female, while a high proportion reported having a university degree (88 %) and engaging in full-time work (85 %). A small percentage of respondents reported a high income (14 %), whereas a majority (89 %) indicated ownership of their property, either personally or through family members such as parents. About 41 % of the respondents were members of environmental organisations, a figure that is much above the level of around 5 % found in a cross-national comparison (Sønderskov, 2008). In terms of discretionary time, respondents reported an average of 17.92 h per week. Regarding the perception and use of urban greenspaces, approximately 31 % of respondents reported visiting greenspaces at least 1–2 times per week, while 22 % reported spending at least 3–4 h per week in greenspaces. Additionally, 39 % of respondents in the WTP sample indicated to agree to pay a monthly fee for improved greenspace management, while 51 % in the WTCT sample expressed a willingness to contribute time for greenspace management. Finally, 57 % of respondents in the WTCS sample agreed to convert private space into greenspace. Across the different samples, protest responses accounted for 1.43 % ($N = 22$) of the total responses, suggesting a relatively low occurrence of protest within the sample. Protest responses were observed when participants consistently selected the *no*

Table 2

Summary statistics of respondents (Total $N = 1536$; N = 517 for WTP, N = 505 for WTCT, N = 514 for WTCS). University degree: dummy for respondents with university degree, compared to all other education levels. Full-time work: dummy for respondents who work full-time (> 30 h/week). High income: dummy for respondents with household income above ¥ 40,000 per month. Environm. org. membership: dummy for respondents who are members or environmental organisations.

Variables	WTP		WTCT		WTCS		Total
	Mean	SD	Mean	SD	Mean	SD	
Sociodemographic information							
Age (years)	23.1	7.5	22.60	7.8	22.40	7.59	22.7
Female[a]	0.50	0.50	0.59	0.50	0.57	0.49	0.55
University degree[a]	0.88	0.32	0.90	0.32	0.86	0.32	0.88
Full-time work[a]	0.87	0.34	0.85	0.36	0.84	0.36	0.85
High income[a]	0.13	0.34	0.15	0.40	0.15	0.36	0.14
Owning property[a]	0.89	0.31	0.88	0.32	0.92	0.28	0.89
Environm. org. membership[a]	0.39	0.49	0.45	0.50	0.38	0.49	0.41
Amount of discretionary time (h/week)	18.11	14.08	17.3	13.99	18.35	14.24	17.92
Perception and use of urban greenspaces							
Greenspace use ≥1–2 times/ week[a]	0.36	0.47	0.28	0.45	0.28	0.44	0.31
Time spent in greenspaces ≥3–4 h/week[a]	0.19	0.39	0.22	0.42	0.24	0.43	0.22
Agree to pay a monthly fee for greenspace management[a]	0.39	0.49	—	—	—	—	—
Agree to contribute time for greenspace management[a]	—	—	0.51	0.50	—	—	—
Agree to convert private space into greenspace[a]	—	—	—	—	0.57	0.49	—

[a] Dummy variables coded as 1: yes, 0: no.

change option across all scenarios. The reasons for protest varied among respondents and encompassed statements such as “I already pay enough taxes” ($N = 8$), “I prefer to spend money on other things” (N = 5), “I could not afford any proposed changes” ($N = 4$), “I do not think the greenspace program will have an effect” ($N = 3$), and “greenspaces do not mean anything to me” ($N = 1$).

3.1. WTP sample

In the WTP sample, about 87.6 % of the respondents selected either the ‘Urban Greenspace Programme’ scheme A or B, while 12.4 % chose the *no change* option. The first WTP MNL model was based on the attributes of the choice experiment (Table 3). All attributes were found to be statistically significant. Both Alternative A and B (*Asc_a, Asc_b*) had strongly positive marginal utilities, with respondents expressing the highest utility for Alternative A (0.730 and 0.579, respectively). The attribute associated with the highest utility in the model was 50 % flood reduction (*Flood − 50 %*; 1.677), while the 25 % flood reduction attribute (*Flood − 25 %*) also had a strongly positive marginal utility (0.774). Respondents indicated positive utilities for temperature reductions of 2 °C and 4 °C (0.253 and 0.833, respectively). In terms of greenspace management intensity, respondents expressed a positive utility for knee-high vegetation (*Veg knee-high*; 0.249), but a strongly negative utility for vegetation growing up to hip-height (*Veg hip-height*; −1.175). Improved

Table 3

Results of the choice experiment for willingness to pay (WTP; $N = 517$). Multinomial logit model 1 only includes the choice experiment attributes. Multinomial logit model 2 includes interactions with sociodemographic variables as direct main effects. Socio-economic dummy variables include ‘university degree’ (dummy for respondents with university degree), compared to all other education levels; full-time work (dummy for respondents who work full-time (>30 h/week)); high income (dummy for respondents with household income above ¥ 40,000 per month); environm. org. membership (dummy for respondents who are members or environmental organisations). Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) were included to assess goodness-of-fit of models.

Variables	Multinomial logit model 1		MWTP[a]	Multinomial logit model 2	
	Coeff.	Std. error		Coeff.	Std. error
Asc_a	**0.730*****	0.071	505.18 (66.49)	−0.23	0.25
Asc_b	**0.579*****	0.075	400.98 (52.78)	−0.37	0.25
Flood −25 %	**0.774*****	0.098	535.98 (70.54)	**0.79*****	0.10
Flood −50 %	**1.677*****	0.096	1161.16 (152.83)	**1.65*****	0.10
Temp −2 °C	**0.253*****	0.095	175.17 (23.06)	**0.21****	0.10
Temp −4 °C	**0.833*****	0.083	577.02 (75.94)	**0.81*****	0.08
Veg knee-high	**0.249*****	0.074	172.10 (22.65)	**0.23*****	0.07
Veg hip-height	**−1.175*****	0.093	−813.58 (−107.08)	**−1.16*****	0.09
Channel partly natural	**0.299*****	0.088	207.10 (27.26)	**0.27*****	0.09
Channel nearly natural	**0.408*****	0.093	282.28 (37.15)	**0.35*****	0.09
Fee	**−0.001*****	0.000	—	**0.00*****	0.00
Socio-economic interactions					
Age	—	—	—	0.00	0.01
Female	—	—	—	−0.07	0.10
University degree	—	—	—	**0.61*****	0.13
Full-time work	—	—	—	**−0.30****	0.15
High income	—	—	—	**0.30****	0.16
Owning property	—	—	—	0.19	0.14
Environm. org. membership	—	—	—	**0.55*****	0.11
Perception and use of greenspaces					
Greenspace use ≥1–2 times/ week	—	—	—	0.00	0.11
Time spent in greenspaces ≥3–4 h/week	—	—	—	**0.43*****	0.15
Agree to pay a monthly fee for greenspace management	—	—	—	**0.80*****	0.11
Log-likelihood (LL)					
Log-likelihood ratio test	−4071.164	—	—	−3993.6	—
AIC	8164.33	—	—	8029.04	—
BIC	8235.16	—	—	8157.83	—

***, **, * indicate significance at 1 %, 5 % and 10 % level, respectively, and are highlighted in bold.

[a] Marginal willingness to pay in CYN (EUR).

water channel status (*Channel partly natural, channel nearly natural*) was associated with positive utilities (0.299 and 0.408). The fee attribute revealed that respondents' utilities decreased as the fee increased. Among the significant attributes, the estimated marginal willingness to pay for changes in attributes ranged from ¥ - 813.58 (€ - 107.08) to ¥ 577.02 (€ 75.94) per month, with the highest estimate observed for the 50 % flood reduction attribute (*Flood − 50 %*), and the lowest estimate associated with the lowest greenspace management intensity (*Veg hip-height*) (Table 3).

The second WTP MNL model included both the choice experiment attributes and socio-demographic variables (Table 3). Marginal utilities of the choice experiment attributes were very similar to the results of WTP model 1, except for the alternative specific constant (ASC). This difference can be attributed mainly to the integration of socio-demographic variables and variables on the perception and use of greenspaces into WTP model 2 through their interactions with the ASC. Four socio-demographic variables were significant in the model. The education and income variables highlighted that respondents with a university degree and with high income were more likely to choose the 'Urban Greenspace Programme' schemes (*University degree*, 0.61; *High-income*, 0.30). In contrast, respondents who indicated working full-time were more likely to select the *no change* option compared to those working less (−0.30). Membership in environmental organisations was strongly associated with a preference for greenspace schemes (0.55). Regarding the perception and use of urban greenspaces, respondents spending at least 3–4 h per week in greenspaces showed a strong positive utility (0.43), and those who conceptually agreed to pay a fee for improved greenspace management demonstrated a strong preference for the greenspace schemes (0.80).

3.2. WTCT sample

In the WTCT sample, about 91.5 % of the selected choice experiment sets opted for either scheme A or B of the 'Urban Greenspace Programme', with only 8.5 % choosing the *no change* option. We developed the initial WTCT MNL model based on the attributes presented in Table 4. The WTCT model closely resembled the WTP MNL model, showing strongly positive marginal utilities for both schemes A and B (*Asc_a, Asc_b*) at 1.087 and 1.183, respectively. While respondents demonstrated a preference for the 50 % flood reduction attribute (*Flood − 50 %; 0.835*), the model indicated that the attribute with the highest utility was the 4 °C temperature reduction (*Temp −4 °C; 0.951*). Regarding greenspace management intensity, respondents exhibited a slightly less negative utility for vegetation growing up to hip-height (*Veg hip-height; −0.749*). The time attribute revealed a decreasing trend in respondents' utilities as the time invested in greenspace management increased (*Time, −0.096)*. The estimated marginal willingness to contribute time for changes in attributes ranged from −7.752 to 9.829 h per month, with the highest estimate observed for the 4 °C temperature reduction attribute, and the lowest estimate associated with the lowest greenspace management intensity (*Veg hip-height*) (Table 4).

The second WTCT model encompassed both the choice experiment attributes and socio-demographic variables (Table 4). Like the WTCT model 1, the ASCs exhibited positive utilities. Six socio-economic variables demonstrated significance in the model. Women displayed a considerably higher likelihood of selecting the *no change* option compared to men (−0.626). In contrast, those who indicated property ownership (0.873) and membership in environmental organisations (0.433) displayed a strong preference for the greenspace schemes. Respondents with more discretionary time available than the sample average expressed a pronounced preference for the greenspace schemes (0.377). Additionally, individuals spending 3–4 or more hours per week in greenspaces (0.579) and those who conceptually agreed to contribute time for greenspace management were strongly in favour of the greenspace schemes (0.744).

Table 4
Results of the choice experiment for willingness to contribute time (WTCT; N = 505). Multinomial logit model 1 only includes the choice experiment attributes. Multinomial logit model 2 includes interactions with sociodemographic variables as direct main effects. Socio-economic dummy variables include 'university degree' (dummy for respondents with university degree), compared to all other education levels; full-time work (dummy for respondents who work full-time (> 30 h/week)); high income (dummy for respondents with household income above ¥ 40,000 per month); environm. org. membership (dummy for respondents who are members or environmental organisations). Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) were included to assess goodness-of-fit of models.

Variables	Multinomial logit model 1		MWTCT[a]	Multinomial logit model 2	
	Coeff.	Std. error		Coeff.	Std. error
Asc_a	**1.087*** **	0.085	11.239	**0.528** **	0.26
Asc_b	**1.183*** **	0.085	12.231	**0.631*** **	0.26
Flood −25 %	**0.214** **	0.100	2.215	**0.223*** **	0.10
Flood −50 %	**0.835*** **	0.098	8.639	**0.809*** **	0.10
Temp −2 °C	**0.437*** **	0.097	4.517	**0.405*** **	0.09
Temp −4 °C	**0.951*** **	0.082	9.829	**0.928*** **	0.08
Veg knee-high	**0.511*** **	0.074	5.286	**0.501*** **	0.07
Veg hip-height	**−0.749*** **	0.094	−7.752	**−0.733*** **	0.09
Channel partly natural	**0.529*** **	0.093	5.471	**0.503*** **	0.09
Channel nearly natural	**0.447*** **	0.093	4.624	**0.412*** **	0.09
Time	**−0.096*** **	0.017	—	**−0.105*** **	0.01
Socio-economic interactions					
Age	—	—	—	−0.001	0.01
Female	—	—	—	**−0.626*** **	0.12
University degree	—	—	—	−0.107	0.17
Full-time work	—	—	—	0.247	0.15
High income	—	—	—	0.237	0.17
Owning property	—	—	—	**0.873*** **	0.14
Environm. org. membership	—	—	—	**0.433*** **	0.12
>Mean discretionary time	—	—	—	**0.377*** **	0.11
Perception and use of greenspaces					
Greenspace use ≥1–2 times/ week	—	—	—	0.044	0.14
Time spent in greenspaces ≥3–4 h/week	—	—	—	**0.579*** **	0.17
Agree to contribute time to greenspace management	—	—	—	**0.744*** **	0.12
Log-likelihood (LL)					
LL ratio test	−4012.83	—	—	−3939.17	—
AIC	8047.65	—	—	7920.33	—
BIC	8118.51	—	—	8055.6	—

***, **, * indicate significance at 1 %, 5 % and 10 % level, respectively, and are highlighted in bold.
[a] Marginal willingness to contribute time in hours.

3.3. WTCS sample

In the WTCS sample, only 6.7 % of the respondents selected the *no change* option, while 93.3 % chose either the 'Urban Greenspace Programme' scheme A or B. As in the WTP and WTCT models, the ASCs in the first WTCS model were associated with a strong positive utility (0.949, 1.084 respectively). Most attributes were significant, except the 2 °C temperature reduction (*Temp −2 °C*) and improved water channel status (*Channel nearly natural*). As in the WTP and WTCT models, the flood reduction attributes had positive utilities (0.22, 0.67). However, unlike in the WTP model, the 4 °C temperature reduction (*Temp −4 °C*) attribute had the highest utility in the model (0.87). Contrary to our hypothesis, the space attribute showed a positive trend as the amount of space on private properties converted from sealed surfaces into greenspace increased (0.033). The range of estimated marginal willingness to contribute space spanned from −19.771 to 26.655 m^2. The attribute associated with a 4 °C reduction in temperature garnered the highest estimate, while the attribute indicating the least intensive greenspace management *(Veg hip-height*) resulted in the lowest estimate, as detailed in Table 5.

The second WTCT model incorporated both the choice experiment attributes and socio-demographic variables (Table 5). Like the WTP model, the ASCs in the second WTCT model exhibited a reversed sign and were found to be statistically insignificant. Most attributes had utilities that closely aligned with those in model 1, except for the space attribute, which did not reach statistical significance in the second model. Among the socio-economic variables, seven variables were found to be significant. Women showed a slightly lower likelihood of selecting the greenspace schemes compared to the *no change* option (0.26). Conversely, respondents with a university degree and those employed full-time expressed positive utility towards the greenspace schemes (0.49, 0.28 respectively). Consistent with our hypothesis, owning property was strongly associated with a positive utility (0.48), similar to individuals who conceptually agreed to convert privately owned space into greenspace (0.31). Surprisingly, using greenspaces at least 1–2 times per week exhibited a strongly negative utility (−1.10), in contrast to the variable representing time spent in greenspaces (0.39).

Table 5
Results of the choice experiment for willingness to contribute time (WTCS; N = 514). Multinomial logit model 1 only includes the choice experiment attributes. Multinomial logit model 2 includes interactions with sociodemographic variables as direct main effects. Socio-economic dummy variables include 'university degree' (dummy for respondents with university degree), compared to all other education levels; full-time work (dummy for respondents who work full-time (> 30 h/week)); high income (dummy for respondents with household income above ¥ 40,000 per month); environm. org. membership (dummy for respondents who are members or environmental organisations). Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) were included to assess goodness-of-fit of models.

Variables	Multinomial logit model 1		MWTCS[a]	Multinomial logit model 2	
	Coeff.	Std. error		Coeff.	Std. error
Asc_a	**0.940*****	0.095	28.073	−0.30	0.29
Asc_b	**1.084*****	0.092	32.349	−0.15	0.29
Flood −25 %	**0.208****	0.111	6.202	**0.22****	0.11
Flood −50 %	**0.687*****	0.106	20.506	**0.67*****	0.11
Temp −2 °C	0.040	0.106	1.205	0.02	0.11
Temp −4 °C	**0.893*****	0.089	26.655	**0.87*****	0.09
Veg knee-high	**0.503*****	0.077	15.011	**0.49*****	0.08
Veg hip-height	**−0.662*****	0.096	−19.771	**−0.66*****	0.10
Channel partly natural	**0.459*****	0.097	13.707	**0.44*****	0.10
Channel nearly natural	0.134	0.097	4.01	0.11	0.10
Space	**0.033*****	0.003	–	0.03	0.00
Socio-economic interactions					
Age	–	–	–	0.01	0.01
Female	–	–	–	**0.26****	0.12
University degree	–	–	–	**0.49*****	0.17
Full-time work	–	–	–	**0.28***	0.17
High income	–	–	–	0.23	0.19
Owning property	–	–	–	**0.48*****	0.20
Environm. org. membership	–	–	–	0.00	0.13
Perception and use of greenspaces					
Greenspace use ≥1–2 times/week	–	–	–	**−1.10*****	0.13
Time spent in greenspaces ≥3–4 h/week	–	–	–	**0.39*****	0.16
Agree to convert private space into greenspaces	–	–	–	**0.31*****	0.12
Log-likelihood (LL)					
LL ratio test	−3755.290	–	–	−3698.45	–
AIC	7532.58	–	–	7438.91	–
BIC	7603.24	–	–	7573.81	–

***, **, * indicate significance at 1 %, 5 % and 10 % level, respectively, and are highlighted in bold.
[a] Marginal willingness to contribute space in m^2.

4. Discussion

In this study, we assessed the preferences of urban residents in China regarding ecosystem services provided through nature-based solutions and tested a novel approach for capturing individuals' willingness to contribute their privately owned space for the implementation of nature-based solutions. Gaining a nuanced understanding of urban residents' preferences in China for contributing to addressing urban sustainability challenges related to stormwater management, urban heat island reduction, and biodiversity support is crucial for effectively tackling these pressing issues.

In our study, we analysed WTP, WTCT, and WTCS in relation to nature-based solution programs focused on stormwater management, reducing urban heat islands, and supporting biodiversity. The results indicated a predominantly positive response towards these nature-based solutions. Notably, despite inherent conceptual differences among these payment vehicles, our findings showed a consistent pattern across WTP, WTCT, and WTCS. This contrasts with prior research, which often reports a significantly higher WTCT compared to WTP (Gibson et al., 2016; Ofori, 2023). While WTP is influenced by a set of distinct factors, WTCT and WTCS are shaped differently as they represent voluntary contributions, potentially leading to greater variability in their estimates. One possible explanation for our findings relates to the specific demographics of our sample and the economic context of China, an upper-middle-income country with relatively robust labour markets (Zhu, 2023). Our sample predominantly consisted of young, highly educated individuals who are actively engaged in environmental conservation, as evidenced by their high membership rates in environmental organisations. As such, marginalised or low-income population groups may not be well represented in our sample. This demographic profile might explain why in our study, WTP appears to align more closely with WTCT and WTCS.

However, it is important to note that this demographic skew in our sample could limit the generalisability of our findings. There is a potential risk of overestimating WTP, WTCT, and WTCS for the broader population, given that our sample may not accurately represent the diverse perspectives and preferences of different demographic groups in China. Therefore, future research should be directed towards including a more representative sample to gain a comprehensive understanding of these measures across varied demographic segments.

We found strong preferences for temperature and flood reduction through nature-based solutions, consistent across all three samples. These preferences may reflect the intensifying urban heat issues in Chinese cities. For instance, heatwaves across China doubled both in magnitude and frequency between the 1960s and 2018 (He et al., 2022). Similarly, the preferences expressed for flood reduction through nature-based solutions align with the increasing severity and frequency of urban flooding in Chinese cities in the past decades (Ma et al., 2022). The preferences are consistent with previous research from China, which showed that the public generally supports nature-based solutions to tackle urban stormwater issues (Wang et al., 2017). These preferences may also reflect the perception that rising global temperatures due to climate change may further exacerbate urban heat (Sachindra et al., 2016) and extreme weather events (Clarke et al., 2022) in the future, potentially driven by a substantial increase in news media coverage on climate change (Hase et al., 2021; Legagneux et al., 2018).

While the ecological status of water channels was associated with positive utilities, preferences for ecological improvements in water channels were less pronounced compared to other attributes. This may suggest that respondents prioritise addressing urban heat and flooding issues over the ecological restoration of water channels. This prioritisation may be driven by the immediate and tangible impacts of urban heat and flooding on people. As a result, efforts to mitigate urban heat and flooding through nature-based solutions may receive higher public support compared to ecological restoration initiatives. To increase public support for highly important channel restoration initiatives, policymakers may use measures such as environmental education (Fischer et al., 2020). This is important because through rapid urbanisation, urban streams have experienced substantial ecological degradation in Chinese cities through morphological adjustments in river systems (Zhou et al., 2011). Degraded urban channels tend to provide fewer ecosystem services which are important for ecosystem functioning (Gao et al., 2022) and provide fewer benefits for the well-being of urban residents (Åberg and Tapsell, 2013).

Respondents consistently expressed strongly negative utilities for the lowest level of greenspace management intensity, characterised by vegetation growing up to hip-height, across all three payment vehicle samples. This is consistent with evidence indicating a preference among urban residents in China for highly managed and manicured greenspaces over less managed, yet more biodiverse areas (Buijs et al., 2009; Hu et al., 2022). This may be due to cultural norms and practices that are common in Chinese society, which determine environmental preferences (Li, 2014). However, we found that respondents expressed a moderately positive utility for the moderate level of greenspace management, with vegetation growing up to knee-height, compared to the baseline of short-cut vegetation. This may suggest that cultural norms and attitudes towards greenspace management are not static in China but change over time. This is consistent with recent evidence indicating that the public in Singapore today are generally more accepting towards moderately less managed, wilder greenspaces (Hwang et al., 2019). A potential reason for this could be rising environmental awareness (Du et al., 2018) through increased news media coverage on biodiversity loss (Legagneux et al., 2018), resulting in growing societal interest in reduced greenspace management intensities (Buck, 2015).

Our findings indicate that urban residents in China prefer a moderate reduction of greenspace management intensities to support urban biodiversity. Currently, urban greenspaces in China tend to be characterised by high management intensities (Yang et al., 2019). This indicates synergistic opportunities: moderately lower greenspace management intensities could yield additional biodiversity benefits while ensuring cost savings and carbon emission reductions (Watson et al., 2020). For instance, a Canadian case study found a 36 % cost reduction by reducing greenspace lawn cutting frequency from 15 to 10 times per year (Watson et al., 2020). Therefore, we recommend policies that facilitate a moderate reduction of greenspace management intensities in Chinese cites as a promising approach to simultaneously support urban biodiversity, achieve cost savings and carbon emission reductions. As with channel restoration, to further increase public acceptance of policies that facilitate biodiversity conservation within cities, measures such as environmental education could be employed (Fischer et al., 2020). Future research could further explore preferences for low-management alternatives to lawns such as perennial meadows in China (Hitchmough and de la Fleur, 2006; Yang et al., 2019).

Preferences varied based on socio-demographic characteristics and individual perceptions of nature-based solutions. Regarding gender differences, the slightly negative utility for women in the WTP model, although not statistically significant, may be attributable to their lower disposable income compared to men (Iwasaki and Ma, 2020). This financial constraint could potentially impact women's willingness to pay for nature-based solutions programs, as they tend to have fewer financial resources available. In the WTCT model, women expressed a strongly negative utility for the greenspace schemes, which may be attributed to their limited discretionary time compared to men. Traditional gender roles often result in women dedicating more time to unpaid labour such as household chores and childcare (De Bruin and Liu, 2019), potentially influencing their negative perception of voluntary greenspace management activities. However, the WTCS model showed that women were more likely to convert privately owned space to greenspace, possibly due to their limited control over property-related decisions in China (Deng et al., 2019). This may also imply that the WTCS payment vehicle works less well for women since they tend to have less property-related decision-making power. Specifically, in the context of time contributions, policies could be designed to accommodate the limited discretionary time of women, for instance through flexible scheduling of voluntary greenspace management activities. Our findings highlight that policymakers should actively involve diverse stakeholders including women and marginalised groups in the design and implementation of nature-based solutions policies to ensure that programs reflect the needs and preferences of diverse urban communities (Ferreira et al., 2020). The needs and perspectives of women and other marginalised groups should be integrated into the design, implementation, and monitoring of nature-based solutions programmes in China (Ouyang et al., 2021).

The WTCS payment vehicle used in this study is a novel approach in the context of choice experiments, capturing individuals' willingness to contribute their privately owned space for the implementation of nature-based solutions. Our findings reveal that urban residents in China are willing to voluntarily convert privately owned impervious surfaces into greenspace, highlighting untapped potential for greening policies in Chinese cities. By introducing the WTCS payment vehicle, we aimed to explore a novel dimension of individuals' preferences and engagement with nature-based solutions in our rapidly urbanising world. This approach acknowledges that the provision of ecosystem services through nature-based solutions in cities often requires physical space to be converted into greenspace (Croeser et al., 2022). The limited availability of land has been identified as a major barrier to implementing nature-based solutions at scale (Albert et al., 2019; Pontee et al., 2016), particularly in urbanising countries such as China (Zhuang et al., 2017). The WTCS payment vehicle aims to address this barrier by expanding the methodological toolkit for choice experiments and offers a novel way to investigate preferences for implementing nature-based solutions. By considering space as a resource that individuals are willing to contribute, the WTCS payment vehicle enables policymakers to better understand the level of support and engagement they can expect from urban residents when planning nature-based solutions projects. This information can be vital for the design and implementation of effective nature-based solutions initiatives as it provides insights into the feasibility and social acceptance of interventions (Wolf et al., 2022). Based on our findings, we recommend that policymakers consider incentivising and promoting the conversion of privately owned impervious surfaces into greenspaces through targeted programs or financial incentives. Incentive mechanisms that foster behavioural changes by creating opportunities, building capacities, and supporting motivation (Michie et al., 2011) for transforming privately owned urban space into greenspace (Clements, 2018) could be employed for this purpose. Such mechanisms have been implemented successfully in countrries such as the USA and Norway, where auctions for the implementation of nature-based solutions for stormwater management on private properties were run (Furuseth et al., 2018; Thurston et al., 2010). However, more research is needed to fully understand the applicability of the WTCS payment vehicle in different contexts and populations. Specifically, the long-term effectiveness and applicability of the WTCS payment vehicle require further validation in various urban contexts. Future studies may explore socio-economic and demographic factors that may influence individuals' willingness to contribute space and explore different geographic and cultural contexts. Additionally, further investigating the relationship between WTCS and other payment vehicles, such as monetary and time contributions, could provide a more comprehensive understanding of the motivations underlying individuals' support for nature-based solutions through space contributions.

In addition, it is important to acknowledge the important role of external factors such as government policies and economic conditions in shaping the feasibility and acceptance of nature-based solution programs in China. Policies such as the Sponge City Programme exemplify China's commitment to sustainable urban development (Qi and Dauvergne, 2022). Despite these initiatives, a cohesive policy system with nature-based solutions at its core remains underdeveloped (Ouyang et al., 2021). Funding for these is also a challenge, as it primarily relies on financial inputs, with diverse funding mechanisms involving broad social participation yet to be established (Ouyang et al., 2021). This highlights the relevance of exploring various contributions from urban residents, including monetary, time, and space, towards supporting nature-based solutions such as in our study. However, the long-term sustainability of citizen contributions depends on effective institutional structures, governance arrangements, and funding mechanisms (Kiss et al., 2022). For nature-based solutions to achieve their full potential, they need to be socially embedded, considering diverse human interests, needs, and perceptions (Kiss et al., 2022). Deeper citizen engagement is essential for promoting empowerment and ownership, thereby supporting paths to long-term sustainability of citizen support (Nunes et al., 2021).

5. Conclusions

This study provides important insights into the preferences of urban residents in China for ecosystem services provided by nature-based solutions. Based on our findings, nature-based solutions policies aiming to reduce urban heat and flooding can expect high public support in Chinese cities, while ecological restoration initiatives may only be supported to a lesser extent. We found that urban residents in China may prefer a moderate reduction of greenspace management intensities, indicating synergistic opportunities for yielding additional biodiversity benefits while ensuring cost savings and carbon emission reductions. Therefore, policies aiming to reduce management intensities may be a promising avenue for facilitating biodiversity conservation in Chinese cities. Moreover, our findings indicate that policymakers should actively involve a diverse range of stakeholders in designing and implementing nature-based solutions initiatives to ensure that the needs and preferences of diverse urban communities are met.

By introducing the WTCS payment vehicle, we aimed to expand the methodological toolkit for assessing voluntary space contributions to nature-based solutions initiatives, to address the barrier of the limited availability of urban land for implementing nature-based solutions (Albert et al., 2019; Pontee et al., 2016). We hope this novel payment vehicle will enable policymakers to better understand the level of support they can expect from urban residents regarding space contributions. This may inform the design of incentive policies for urban greening initiatives. However, more research is needed to fully elucidate the applicability of the WTCS payment vehicle in different cultural and geographic contexts. Advancing our understanding of preferences for nature-based solutions in rapidly urbanising countries such as China may ultimately foster sustainable urban development and create resilient and liveable cities for present and future generations.

CRediT authorship contribution statement

Maximilian Nawrath: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Kathinka Fürst:** Conceptualization, Project administration, Writing – review & editing. **Michael Hutchins:** Funding acquisition, Methodology, Writing – review & editing. **Isabel Seifert-Dähnn:** Conceptualization, Funding acquisition, Methodology, Supervision, Writing – original draft, Writing – review & editing.

Declaration of competing interest

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.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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