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ORIGINAL PAPER

Public preferences for green infrastructure improvements in Northern New Jersey: a discrete choice experiment approach

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Abstract

Significant water pollution caused by flooding due to heavy precipitation and extreme weather events has become a considerable problem in urbanized areas such as in Northern New Jersey. These cities experience heavy downpour-related contamination and water pollution when stormwater and untreated sewage are diverted through combined sewer overflow drainage systems to adjacent water bodies. Green infrastructure has proven a successful intervention method for mitigating these unintended environmental consequences. However, while the effects of CSOs and the ability of GI to reduce them are well documented, there has been considerably less study addressing public preferences and willingness to pay for GI-based solutions. As such, this study seeks to understand these facets of GI management in urbanized areas of New Jersey, focusing on Newark, Paterson, and Elizabeth townships. A discrete choice experiment method was used to analyze the willingness of residents to pay for additional CSO infrastructure through the installation of GI options such as bioretention gardens, rain barrels, and green roofs. Furthermore, study identified attributes such as secondary benefits, proximity, and water retention that respondents found the most utility in when choosing GI stormwater management interventions. We found that several attributes, including improved air quality (\$58.60), increased water supply (\$49.71), and closer proximity (\$110.01–\$125.97) had the highest utility and similarly were associated with a higher willingness to pay than other tested attributes. These findings are important in assessing the overall attitude toward these fixtures, and may be critical in crafting local policy and development, especially to address environmental equity.

Keywords Stormwater management · Combined sewer overflow · Green infrastructure · Discrete choice experiment · Willingness to pay

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Introduction

As a result of dense urbanization over decades, northern New Jersey towns and cities are exposed to significant risk from high precipitation and flooding events. These hydrologic events can have significant adverse effects for both human and environmental health (Soriano and Rubio 2019). Combined sewer overflow (CSO) infrastructure is one of the most critical water quality issues facing coastal and river communities; limited control of CSOs is one of the foremost problems leading to surface water impairment in urban environments (Soriano and Rubio 2019; Fu et al. 2019). CSOs are common in the Northeastern United States, and are considered public health risks as a result of discharge containing domestic, commercial, industrial, and stormwater pollution, especially when exacerbated by the growth of impermeable surfaces that characterize urbanization (Chen et al. 2019; Fu et al. 2019). This infrastructure largely represents an aging fixture for stormwater management in older urban areas across the United States, and has come under increased scrutiny in recent years for its potentially harmful effects on the environment and human health (NJDEP 2019).

Combined sewer systems are characterized by a design of sewer infrastructure that uses a common pipe in order to transport sewer water, such as sewage and other residential waste, along with runoff and waste water, to its destination at a water treatment plant. Under normal circumstances, runoff stormwater will travel from the street level down into this combined pipe, keeping this water separate until treatment. However, this combined design can fail during rain events with high runoff; too much water entering the pipes may overwhelm the system, and the wastewater will then be discharged. Urban areas, which are characterized by a high percentage of impervious surfaces, contribute to this problem, and rainfall events that are not particularly significant may still cause CSOs to be overwhelmed. (NJDEP 2019, Salerno et al. 2018). Changing water dynamics and other uncertainties caused by global climate change have given these issues more urgency, as increased discharge from CSOs brought on by rising water levels or increased storm frequency or strength could make contamination more common (Jagai et al. 2015; Li et al. 2019). Further, these events exacerbate existing problems with increasing flooding, including threats to public infrastructure, urban networks, resident health, and property, especially for vulnerable populations (Venkataramanan et al. 2020).

The socio-economic aspects of stormwater management options (especially aging solutions such as CSOs) are not well understood and rarely reported in the literature, or integrated with more common physical and technological solutions. A better understanding of the socio-economic features of stormwater problems is needed to develop successful design and public policy solutions (Jayasooriya and Ng 2014). In the wake of large storms such as Hurricane Sandy, there has been heightened perception of the problems presented by continued use of CSO infrastructure, and efforts by the New Jersey Department of Environmental Protection (NJDEP) and the United States Environmental Protection Agency (USEPA) to mitigate CSO discharges are improving (NJDEP 2019). While several technical solutions for CSO mitigation exist, including improved gray infrastructure and different GI solutions, there is limited understanding of the public perception and comprehension of the economic and environmental tradeoffs of these solutions, particularly regarding GI (Jayasooriya and Ng 2014; Tsihrintzis and Hamid 1997). As such, this study proposes to bridge this research gap by studying the socio-economic aspects of stormwater management and assessing public perceptions to ultimately improve management decision making for public officials.

While the costs and benefits of gray infrastructure have a broad base of understanding and standardized methods of valuation, green infrastructure (GI) options are less understood (Bowen and Lynch 2017). GI can necessitate considerable public investment in terms of both private property and capital, which creates a need for better understanding (Bowen and Lynch 2017; Nordman et al. 2018). Public willingness to pay analyses for different GI options may be able to help identify the best approach to improve public participation in investing, managing, and overall taking a more active role in stormwater management strategies. This may be able to not only help allocate resources more effectively, but also add resources in the form of social capital. The results of this study will be of interest to government agencies, city planners, and environmental managers, may help to fill in gaps in the current research, and also create a more complete picture of the socio-economic structure behind management decisions.

Literature review

Human and environmental health of CSOs

CSOs create a significant problem for both human and environmental health, and their effects have been well documented by scientific literature (NJDEP 2019; Soriano and Rubio 2019; Salerno et al. 2018; Fu et al. 2019). CSOs, when they discharge, can put significant amounts of environmental, chemical, and anthropogenic wastes and hazards into waterways; the USEPA estimates that over 23 billion gallons of untreated sewage may be discharged into North Jersey waters due to CSO failures annually (EPA 2012).

During a discharge event, untreated sewage is the biggest cause of concern for human health as it includes microbial pathogens, viruses, and protozoa, which are all linked to illness in humans; high concentrations of fecal coliforms and other dangerous microbes as a result of CSO discharge have been tied to waterborne disease outbreaks in the United States and abroad, such as in Milwaukee, Cincinnati, New York, and Tokyo (Donovan et al. 2006; Brokamp et al. 2017; Jagai et al. 2015; Shibata et al. 2014). Though drinking water contamination presents the most serious risks to human health, CSO contamination can also be dangerous even in cases that do not involve ingestion. The EPA estimates that between 1.8 and 3.5 million people become ill due to recreational contact with water contaminated by sewer outfalls (Veronesi et al. 2013). CSOs also contribute to pollution through the collected storm runoff being discharged into the stream, as it may contain chemicals, fertilizers, and other pollutants that can cause environmental damage such as significant decreases in dissolved oxygen and toxic exposure (Varonesi et al. 2013; Soriano and Rubio 2019).

To further exacerbate these issues, CSOs can be relatively easily overwhelmed, as some urban areas of New Jersey can face discharge events with as little as one inch of rainfall (Battelle 2005; Donovan et al. 2006). These mild events, though not to the scale that larger storms such as Irene or Sandy, can still trigger stormwater discharge that is sufficient to cause significant waterway contamination or toxicity, especially near the discharge site (Casadio et al. 2010; Sandoval et al. 2013).

Green infrastructure as a mitigation option

GI refers to source control measures that reduce stormwater flow by promoting infiltration, evapotranspiration, and the capture and reuse of rainwater (de Sousa et al. 2012). GI can be in different forms, including green roofs, rain gardens, biofiltration basins, and permeable pavement, all of which act in varying capacity to reduce the overall amount of impervious surface area (USEPA 2013). Reducing impermeable area can reduce stormwater runoff and delay infiltration, which can reduce flooding and the negative effects caused by it (Li et al. 2019). GI's adaptability facilitates its use in a number of settings, including in areas that traditional gray infrastructure options generally has difficulty utilizing effectively, such as rooftops (USEPA 2013; Li et al. 2019). Though the increased infiltration of stormwater is one of the primary draws of GI options, these also have a host of other benefits, both for sustainability and more generally. Studies have found that different kinds of GI can remove pollutants from water, enhance carbon sequestration, reduce the urban heat island effect, improve air quality, increase drought resilience, control temperature, and improve esthetics and real estate value, among other benefits (Abhijith et al. 2017; Cohen et al. 2012; De Sousa et al. 2014; Li et al. 2019; Venkataramanan et al. 2019; Venkataramanan et al. 2020; Zhang and Chui 2019). Though gray infrastructure can present a more effective solution in terms of flooding risk, the use of GI can avoid some of its shortcomings, including increasing non-point source pollution, water quality deterioration, groundwater shortage, and changes in air temperature, humidity, and evapotranspiration (Zhang and Chui 2019).

Cities around the United States and abroad have begun to make GI a part of their plans for stormwater management, including Philadelphia, New York, Kansas City, and Chicago (De Sousa et al. 2014; Cohen et al. 2012). Philadelphia, for example, relies heavily on GI installations around the municipality to incrementally reduce discharges while providing significant benefit to its economy (Econsult 2016; Philadelphia Water Department 2017a, b). Studies suggest that GI can work as a cost-effective solution, especially in comparison to traditionally used gray infrastructure (USEPA 2007; USEPA 2013; Auckland Regional Council 2009; Li et al. 2019; Nordan et al. 2018). Cohen et al. (2012) used the study area in Turkey Creek, Kansas to model and compare the prices of GI as compared to gray infrastructure alternatives. They found that applying rain gardens to augment some gray infrastructure improvements rather than use gray infrastructure exclusively could save between $22 and $35 million for this CSO drainage area, and significantly reduce the amount of storm runoff to force CSO discharge. Thus, as both a cost-saving and effective measure against CSOs and increasing storm runoff in general, GI has become a staple in many areas worldwide. However, despite these quantified benefits, the adoption of GI has been relatively slow (Bowen and Lynch 2017).

Public perception regarding green infrastructure

While GI is growing in popularity and has been used effectively, it remains a relatively new solution compared to traditional gray infrastructure, and therefore research gaps exist in areas such as pricing and public perception. Thus, the body of literature on areas such as social perception (specifically with discrete choice experiment) is not yet comprehensive, though there have been some studies that have explored this facet of GI. Veronsei et al. (2013) utilized a discrete choice experiment on a local population in Switzerland to understand their willingness to pay to reduce the negative effects of CSOs, and what factors affected their willingness. They found that most of the selected sample was willing to pay higher taxes to reduce this risk, largely to protect water bodies and prevent environmental and human health risks. Meng and Hsu (2019) explored the use of GI in public municipalities with public officials as respondents. They found that public agencies are willing to pay more for smart GI with lower maintenance and operating costs over time, and that agencies that had utilized GI previously were more likely to do so again with smart infrastructure. Shr et al. (2019) used choice experiment approach to understand how visual aids affected respondent perception of GI, and found more favorable results from surveys that included images. Halkos and Matsiori (2012) used contingent valuation to understand willingness to pay and desired attributes for coastal zone quality improvements, and concluded that previous environmental behavior was critical in predicting willingness to pay.

This study applied a discrete choice experiment methodology to GI in the general public to reveal new insights on perceptions and willingness to pay. This built on existing literature by using discrete choice experiment and willingness to pay to understand public preferences for GI. Such a study will not only be able to inform city planning and management for GI projects, but may be able to suggest effective ways to move forward with stormwater management (particularly in mitigating CSOs) with more public support. To our knowledge, no such study has been carried out in New Jersey, which may be a critical area due to the confluence of urban and coastal climate change challenges it faces.

Methodology

Study area

New Jersey is home to a significant number of CSO sites, particularly in the industrialized and urbanized areas in the northern part of the state. The Newark Bay and the Lower Passaic region of New Jersey are noted for the considerable pollution and contamination of water bodies, largely as a result of historical and continuing industrialization, manufacturing, and urbanization. Several water bodies, including the Passaic River, flow through this densely populated area. Nearly 40 CSO outlets discharge into the Newark Bay/Kill van Kull area, and another 22 discharge into other waterways in this region. This area has several of the factors that put it at risk for high frequency and volume of CSO discharge events, notably a significant area of impervious surface. In the wake of Hurricane Sandy, in which large amounts of discharge contamination were released into local waterways, the state administration took steps to improve the resilience of areas that will be at risk during future extreme weather events (NJDEP 2015).

Newark, Elizabeth, and Paterson are cities within this area that have some of the highest numbers of outfalls in the state, with 17, 28, and 24 outfalls, respectively (NJDEP 2019). All three cities are among the highest population centers in New Jersey for both population and population density, which exacerbates the health issues that CSOs present. Because CSO discharges are strongly affected by stormwater runoff due to impervious urban surfaces, these cities serve well as examples for areas vulnerable to worsening consequences of using CSOs. Further, these areas have high rates of poverty, low college graduation rates, and high minority populations, which can make these areas of note for environmental justice concerns (US Census Bureau 2020). The most recent census estimates for these areas are summarized in Table 1.

Discrete choice experiment

A discrete choice experiment (DCE) approach can help understand consumer preferences for products or services that do not have a traditional market. This technique presents respondents with a number of different alternatives with varying attribute levels in order to understand which choices are favored over the others. An analysis of the resulting choices can then be used to allow for an estimation of the overall value of each attribute, and can identify both significance of attributes and how individuals are willing to trade attributes (Meng and Hsu 2019; Mangham et al. 2008). This method can also estimate the willingness to pay (WTP) for unit changes in the various attributes, which can be useful in management and planning scenarios (Mangham et al. 2008).

DCEs are grounded in random utility theory, which posits that the utility an individual derives from a good is dependent on the characteristics of a good and its unobserved components (McFadden et al. 1973). When stating their preference in their choice, it is assumed that respondents choose the alternative that yields the highest individual benefit (or utility), which in turn results from the combination of various attributes and attribute levels (Lancaster 1976; Mangham et al. 2008).

In general, a respondent q's utility from choosing alternative j in choice situation t in a utility function with random parameters can be defined as

$$Ujtq = Vjtq + \varepsilon jtq = \beta' qkXjtqk + \varepsilon jtq$$

Table 1 Census and EPA population and demographic statistics for study areas

	Newark	Elizabeth	Paterson
Population	280,463	128,153	145,800
Number of CSO outfalls	17	28	24
Poverty rate	28%	18.4%	28.1%
Demographics	White alone 26.1% Black or African American alone 49.7% American Indian and Alaska Native alone 0.5% Asian alone 2.1% Hawaiian or Other Pacific Islander alone 0% Some other race alone 19.1% Two or more races 2.4%	White alone 45% Black or African American alone 18.6% American Indian and Alaska Native alone 0.5% Asian alone 2.0% Hawaiian or Other Pacific Islander alone 0% Some other race alone 30.2% Two or more races 3.7%	White alone 29.3% Black or African American alone 26.5% American Indian and Alaska Native alone 0.1% Asian alone 3.8% Hawaiian or Other Pacific Islander alone 0% Some other race alone 35.6% Two or more races 4.7%
College education	Associate's Degree 5.5% Bachelor's Degree 10.4% Graduate or professional degree 4.4%	Associate's Degree 4.5% Bachelor's Degree 9.3% Graduate or professional degree 3.9%	Associate's Degree 3.4% Bachelor's Degree 8.4% Graduate or professional degree 2.4%
Median household income	$35,181	$46,975	$39,282

2018 American Community Survey 5-Year Estimates via data.census.gov (US Census Bureau 2020)

where respondent q ($q=1,\ldots.Q$) obtains utility U from choosing alternative j (Option A, B or C) in each of the choice sets t ($t=1,\ldots0.6$). The utility has a non-random component (V) and a stochastic term (ε). The non-random component is assumed to be a function of the vector k of choice specific attributes: X_{jtqk}, with corresponding parameters β_{qk} which may vary randomly with a mean β_k and standard deviation δ_k. The utility function of the model with the error term ε_{jtq} that includes the alternative specific constant representing a dummy for respondent choosing the status quo, can be expressed as a linear function of an attribute vector ($X1, X2, X3, X4$) = (secondary benefit, proximity, reduced flooding, payment).

$$Vjq = ASCq + \beta 1X1qj + \beta 2X2, qj + \beta 3X3, qj + \beta 4X4, qj$$

The probability that an individual q will choose alternative i over any other alternative j belonging to some choice set t of:

$$Prob_{iq} = Prob\left(V_{iq} + \varepsilon_{iq} > V_{jq} + \varepsilon_{jq}\right) \quad \forall j \in \mathrm{t}$$

Which equals

$$= Prob\{(Vin - Vjn) > (Ejn - Ein)\}$$

To empirically estimate the observable parameters of the utility function (3), this study assumed that the stochastic components are independently and identically distributed (IID) with a Gumbel or Weibull distribution. This leads to the use of multinomial/conditional logit (MNL) which assumes that unobserved factors affecting the choice of alternatives are strictly independent of each other (Independence of Irrelevant Alternatives, IIA). Hence determines the probabilities of choosing *i* over *j* options.

$$Probin = exp(\mu Viq) / \sum jexp(\mu Vjq) \ \forall j \in t$$

The willingness to pay (WTP) is the amount a consumer will accept to keep a utility unchanged for a change in attribute (Heng et al. 2020). Hence, the marginal WTP between any attributes and a cost attribute is obtainable.

$$WTP = (\beta a / \beta cost)$$

Attributes and optimal choice profiles

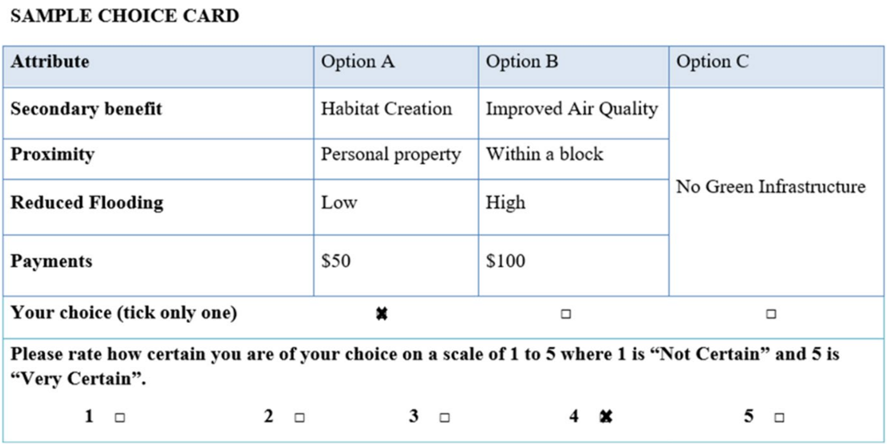
We considered choice experiment literature, GI literature, and previously run studies in the area to determine attributes and their corresponding levels (Veronsei et al. 2013; Meng and Hsu 2019; Shr et al. 2019; Halkos and Matsiori 2012; USEPA 2007). In our analyses, we decided on a total of four attributes, as described in Table 2. Since GI has varied benefits depending on its form, secondary benefits (secondary to its flood mitigation uses) are critical to their utility.

Table 2 Choice set attributes and levels

	Description	Levels
Secondary benefits	The main benefit that the GI option offers besides its water retention/flood mitigation functions	• Increased water supply • Noise reduction • Habitat creation • Improved air quality • Reduced energy use
Proximity	How close the GI would be to a respondent's residence	• On personal property • Within a block • Within the watershed
Reduced flooding	The effect of the GI on local flooding in general terms	• Low • High
Payment	How much the respondent would be willing to pay for the GI package in question as a one-time payment	• $25 • $50 • $75 • $100

To this end, we included some of the more common and more easily recognized benefits of GI, including increased water supply, noise reduction, habitat creation, improved air quality, and reduced energy use. Not in my backyard (NIMBY) has become a common problem with gray infrastructure, wherein residents desire the benefits from the fixture, but do not want it in close proximity to them. To delineate this impact, we included several levels of proximity, including on the property, within a city block, or within the watershed. Though GI may not be subject to the same NIMBYism considering its generally more natural forms, this is a critical measurement for perception, and may have significant influence in how municipalities may address proliferation in the future. In our study, more general values for flood mitigation amounts (high and low), could be more effective given that past studies have shown that the general populace may be unfamiliar with flooding dynamics and prevention methods (Shandas 2015; Barnhill and Smardon 2012). Finally, payment levels were developed from pre-test surveys studies in the area, as respondents reacted favorably to them and we received a higher percentage of completed responses as a result. We conducted a pilot survey as pre-test and included an open-ended response for willingness to pay. Respondents were asked to give a realistic amount that they would be willing to pay for GI improvements. These pre-test values were used to determine four equidistant bid amounts for the final survey.

The associated attribute levels resulted in 120 possible profiles (5 × 3 × 2 × 4). We applied a D-efficient combination accounting for orthogonality, level balance, and minimum overlap using the software R. The resulting fractional factorial design of 60 choice set profiles were randomly paired to create 30 choice set cards. These presented two distinct GI projects along with a status quo option for no GI intervention. Using this design, each respondent was given five choice tasks. A sample choice card is included in Fig. 1.



SAMPLE CHOICE CARD

Attribute	Option A	Option B	Option C
Secondary benefit	Habitat Creation	Improved Air Quality	No Green Infrastructure
Proximity	Personal property	Within a block	
Reduced Flooding	Low	High	
Payments	$50	$100	
Your choice (tick only one)	☒	☐	☐

Please rate how certain you are of your choice on a scale of 1 to 5 where 1 is "Not Certain" and 5 is "Very Certain".

1 ☐ **2** ☐ **3** ☐ **4** ☒ **5** ☐

Fig. 1 Sample choice card for choice experiment segment

Survey design, distribution, and analysis

The survey was developed using an extensive literature review, and was pre-tested in summer 2016 ($n=123$) to improve comprehensiveness and understandability in Elizabeth, NJ. The pre-test survey introduced the topic of GI with a brief explanation of GI and its potential benefits, including a brief infographic describing some common GI types (permeable pavement, rain cisterns, etc.). Questions in the survey asked for a variety of information from the respondents, including perceptions of stormwater dynamics, the behavior and dangers of stormwater in their area, and how they had personally been affected by flooding or other stormwater event in the past.

The improved survey used questions from the earlier pre-test version, and was expanded to include the discrete choice experiment question. This improved version excluded any questions from the earlier version that did not adequately contribute to GI understanding, or that appeared to have comprehension issues. The improved survey was again pre-tested via Qualtrics random sampling, which was refined to arrive at the final survey. The survey began with Likert scale questions to understand their perceptions on GI, current gray infrastructure, flooding in their area, and their health and safety. Respondents were then presented with choice experiment sets, wherein they were asked to choose between three options to showcase their preferences for various GI attributes. Finally, respondents were asked questions regarding their socio-demographic background information.

Surveys were distributed online via Qualtrics, a third-party polling company, between March and May 2020; surveys were delivered via an email link and respondents were compensated with a small undisclosed reward. In order to ensure a non-biased, representative sample of the cities targeted for the study, surveys were distributed only to residents living in those zip codes. The targeted respondents needed only to be residents of the targeted study areas, and were not chosen for any specific expertise. In total, we received 471 complete responses, including 226 in Newark, 110 in Elizabeth, and 135 in Paterson. These responses were imported into the analytics software STATA 15 E for analysis.

Results and discussion

Demographic results and goodness of fit

Our survey received 471 total responses throughout the three cities in the study area. Before moving on to the choice experiment analysis, we used a Pearson χ^2 test to understand if our sample was a reasonable representation of the areas in question and New Jersey as a whole. Most of our socio-demographic characteristics had equal means at the 1% level, indicating a goodness of fit. At a 1% significance level, the evidence for rejection of the null hypotheses of the equality of means was found for annual household income only. This information is detailed in Table 3.

Table 3 Socio-demographic characteristics of survey respondents for Elizabeth, Newark and Paterson and Total Response vs US Census for the Elizabeth, Newark, Paterson and New Jersey

	Elizabeth		Newark		Paterson		Total NJ	
	Sample	Population	Sample	Population	Sample	Population	Sample	Population
Sample size	107	129,216	224	282,011	140	145,233	471	8,882,190
Gender (% female)	38.32%	49.8%	45.94%	51.2%	54.28%	51.4%	46.7%	51.1%
Age (median)	35.5	34.5	35.5	34.4	35.5	33.5	35.5	39.9
Household size	3.08	2.39	3.22	2.67	2.89	3.25	3.09	2.69
Annual household income (median)	*87,499.5*	*48,407*	*62,499.5*	*35,199*	*42,499.5*	*41,360*	*62,499.5*	*82,545*
Housing (% Ownership)	*53.27%*	*24.2%*	*52.23%*	*22.3%*	*45%*	*26.1%*	50.32%	63.9%
High school completion rate	92.52%	73.4%	95.98%	75.3%	95.14%	74.8%	94.59%	89.8%

In italics the sample mean and the population mean are not equal at the 1% level according to the Pearson χ^2 test

Interpretation of the goodness of fit means that the sample and population at 1% are a good fit (for those demographics without italics)

Choice experiment analysis

Following the procedure for choice experiment evaluation, we ran a conditional logit regression (MNL) in STATA. In order to avoid a saturated model, we considered the attribute levels with the lowest utility to be the baseline that was dropped and considered the reference case; this in line with the choice experiment criteria we utilized. The baseline attribute for secondary benefits was noise reduction, for proximity we considered within a watershed, and for reduced flooding the baseline level was low. Further, we applied interaction factors such gender, education and income on the attributes levels within a watershed and personal property to further delineate factors that may influence respondents' preferences. Because these areas are notable for lower levels of education and income, we felt that interactions with these attributes could make for interesting interaction. Gender, though not particularly notable in the demographic sense, is nevertheless an important attribute that we wanted to explore, as it has implications for targeted outreach as GI initiatives move forward. These results can be found in Table 4.

Table 4 Conditional logistic regression (MNL) of choice experiment

Attribute levels and interactions	Conditional logit		
	Estimate	$P>\|z\|$	Robust std error
Secondary benefit			
Improved air quality	0.254	0.005***	0.090
Increased water supply	0.208	0.016**	0.085
Habitat creation	0.0415	0.661	0.094
Reduced energy use	0.0544	0.539	0.088
Proximity			
Personal property	0.348	0.007***	0.128
Within a block	0.217	0.074*	0.121
Reduced flooding			
High	0.366	0.000***	0.046
Cost	−0.004	0.000***	0.0009
ASC	−0.794	0.000***	0.168
Interactions			
Within watershed × gender	−0.399	0.000***	0.109
Personal property × gender	−0.389	0.000***	0.105
Personal property × education	−0.204	0.078*	0.116
Within watershed × income	3.74e-06	0.000***	9.25e-07
Pseudo R^2	0.1053		
Wald chi^2 (13)	547.13		
Prob > Chi^2	0.000		
Log pseudolikelihood	−2657.8879		
No of observations	1006		

***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively

We received 471 responses, each with several choice experiment sets, giving us an overall total of 1006 observations. The R^2 value of 0.1053 indicates a goodness of fit for the model, and suggests that the model provides good parameter estimates. The regression reveals that a number of the choices in the choice sets were significant, including air quality, GI on personal property, high water retention, cost, and increased water supply and GI within a block, albeit at higher levels of significance (0.95 and 0.90, respectively). Further, interactions between proximity (within the watershed and on personal property) and gender and proximity (within watershed) and income were also significant, with the interaction between proximity (on personal property) and education significant at the 0.90% interval.

Our regression reveals that a number of these attributes provide utility to respondents. Improved air quality and increased water supply were the most important secondary benefit attributes, with improved air quality having the highest coefficient among them. We hypothesized that the attributes that respondents would use most frequently would have the most utility, and the results appears to support this. Improving air quality may have high utility because of the rising importance of clean air, especially in urban areas (Derkzen et al. 2017). Further, past studies have found that air purification generally enjoys higher preference and willingness to pay (Derkzen et al. 2017; Lera-Lopez et al. 2012). Increased water supply may appeal to homeowners that may see easy applications for retained water in irrigation for their property, as respondents in past studies have placed higher values on GI that can provide water (Miller and Montalto 2019). Habitat creation and reduced energy use had considerably lower coefficients when compared to improved air quality and improved water supply. This may be because these attributes do not provide a high level of personal benefit, as ecosystem services that provide more direct benefits to health and well-being tend to be rated more highly (Derkzen et al. 2017). Further, it could also be a symptom of low levels of familiarity or understanding of GI, which have been observed in the literature (Barnhill and Smardon 2012; Shandas 2015).

Proximity was a major component of the choice experiment and proved significant. Respondents significantly found utility in GI that was within a city block or on their personal property; personal property had one of the highest coefficients in the model (0.348), and was considerably higher than within a block, which was also relatively high. This is a somewhat surprising result, as NIMBYism is a fairly common phenomena in the United States. Further, while literature connecting this phenomenon to GI explicitly is scarce, studies like the one done by Katy and Jari (2016) in Finland found that residents preferred stormwater ponds be sited away from their residences. Given that the least preferred option was within the watershed, and that the most preferred one was on personal property, our results suggest that this NIMBY trend is fading, or simply may not be as strong in this area of the United States. This may be due to changing perceptions, but may also be a result of GI being much smaller and less intrusive than the clean energy generators that NIMBYism is often associated with. Personal property GI had the most utility to respondents; this may reflect homeowners who perceive this as the best way to maximize their benefit while also giving them greater leverage and control over form, function, and maintenance.

Unsurprisingly, respondents found high utility in GI that has a high level of water retention rather than a low level. This is in line with our hypothesis, as we expected respondents that were interested in GI to want to maximize the utility of their expressed purpose in terms of flood mitigation. While we did not quantify this attribute, the general nature of the analysis suggests that homeowners, when faced with a choice, will prefer the option that gives better flood protection and reduce water flow around their home, which is in line with previous findings (Derkzen et al. 2017). Similarly, cost was found to be significant, and negative, which follows general trends for choice experiment models. As a result, this is fairly commonplace, as respondents can be expected to want to pay the lowest amount possible to maximize their utility.

We generated interactions with the intention of investigating how various attributes interacted with demographic attributes in hopes of revealing some insights as to what factors influence respondent's decisions. Specifically, we interacted variables on gender, income, and education, as we wanted to explore how they could influence CSO and GI policy in New Jersey. Interactions with gender and proximity were significant, namely with proximity within the watershed and on personal property. Our regression found that respondents that identified as female attributed less utility to both of these levels of proximity. This may suggest that females have a higher preference for GI on their property as opposed to their male counterparts, which may reveal outreach opportunities and needs for future policy. Respondents with higher levels of education tended to attribute less utility to GI on personal property. This may potentially be a result of better education on water dynamics and GI utility; while other respondents may want the assurances of seeing and maintaining GI personally, respondents with more education may be content to reap the benefits of infrastructure that they don't interact with. Finally, we found that respondents with higher incomes found higher utility for GI within their watershed. This may be due to a preference to use personal property and the surrounding neighborhood for other uses. These interactions may provide insight during policy creation, as they may be able to target various groups to increase acceptance.

Willingness to pay

We used a marginal willingness to pay analysis and analyzed the interactions between cost and various attributes on the choice experiment set, to understand which attributes were considered the most valuable in monetary terms. The results can be found in Table 5.

The results show a fairly wide distribution of effects. In terms of secondary benefits of the GI itself, respondents were willing to pay more for increased water supply and improved air quality. Improved air quality had the highest willingness to pay, with respondents willing to pay an additional $8.89 over increased water supply, and over four times more than they would pay for reduced energy use or habitat creation. This confirms our findings from the earlier parameter estimate analysis in Table 3, wherein we found that respondents found significant utility in these attributes; they are willing to pay a premium to receive the benefits. Furthermore, this reflects

Table 5 Marginal willingness to pay estimates (95% confidence intervals)

Attribute	MNL		
	WTP ($USD)	Lower limit	Upper limit
Secondary benefit			
Improved air quality	58.60	4.483	112.716
Increased water supply	49.71	−1.465	100.884
Reduced energy use	13.68	−28.421	55.787
Habitat creation	10.28	−34.601	55.168
Proximity			
Personal property	125.97	42.125	209.806
Within a block	110.01	32.462	187.552
Water retention			
High	84.90	37.777	132.027

findings in earlier studies, in which air quality and water supply had high utility, and thus enjoyed a higher willingness to pay (Derkzen et al. 2017; Lera-Lopez et al. 2012).

Though these secondary benefits were valuable, respondents were willing to pay higher premiums for placement than for any of the benefits. Respondents were willing to pay about $16 more for GI closer to home as compared to within the block, mirroring our findings in the earlier analysis. However, this constitutes a $67.37 increase from the highest secondary benefit and a $41.07 increase from the water retention attribute, making it the most valuable attribute by a considerable margin. This may be in an effort to realize more of the benefits, or to have more control in the implementation and maintenance. Respondents were also willing to pay more for retaining high amounts of water and mitigating floods than for any of the secondary benefits, which may suggest that respondents are more concerned with damages from flooding than with any of the problems that the secondary benefits could potentially help mitigate. This conforms to our expectations, as these areas are prone to flooding, and thus residents should be interested in reducing their frequency through mitigation. These findings suggest that GI that focuses on increasing water supply and improving air quality closer to residences may be ideal in term of garnering social capital.

Policy implications

Taken together, these findings can provide some insight into potential policies. Given the utility of an increased water supply and improved air quality, decision makers may want to prioritize GI that can more effectively provide them, such as rain barrels and bioretention gardens, respectively. Further, the preference for GI closer to respondents' properties may suggest an opportunity for outreach through offering grants or discounts on the installation of GI on personal property or on a neighborhood basis. As there was considerable utility and willingness to pay attached to high levels of runoff mitigation, it will also be important to ensure that

GI is chosen and sited in such a way to maximize that benefit. Finally, our interactions may reveal useful clues as to how to target outreach by gender, education, and income depending on the desired GI installation.

Conclusions

GI is an increasingly popular environmental management tool in mitigating the increasing effects of climate change, and has shown increased popularity throughout the United States and abroad. Though it has been proven effective, there remain many questions on the public preferences of its various forms, and how municipalities might best implement their use of GI with public favor. To this end, this study used discrete choice experiment surveys to gauge the perceptions and willingness to pay of New Jersey residents of three major urban cities (Newark, Elizabeth, and Paterson). Surveys were distributed by Qualtrics online in the spring of 2020, eliciting 471 total responses. The data was analyzed in STATA 15 E using conditional logit regression and marginal willingness to pay analyses. The survey results suggests considerable utility for many secondary attributes (air quality, habitat creation, water supply, noise reduction, etc.), with improved air quality and increased water supply as the most preferred benefits. We also found that respondents found more utility in GI fixtures either on their own property or within a block of them, perhaps due to greater perceived benefits or better control over the form and function of the GI in use. Overall, the utility from GI fulfilling its main purpose, namely increasing water infiltration, was significant and high, showing that respondents, while interested in the other benefits to be gained from infrastructure, are significantly invested in preventing flooding using these tools. Our willingness to pay analysis, suggests a direct correlation between utility and willingness to pay, and thus attributes that were preferred in the choice experiment had higher willingness to pay. This information can be valuable to policy makers and municipal governments for designing GI and other flood mitigation policies in New Jersey by informing some of the qualities that residents' value more highly when choosing GI. Ideally, this study may help inform policy by identifying opportunities to garner public support, add social capital, and allocate resources for more effective deployment of GI. This study helps explain trends across populations, and thus can inform environmental policy in similar urbanized areas.

Our study did suffer from some limitations. A key limitation lay in the fact that knowledge of complex issues such as water dynamics and green engineering is generally uncommon, and thus it can be difficult to evaluate the effectiveness of GI. COVID-19 and the ensuing pandemic limited our survey to an online format, as in person surveys were nearly impossible and mail surveys may have been viewed skeptically given unknowns about how the virus spread. However, due to lockdowns and other restrictions, it is possible that the pandemic led to a higher response rate for an online survey. Future study could utilize a mixed method approach, which could richen the dataset and reduce biases that come from only using an online survey. As this study was largely concerned with understanding perceptions with the intention of identifying areas for policy, future study could also use surveys to assess various GI programs and policies to predict public response. Further, our analysis focused on a relatively small subset of urban areas by focusing on New Jersey. To date, there are relatively few large GI initiatives in the state. Thus, it could be interesting to use future work to compare attitudes in areas such as these with ones that have seen large scale mobilization of GI initiatives, such as Philadelphia.

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Data availability Data available upon reasonable request.

Declarations

Conflict of interest Authors declare no conflict of interest.

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