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# Understanding the public's behavior in adopting green stormwater infrastructure

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ABSTRACT

Green stormwater infrastructure (GSI) is promoted to sustainably manage stormwater in the United States. Aside from mitigating floods, it provides other ecosystem services such as improved water quality, scenic beauty, and an increase in property values of surrounding houses, among others. Because of the importance of community participation in the success of GSI, we investigated the factors affecting the household's intention to adopt GSI practices on their properties. We sent out an online survey to the coastal residents from eight coastal counties of South Carolina. The final samples included 1,031 residents. Using generalized ordered logit models (GOLM), we assessed the factors affecting their level of intention to adopt three common GSI practices— rain gardens, rooftop disconnection, and rain barrels. We also applied logit regression to identify the determinants of their intention to adopt one or more GSI practices. Household characteristics such as age, house ownership, property flooding history, and perception of flooding impacts and stormwater management were found to be significant in most of the models. On the other hand, only a few adoption barriers and ES became significant across the models. The findings of this study could help stormwater professionals in encouraging residents to participate in onsite stormwater management.

## 1. Introduction

Rapid urbanization is changing how water flows in urban landscapes. To mitigate the hydrological impacts of increasing impervious surfaces, many cities in the United States started to invest in green stormwater infrastructure (GSI) (Baptiste et al., 2015; Miller and Montalto, 2019). GSI practices facilitate higher onsite infiltration (Sparkman et al., 2017; US EPA, 2019), thereby reducing surface runoff and flood risk (Bertule et al., 2014). By combining nature-based and engineered solutions (Miller and Montalto, 2019; Venkataramanan et al., 2020), GSI delivers broader ecosystem services (ES) in addition to reducing floods (Londoño Cadavid and Ando, 2013; Fletcher et al., 2015). This is contrary to conventional stormwater designs, which get the water off the landscape as quickly as possible. Although effective in reducing peak flows, these centralized systems were proven to have adverse water quality consequences (Gilroy and McCuen, 2009; Sparkman et al., 2017). As runoff travels through the landscape, it also transports multiple pollutants that contribute to nonpoint source pollution. This is especially problematic for cities with combined sewer systems (CSOs) since overflow of untreated stormwater and liquid wastes could happen once system capacity is exceeded (Irwin et al., 2017). As a new generation of decentralized stormwater designs, GSI is seen as innovative (Carlet, 2015), cost-effective (MacMullan and Reich, 2007; Houle et al., 2013; Dhakal and Chevalier, 2017; Nordman et al., 2018), and sustainable way to manage stormwater (Roy et al., 2008; Qiao et al., 2018).

Green stormwater infrastructure (GSI) mimics natural hydrology by infiltrating and treating runoff close to its source (Fletcher et al., 2015; US EPA, 2019). Across the literature, GSI is also referred to as stormwater best management practices (BMPs), low impact development (LID), or sustainable drainage systems (SuDS), among others (Fletcher et al., 2015; Prudencio and Null, 2018). While these types of stormwater practices are closely related and share similarities and benefits, the term GSI specifically encompasses stormwater practices that deliver multiple ecosystem services (Fletcher et al., 2015; Prudencio and Null, 2018). Various studies recorded that GSI practices are effective in reducing floods and improving water quality (Ahiablame and Shakya, 2016; Seo et al., 2017; Sparkman et al., 2017), and even for sequestering carbon (McPherson et al., 2011; Bouchard et al., 2013; Kremer et al., 2016).

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Also, it provides socio-economic benefits such as improved scenic beauty (Tupper, 2012; BenDor et al., 2018) and property values of the surrounding neighborhood (Ward et al., 2008; Donovan and Butry, 2010; Netusil et al., 2010; Ichihara and Cohen, 2011). Some examples of GSI practices include rain gardens, bioretention cells, vegetative swales, permeable pavements, and green roofs. Recently, some studies also considered stormwater practices with larger service areas (e.g., constructed wetlands, stormwater ponds) as GSI because of the multiple benefits they provide to the public (Moore and Hunt, 2011; Prudencio and Null, 2018; Beckingham et al., 2019; Venkataramanan et al., 2020).

Due to the decentralized nature and typically smaller service areas of GSI, its widespread adoption is necessary for its environmental benefits to manifest on a landscape (Ahiablame and Shakya, 2016; Seo et al., 2017; Garcia-Cuerva et al., 2018). Hence, community participation is essential for GSI practices to deliver cumulative benefits at a larger scale (Montalto et al., 2013; Baptiste et al., 2015; Jayakaran et al., 2020; Zuniga-Teran et al., 2020). For instance, Ahiablame and Shakya (2016) simulated that the widescale adoption of GSI practices (i.e., porous pavement, rain barrel, rain garden) under different implementation scenarios could reduce runoff by 3–47 % in an urban watershed in central Illinois. In North Carolina, Garcia-Cuerva et al. (2018) argued that strong community involvement and commitment are necessary to optimize the flooding reduction benefit of decentralized bioretention cells as they require a large cumulative area and consistent maintenance. Despite the importance of engaging stakeholders in fully mainstreaming GSI, its engineering aspect has been the main focus of GSI-related literature (Gao et al., 2018), and its human dimension is not thoroughly investigated (Venkataramanan et al., 2020).

Venkataramanan et al. (2020) highlighted that understanding public perception and adoption barriers is crucial to elevating the use of GSI as an integral part of stormwater management programs. To assess how the public views and understands GSI, various studies explored the individual's perception to implement these practices on private properties (Baptiste et al., 2015; Coleman et al., 2018; Gao et al., 2018). As proven in various studies, residents' willingness to implement GSI could be influenced by their prior knowledge on stormwater impacts and GSI; by household characteristics (e.g., demographic, flooding experiences); and by cognitive barriers (Baptiste et al., 2015; Brown et al., 2016; Coleman et al., 2018; Venkataramanan et al., 2020), among others.

The household's willingness to adopt GSI is highly dependent on its effectiveness to reduce flood, aesthetics, and affordability (e.g., low installation and maintenance costs) (Baptiste et al., 2015; Gao et al., 2018). High awareness on GSI and its benefits usually positively influences residents' adoption behavior (Brehm et al., 2013; Gao et al., 2016, 2018). Aside from flooding reduction benefits of GSI, perception about the improvement of other ecosystem services (e.g., water quality, wildlife habitat, aesthetics) could motivate residents to adopt GSI (Gao et al., 2016, 2018; Persaud et al., 2016; Miller and Montalto, 2019; Williams et al., 2019). Several studies agree that residents view the environmental benefits of GSI more favorably than its flooding reduction feature (Crisostomo et al., 2014; Miller and Montalto, 2019; Williams et al., 2019). In contrast, Gao et al. (2018) recorded that environmental benefits are less considered than functional benefits (e.g., effectiveness in managing floods) of GSI. Aside from the residents' prior knowledge on onsite benefits of GSI, various studies also noted that their perceived cumulative benefits at the watershed level could shape their attitude and motivation to adopt these practices (Baptiste et al., 2015; Gao et al., 2016, 2018; Shin and McCann, 2018; Venkataramanan et al., 2020).

The demographic characteristics and flooding-related experiences of households could affect their intention to adopt GSI practices. Some studies recorded that older people were more likely to adopt GSI (Venkataramanan et al., 2020), while others showed that younger generations were more interested in the idea (Turner et al., 2016). Households with higher income were also more likely to implement GSI on their properties (Brehm et al., 2013; Cote and Wolfe, 2014; Shandas, 2015); although lower-income households showed a willingness to participate, primarily if financial incentives are provided (Montalto et al., 2013; Brown et al., 2016). Various studies also found a significant influence of education (Shandas, 2015; Gao et al., 2016; Miller and Montalto, 2019) and house ownership (Brown et al., 2016; Gao et al., 2016; Turner et al., 2016) on the intention to adopt GSI. Also, prior knowledge and experiences on flooding could motivate homeowners to adopt flooding solutions (Shin and McCann, 2018).

Several studies also investigated how adoption barriers hinder GSI implementation on private properties. While there is a wide array of obstacles from federal to state policies to local resources and expertise (Roy et al., 2008; Brown and Farrelly, 2009), cognitive barriers remain a significant hindrance for residential adoption of GSI. Some of the cognitive barriers identified in the literature include the insufficient understanding about GSI (Turner et al., 2016; Shin and McCann, 2018; Miller and Montalto, 2019); perceived cost and time required to maintain the practice (Cote and Wolfe, 2014; Turner et al., 2016; Shin and McCann, 2018); and incompatible property rules (Montalto et al., 2013; Coleman et al., 2018), among others.

Similar to other states in the US, South Carolina (SC) is increasingly looking to GSI practices. To date, wet detention ponds (commonly known as stormwater ponds) are the most widely adopted stormwater practice in coastal SC (Smith, 2018). While knowledge and resources about onsite stormwater practices are growing, coastal SC residents were hesitant to adopt GSI mainly because of perceived installation and maintenance requirements and lack of expertise (Dickes et al., 2016). To understand better how coastal SC residents view GSI, we assessed their perception of stormwater practices and their intention to adopt them on their properties. We hypothesized that the residents' intention to adopt GSI practices is influenced by their profile, adoption barriers, and perception of ecosystem services. The findings of our study are useful for stormwater educators to help the SC residents address adoption barriers. This could also guide stormwater programs towards a more inclusive and participative approach to handle stormwater from the household scale up to the county-level. Furthermore, this study contributes to the limited literature on the public's perception and attitudes towards GSI practices. This information could be an input to planning resilient cities by enhancing the adoption of sustainable stormwater management practices.

## 2. Methodology

### 2.1. Study site

Flooding is a major concern across the eight coastal counties of South Carolina (Fig. 1). Like other southeastern states, SC is experiencing rapid development and a continuous shift from vegetated areas into impervious surfaces (Drescher et al., 2007; Schroer et al., 2018). This makes stormwater management more challenging, especially considering that one-third of its coastal population lives in Federal Emergency Management Agency (FEMA) floodplain areas (Fig. 2). While the distribution of people residing in floodplains varies per county, the percentages range from 15 % to 49 %. For instance, almost half of the population in Beaufort (48 %) and Charleston (49 %) counties are residing in floodplain areas, while only 15 % each in Dorchester and Horry (NOAA Office for Coastal Management, 2019).

Wet detention ponds are the most widely adopted stormwater control measures in coastal SC. Due to regulatory requirements of maintaining water quality standards (Dickes et al., 2016), they became a crucial feature of the coastal landscape beginning in the early 1990s (Drescher et al., 2007). Although wet detention ponds remain the most common and well-studied stormwater strategy in SC, designs for small-scale onsite stormwater practices are also widely available (e.g., Ellis et al., 2014; US EPA, 2019; Clemson University, 2020). At a workshop held in Charleston, SC, these innovative practices (e.g., bioretention cells, pervious pavement, rainwater harvesting) were seen as

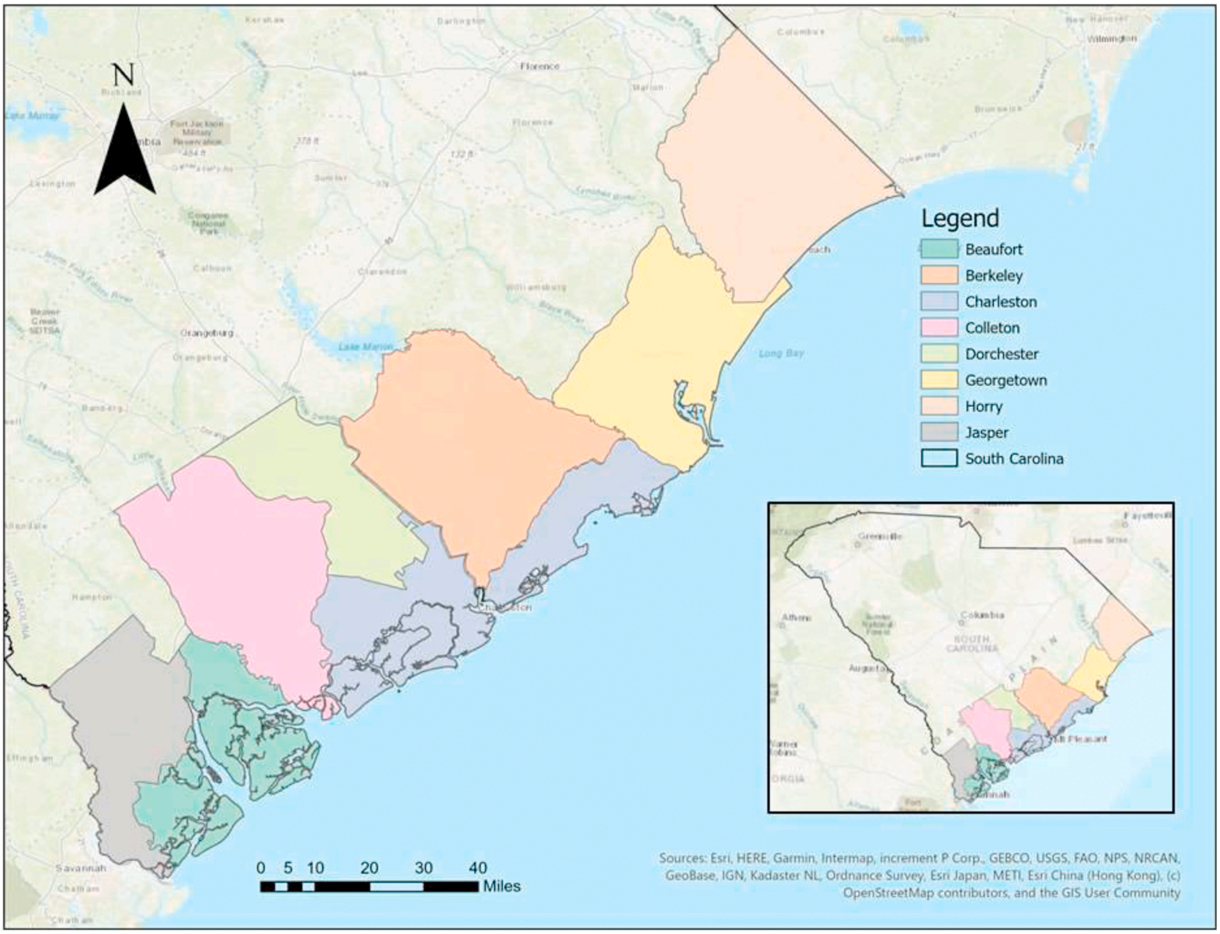


**Fig. 1.** Location of the study site.

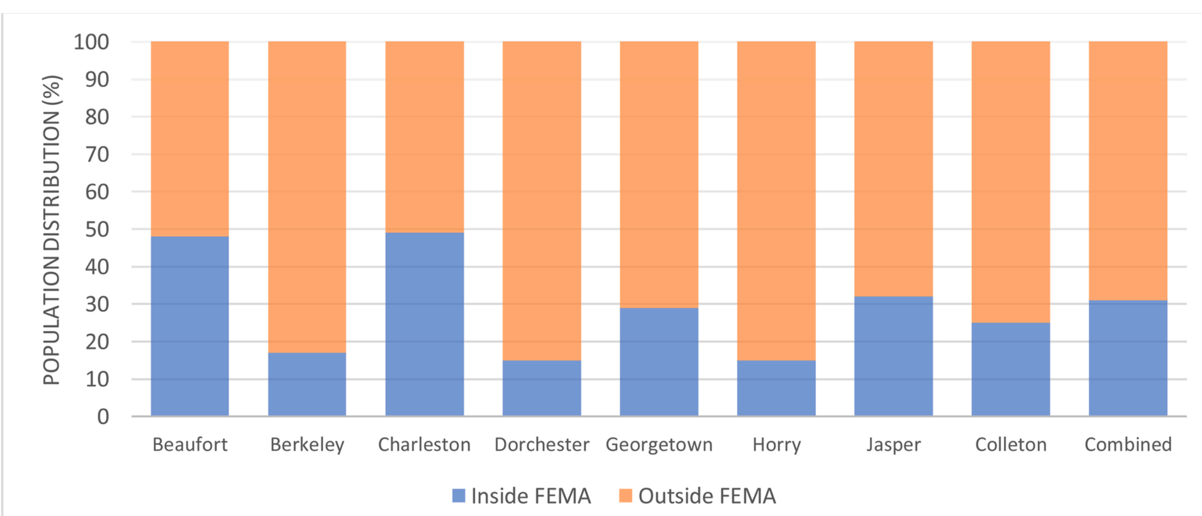


**Fig. 2.** Distribution of population living inside FEMA floodplain areas, 2013.
Source: Derived from individual coastal county snapshots by NOAA Office for Coastal Management (2019)

reasonable alternative to ponds by professional stormwater practitioners (Vandiver and Hernandez, 2004). However, the study conducted by Martin et al. (2008) revealed that only about one-third of developers and builders, regulatory managers, and engineers share the same sentiment that GSIs were innovative, less expensive, and more efficient compared to traditional practices.

Educational barriers, particularly lack of knowledge about GSI practices, have been the primary constraint for widespread adoption of GSIs in coastal SC (Vandiver and Hernandez, 2004; Halfacre et al., 2007; Martin et al., 2008; Castiglia, 2011; Vandiver, 2011; Dickes et al., 2016). Unlike the conventional practices (e.g., ponds), there were limited studies that support the technical effectiveness, cost efficiency, and site suitability of GSI in coastal SC (Vandiver and Hernandez, 2004; Castiglia, 2011). To address this knowledge gap, the National Estuarine Research Reserves and the SC Sea Grant Consortium brought together stormwater agencies, practitioners, and academicians to prepare and publish a guidebook, known as LID manual of South Carolina (Ellis et al., 2014). To date, this is the most comprehensive document that discusses the different stormwater practices in SC. However, despite the increasing knowledge and resources on GSI practices, little research has been conducted to assess the GSI adoption behavior of residents.

### 2.2. Data collection

We designed an online survey to assess the perception of SC coastal residents towards adopting GSI practices. We utilized the questionnaire of Coleman et al. (2018) which they used to evaluate the factors influencing residential intention to adopt GSI in Vermont; although some questions were customized according to our research needs. For instance, we added questions about ES, while we deleted some which did not apply to our study site. We designed the survey to gather information on residents' profiles, flooding-related experiences and perceptions, awareness and intention to adopt specific GSI practices, adoption barriers, and perceived importance of ES. The questionnaire was pretested with 20 stormwater professionals and 50 residents of coastal SC. The survey was then distributed by Qualtrics, an online survey platform, using a simple random sampling technique (Qualtrics, 2021) in January 2019. Considering that 79 % of SC coastal residents have access to the internet (U.S. Census Bureau, 2018), our samples were drawn from the majority of the population. We targeted 1,050 residents living in the coastal zone of SC— Beaufort, Berkeley, Charleston, Colleton, Dorchester, Georgetown, Horry, and Jasper (South Carolina General Assembly, 1977).

Since the survey was distributed online, we included introductory videos about GSI practices (CIRIA, 2013) and ecosystem services (Clemson University, 2019). Our survey focused on eight types of smaller scale GSI practices such as rain gardens, bioretention cells/bioswales, vegetative swales, infiltration trenches, green roofs, rooftop (downspout) disconnection, rain barrels, and continuous permeable pavement systems. Aside from the informative video about GSI, we also showed them pictures with corresponding brief descriptions of each practice (Appendix 1). Using separate 5-point Likert scales, we determined the prevalence of these GSI practices in their counties and their intention to adopt each of them on their properties in the next three years. Aside from a 5-point rating scale wherein 1 represents 'least common', while 5 indicates 'extremely common', we also provided an option to choose 0 for 'not applicable' if they have not seen or heard any of the practices before the survey. For their intention to adopt each of the practices, 1 represents 'extremely unlikely', while 5 represents 'extremely likely'.

We presented the respondents with ten potential barriers for adopting GSI practices in general. These were phrased as '*yes*' or '*no*' questions. Unlike the questionnaire of Coleman et al. (2018), the barriers were not specific to any practice, but they apply to all GSI practices in general. During our questionnaire pretest and discussion with local stormwater experts, we noticed that implementation barriers were the same for many of the practices. Hence, we decided to ask general barriers instead of GSI-specific barriers to improve our questionnaire's readability and minimize the response time per respondent. In this way, more residents will participate and finish the whole survey. On the other hand, we utilized a 5-point Likert scale to determine the importance of ecosystem services, wherein 1 represents 'not important at all', while 5 represents 'extremely important'. We presented the respondents with 14 ecosystem services that were cited from the LID manual of South Carolina (Ellis et al., 2014). We also classified these benefits based on the widely accepted categories of ecosystem services— regulatory, supporting, and cultural services (De Groot et al., 2002; Millennium Ecosystem Assessment, 2005). We did not include any provisioning services in the list of benefits since GSI practices are typically not installed for direct provision of goods (e.g., food, water, raw materials) in SC.

As patterned from the study of Coleman et al. (2018), our survey also captured both the household's social and physical attributes. We recorded their demographic characteristics including age, gender, educational attainment, income, and primary residence ownership. For physical characteristics, we solicited information about their primary residence features (i.e., lot size, percent of impervious surfaces) and locational attributes such as distance from the nearest water body. We also asked the respondents about their flooding experiences and their perception of flooding impacts on their respective neighborhoods and county.

After data cleaning, our final dataset included responses from 1,031 residents. Table 1 shows that most of the socio-economic characteristics of the respondents are comparable with the census data for the eight coastal counties, though our sample overrepresented college degree holders (63 % as opposed to 26 % from census data). Intuitively, this could be associated with college degree holders having typically greater access to online surveys. Various studies recorded that better-educated individuals typically participated more in online surveys since they are likely to use the internet (Duda and Nobile, 2010; Graefe et al., 2011; Sexton et al., 2011). Hence, our results may not represent other social groups' perceptions, especially those without internet access who were excluded in the random selection process.

### 2.3. Data analysis

We assessed if certain household attributes, adoption barriers, and residents' perception of ecosystem services influence their level of intention to adopt GSI practices (Table 1). Since we used a 5-point Likert scale to determine the residents' intention to adopt GSI practices, it is appropriate to analyze their level of preferences using a likelihood regression model such as the ordered logit models. Initially, we ran separate ordered logit models (OLM) (Long and Freese, 2006) for the most desired GSI practices in coastal SC— (1) rooftop disconnection, (2) rain gardens, and (3) rain barrels, respectively. However, Brant test (Long and Freese, 2006) showed that the parallel regression assumption was violated across the three models. Hence, as an alternative, we used the generalized ordered logit model (GOLM), otherwise known as the partial proportional odds model (Williams, 2006). GOLM relaxes the parallel-lines constraint assumption by fitting the partial proportional odds of some variables (Williams, 2006).

The residential intention to adopt a specific GSI practice was coded as an ordinal variable $Y$. Although we initially assessed the household's intention using a 5-point Likert scale, we simplified the scores into three levels since the data is not normally distributed. Respondents who answered 1 (extremely unlikely) or 2 (somewhat unlikely) were coded as 1 representing low intention. Those who responded 3 (neither likely nor unlikely) were coded as 2 which shows neutral intention. Lastly, residents who expressed their adoption intention as 4 (somewhat likely) or 5 (extremely likely) were coded as 3, indicating high intention. The GOLM is specified as:

$$\Pr(y_i > j) = \frac{exp(\alpha_j + X_i\beta_j)}{1 + \left[exp\left(\alpha_j + X_i\beta_j\right)\right]}, \ j = 1, 2, \ldots, M-1 \quad (1)$$

where $X_i$ is a vector of observed nonrandom explanatory variables, while $\beta_j$ is the estimated coefficients for the adoption decision with $j = 1, 2, 3$. Following the example of Coleman et al. (2018), we did not include the respondents who already adopted the GSI of interest. By dropping these observations, we limited our analysis to factors affecting intention to adopt a GSI practice rather than factors that led them to adopt these practices in the past.

Besides specific GSI practices, we also hypothesized that household attributes, adoption barriers, and perception of ecosystem services affect

**Table 1**
Descriptive statistics of the sample.

| Variables | Type | Description | Sample distribution (%) | Census[a] |
|---|---|---|---|---|
| Age | Count | Years | 50.5[b] | 41.4 [c] |
| Male | Dummy | Male | 32 | 48 |
| Education | Dummy | College degree holders or higher | 63 | 26 |
| | 1 | Less than $50,000 | 35 | 49 |
| Annual gross household income | 2 | $50,000- $90,000 | 31 | 51[d] |
| | 3 | More than $90,000 | 34 | |
| | 1 | No, we only rent the house. | 20 | 32[e] |
| Property decision | 2 | No, the property manager and/or HOA decides. | 23 | 68[e] |
| | 3 | Yes, I decide on how to develop my property. | 57 | |
| House flooding | Dummy | Experienced flooding inside the house | 10 | |
| Lawn flooding | Dummy | Experienced flooding in the lawn area | 73 | |
| Damage to water | Dummy | Perceived that flooding reduces the water quality of streams, rivers, and coastal waters | 50 | |
| | 1 | Have not seen a rain garden before | 35 | |
| Prevalence of rain garden in the county | 2 | Not a common practice | 32 | |
| | 3 | Very common practice | 33 | |
| | 1 | Have not seen rooftop disconnection before | 28 | |
| Prevalence of rooftop disconnection in the county | 2 | Not a common practice | 16 | |
| | 3 | Very common practice | 56 | |
| | 1 | Have not seen rain barrel before | 40 | |
| Prevalence of rain barrel in the county | 2 | Not a common practice | 37 | |
| | 3 | Very common practice | 23 | |
| Familiarity with GSI | Dummy | Have seen at least one of the eight GIS practices before | 79 | |
| Do not work | Dummy | Does not believe that GSI can lessen flooding | 20 | |
| Lack of space | Dummy | Not enough space | 50 | |
| Lack of knowledge | Dummy | Lack of knowledge | 59 | |
| Not attractive | Dummy | Believes that GSI are not visually attractive or pleasant | 32 | |
| No contact | Dummy | No contact | 54 | |
| Water quality benefit | Dummy | Improvement of water quality is extremely important | 66 | |
| Water supply benefit | Dummy | Sustaining stream base flow/water supply is extremely important | 44 | |
| Biodiversity benefit | Dummy | Restoration of wildlife habitat is extremely important | 52 | |
| Aesthetic benefit | Dummy | Improve aesthetic value or scenic beauty is extremely important | 34 | |
| Flooding reduction | Dummy | Flooding reduction is extremely important | 66 | |

[a] *Source:* U.S. Census Bureau, 2018 *American Community Survey 5-Year Estimates. We calculated the average values of each variable using the census data of 8 coastal counties of SC.*
[b] *Mean age of respondents across the eight counties.*
[c] *Median age of the entire coastal population as calculated from census data of 8 coastal counties of SC.*
[d] *Proportion of households who were earning at least $50,000 annually.*
[e] *Source: U.S. Census Bureau, American Community Survey 2017 1-Year Estimates. This percentage represents the proportion of households who own their primary residence.*

the household's intention to adopt one or more GSI practices. To address this hypothesis, we ran a logistic regression. We presented the respondents with eight types of GSI practices and asked them to indicate their intention to adopt each of the practices using a scale of 1–5, wherein 5 represents the highest intention. Respondents who gave a score of 4–5 (somewhat and extremely likely) for at least one GSI practice were coded as 1, while those who gave a score lower than 4 to all the practices were coded as 0. Logit model is expressed as:

$$\Pr(y_i \neq 0 \mid X_i) = \frac{exp(X_i\beta)}{1 + exp(X_i\beta)} \quad (2)$$

where $\beta$ is the coefficient of the vector of observed nonrandom explanatory variables $X_i$.

## 3. Results

### 3.1. Perception and awareness of stormwater management

The majority of respondents (75 %) reported that flooding is a problem in their respective counties. Also, 80 % believed that flooding causes damage to roads, buildings, and residential houses, among others. Aside from temporary disruption in daily activities, which was identified by 76 % of the respondents, most households also believed that flooding results in damage to natural resources (56 %) and water quality deterioration (50 %).

When it comes to property flooding, 73 % of the respondents experienced backyard flooding at least once in their primary residence. Typically, this occurs after heavy rainfall, although 16 % of the respondents cited that they are experiencing backyard flooding at least once a month. A small percentage of the respondents also experienced flooding inside their houses (10 %), while others experienced basement flooding (14 %). About 81 % of those who experienced flooding within their properties (n = 798) perceived that flooding is also a county-wide problem.

We also assessed their perception of their property's contribution to nonpoint source pollution. A majority of the respondents (60 %) cited that fertilizers or pesticides and yard waste were the primary pollutants that are washed away by runoff from their properties. This is followed by pet waste (54 %) and oil and grease (35 %). More than half of the respondents also believed that stormwater typically soaks into the ground on their property, while the excess runoff flows to the nearest storm drain.

### 3.2. Barriers to GSI adoption

Respondents perceived high installation (77 %) and maintenance costs (68 %) as one of their barriers to adopting residential GSI practices. Among the respondents who reported installation costs as a barrier (n = 794), 41 % have a household income of less than $50,000 annually. For those who considered maintenance costs as a barrier (n = 700), 44 % came from households with an annual income bracket of less than $50,000 per year. Most households (63 %) identified both installation and maintenance costs as a barrier.

A large percentage of the respondents (63 %) also perceived that GSI is not suitable for their properties, while 51 % reported that installing GSI practices is against property rules. Given the respondents' property ownership profile, we recorded that 64 % of property owners reported property suitability as one of their constraints in adopting GSIs. Also, 43 % of homeowners cited property rules as a constraint for installing GSI practices. Among those who are renting their primary residence, 62 % reported property suitability and property rules as adoption barriers.

Respondents also identified lack of information as a barrier in adopting GSI practices. For instance, 59 % reported that they lack knowledge on how to install these practices. Also, 54 % were unaware of who to contact for installation. Since most of our respondents are college degree holders (n = 647), we compared this barrier to their education profile. We noticed that among degree holders, 60 % reported that they lack knowledge on how to build or use GSI practices. Also, 54 % of the degree holders cited that they do not have contacts to install these strategies. This distribution was also observed with the respondents without college degrees (n = 384). For instance, 56 % reported a lack of information about the practice, while 53 % cited a lack of GSI-related contact persons or providers. We also analyzed these information-related barriers among different age groups (i.e., adults, elderly). Among the adult age bracket (18–64 years old) (n = 736), 59 % reported a lack of information on GSI practices installation, while 54 % cited lack of contact persons as a barrier. When it comes to the elderly group (65 years old and above) (n = 295), 57 % identified a lack of knowledge on GSI installation, while 53 % were also unaware of who to contact for more information.

### 3.3. Importance of GSI ecosystem services

We determined the respondents' preference for ecosystem services provided by GSI practices (Fig. 3). On average, respondents gave the highest rating to water quality improvement capacity of GSI practices, followed by contribution to reducing flooding events. The benefits with the highest scores are related to regulating services of GSI practices. Supporting services also obtained high ratings, which confirm that the residents value the biodiversity impacts of GSI practices. Interestingly, the cultural services of GSI have lower ratings compared to other types of benefits.

Among those who experienced property flooding (n = 798), 68 % considered water quality and flooding reduction benefits of GSI practices extremely important. Of the households who perceived flooding to be a problem in their counties (n = 774), 72 % also recognized these two services as extremely important features of GSI practices.

We also compared the scores they assigned to waste treatment of GSI to their perception of the type of pollutants that are washed out by runoff from their properties. Among the respondents who perceived that they contribute to water pollution because of the fertilizers and pesticides from their lawns (n = 616), 69 % considered an improvement in water quality as an extremely important benefit of GSI. When it comes to the respondents who believed that their yard waste (e.g., grass clippings, leaves) is carried by runoff (n = 616), 68 % recognized water quality benefit as extremely important. Lastly, 69 % of those who reported that bacteria from pet waste are washed out by runoff from their properties (n = 560) considered water quality improvement extremely important.

### 3.4. Determinants of intention to adopt GSI practices

Prior to assessing the respondents' intention to adopt residential GSI, we assessed their level of awareness of stormwater management practices. Results showed that they are most familiar with neighborhood-scale practices such as wet ponds, constructed wetlands, and dry ponds. For residential GSI practices, most households identified rooftop disconnection as the most widely adopted in their respective counties. However, 28 % reported that they had not seen any rooftop disconnection in their area before the survey. Of the households surveyed, 65 % said that rain gardens are currently used in their counties, as well as vegetative swales (64 %), rain barrels (60 %), and permeable pavements (60 %).

A majority of the respondents (58 %) expressed intention to adopt one or more GSI practices on their properties. Many of these respondents (67 %) experienced property flooding and perceived that flooding is a problem in their counties. As illustrated in Fig. 4, rooftop disconnection is currently the most widely adopted strategy to handle stormwater at the household level. It is currently used by 30 % of the sample households. Also, 28 % cited that they are likely to adopt this practice on their properties in the next three years. Many respondents also reported that they are somewhat likely or extremely likely to adopt rain gardens (24 %), rain barrels (23 %), or vegetative swales (18 %) on their properties. On the other hand, the practices that were extremely unlikely to be adopted include green roofs (67 %), permeable pavements (45 %), bioretention cells (44 %), and infiltration trenches (42 %), respectively.

Using GOLM, we determined the specific household attributes,

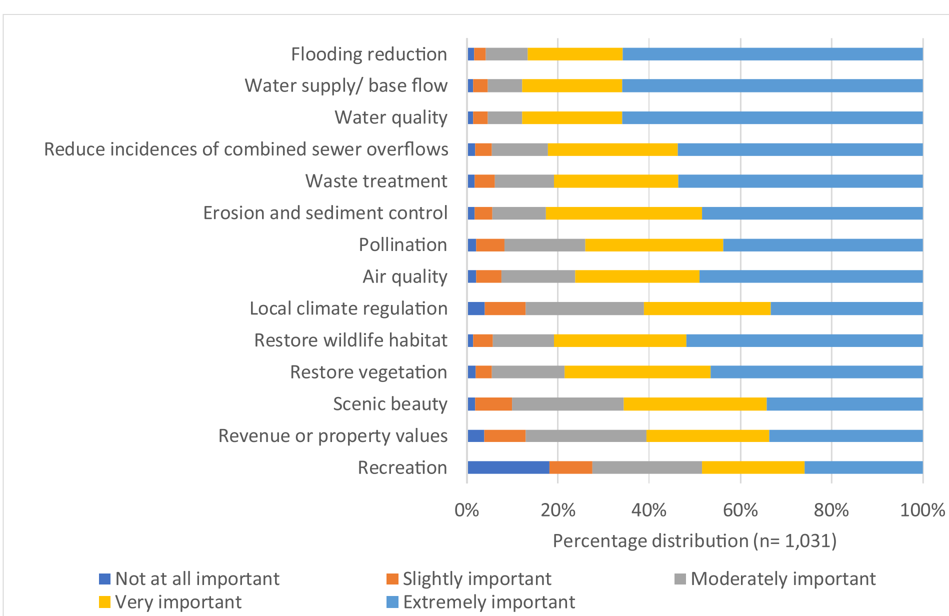


**Fig. 3.** Level of importance of ecosystem services provided by GSI practices.

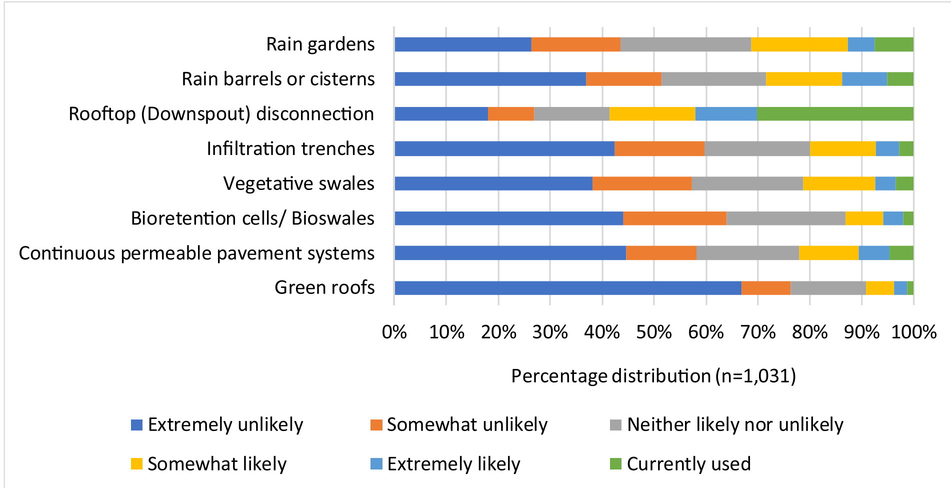


**Fig. 4.** Residential-scale GSI that residents intend to adopt on their properties.

adoption barriers, and ecosystem services that influence the residents' level of intention to adopt three GSI practices. Table 2 presents the results of each model, wherein panel Y > 1 contrasts low intention with neutral to high intention (category 1 versus categories 2 and 3) while panel Y > 2 contrasts low to neutral intention with high intention (categories 1 and 2 versus category 3). Across the models, age consistently has a significant and negative relationship with the dependent variable. It is also classified as a constrained variable for all the models; hence its coefficients are the same for both panels. This implies that as residents age by a year, their intention to adopt GSI practices decreases.

The results of GOLM for assessing the residents' level of intention to adopt rain gardens showed that constraints for parallel lines are relaxed for three variables— water quality benefit, and gross income categories 1 and 2. Constraints for parallel lines were imposed to other variables; hence their parameter coefficients are the same for both panels (Williams, 2016). For the constrained variables, the interpretation of the

**Table 2**
Generalized ordered logit estimation results.

| Variables | Unit | Rain garden | | | | Rooftop disconnection | | | | Rain barrel | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Y > 1 | | Y > 2 | | Y > 1 | | Y > 2 | | Y > 1 | | Y > 2 | |
| | | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. | Coeff. | Std. Err. |
| **A. Respondent's profile** | | | | | | | | | | | | | |
| Age | Year | −0.016*** | 0.004 | −0.016*** | 0.004 | −0.023*** | 0.005 | −0.023*** | 0.005 | −0.023*** | 0.005 | −0.023*** | 0.005 |
| | 1 | omitted | | omitted | | omitted | | omitted | | omitted | | omitted | |
| Income | 2 | 0.051 | 0.162 | 0.426** | 0.187 | 0.092 | 0.174 | 0.092 | 0.174 | 0.121 | 0.193 | 0.121 | 0.193 |
| | 3 | 0.132 | 0.175 | 0.738*** | 0.195 | −0.034 | 0.19 | −0.034 | 0.19 | 0.046 | 0.21 | 0.046 | 0.21 |
| | 1 | omitted | | omitted | | omitted | | omitted | | omitted | | omitted | |
| Property decision | 2 | −0.04 | 0.198 | −0.04 | 0.198 | 0.254 | 0.218 | 0.254 | 0.218 | −0.441* | 0.262 | −0.441* | 0.262 |
| | 3 | 0.411** | 0.162 | 0.411** | 0.162 | 0.588*** | 0.183 | 0.588*** | 0.183 | 0.237 | 0.203 | 0.237 | 0.203 |
| House flooding | 1 | 0.448** | 0.213 | 0.448** | 0.213 | −0.032 | 0.232 | −0.032 | 0.232 | 0.185 | 0.265 | 0.185 | 0.265 |
| Lawn flooding | 1 | 0.373** | 0.147 | 0.373** | 0.147 | 0.46*** | 0.167 | 0.46*** | 0.167 | 0.151 | 0.195 | 0.151 | 0.195 |
| Water deterioration | 1 | 0.277** | 0.129 | 0.277** | 0.129 | 0.158 | 0.148 | 0.158 | 0.148 | 0.049 | 0.165 | 0.049 | 0.165 |
| Prevalence of GSI | 1 | omitted | | omitted | | omitted | | | | | | | |
| practice in the | 2 | −0.117 | 0.152 | −0.117 | 0.152 | −0.341* | 0.201 | −0.341* | 0.201 | omitted | | omitted | |
| county | 3 | 0.346** | 0.156 | 0.346** | 0.156 | 0.378** | 0.163 | 0.378** | 0.163 | 0.52*** | 0.166 | 0.52*** | 0.166 |
| **B. Barriers to GSI adoption** | | | | | | | | | | | | | |
| Do not work | 1 | −0.452*** | 0.165 | −0.452*** | 0.165 | −0.074 | 0.177 | −0.074 | 0.177 | −0.108 | 0.218 | −0.108 | 0.218 |
| Lack of space | 1 | −0.002 | 0.126 | −0.002 | 0.126 | | | | | | | | |
| Lack of knowledge | 1 | −0.06 | 0.13 | −0.06 | 0.13 | | | | | | | | |
| Not attractive | 1 | | | | | | | | | −0.244 | 0.18 | −0.244 | 0.18 |
| No contact | 1 | | | | | | | | | −0.105 | 0.163 | −0.105 | 0.163 |
| **C. Ecosystem Services of GSI** | | | | | | | | | | | | | |
| Water quality benefit | 1 | 0.225 | 0.169 | 0.643*** | 0.195 | 0.111 | 0.162 | 0.111 | 0.162 | | | | |
| Water supply benefit | 1 | 0.026 | 0.157 | 0.026 | 0.157 | | | | | 0.202 | 0.176 | 0.202 | 0.176 |
| Biodiversity benefit | 1 | 0.06 | 0.154 | 0.06 | 0.154 | | | | | | | | |
| Aesthetic benefit | 1 | | | | | 0.11 | 0.162 | 0.11 | 0.162 | | | | |
| Flooding reduction | 1 | | | | | | | | | 0.024 | 0.19 | 0.024 | 0.19 |
| _cons | | 0.074 | 0.295 | −1.757*** | 0.318 | 0.676** | 0.301 | −0.235 | 0.3 | 0.617* | 0.351 | −0.263 | 0.351 |
| Number of obs | | 954.00 | | | | 720 | | | | 615 | | | |
| Pseudo R2 | | 0.05 | | | | 0.04 | | | | 0.03 | | | |
| Log likelihood | | −959.47 | | | | −732.36 | | | | −596.70 | | | |

Significance levels: ***$p$ <1%, **$p$<5%, * $p$<.10 %

coefficients follows that of the ordered logit model. For instance, residents who own their primary residence and decide how to develop their land have a higher tendency to adopt rain gardens compared to those who are renting. Also, residents whose houses or lawns were flooded at least once are more likely to intend to install rain gardens. Residents who also reported that rain gardens are a widespread stormwater strategy in their counties tend to have a higher intention to install rain gardens than those who have never seen a rain garden before. Their perception on the impact of flooding also affects their intention for rain garden installation. Those who believed that flooding causes deterioration of water quality of streams and other water bodies are more likely to install rain gardens. When it comes to adoption barriers, their perception on the ineffectiveness of GSI practices was statistically significant. This proves that residents who believe that GSI practices are not effective tended to have lower intention to install rain gardens. For the three unconstrained variables, their coefficients vary per panel. Income categories 2 and 3 were positive and significant for panel $Y > 2$, which illustrates that compared to the respondents who are earning less than $50,000 a year, those who are earning more are likely to be in a higher category of Y. Lastly, respondents who believe that the water quality benefit of GSI practices are extremely important are likely to have a higher level of intention to install a rain garden.

Unlike the GOLM results for rain gardens, intention to adopt rooftop disconnection is only significantly influenced by variables pertaining to the residents' socio-demographic characteristics and perception. Adoption barriers and ecosystem services variables were not statistically significant in the model. Also, all the variables met the parallel lines assumption; hence the coefficients could be interpreted the same with ordered logit model. Apart from age, intention to adopt rooftop disconnection is affected by homeownership, lawn flooding experiences, and prevalence of the practice in their respective counties. Those who own their primary residence and have the flexibility to decide what to do with their land are more likely to have intention to adopt rooftop disconnection as compared to those who are renting. Also, respondents are more likely to intend to adopt rooftop disconnection if they believe this practice is widespread in their county. Interestingly, those who think that rooftop disconnection is rarely practiced in their county are less likely to adopt it than those who have never seen this practice before.

Similar to the regression results for rooftop disconnection, variables pertaining to the respondents' household profile were the only significant factors in the GOLM for rain barrels. Also, all the variables met the parallel line assumption. Apart from age, property decision arrangement and perception of this practice's prevalence were the only significant factors influencing intention to install rain barrels. As compared to those who are renting their primary residence, homeowners who are not solely in-charged of property development decisions are less likely to have the intention to install rain barrel. Meanwhile, those who think this practice is very common in their counties are more likely to install rain barrels.

We also determined the factors affecting the residents' intention to adopt at least one GSI practice on their properties (Table 3). The results of the logit model show that household attributes significantly influence their intention to adopt GSI practices. Age was recorded to be negative and significant, suggesting that older residents less likely intend to install rain gardens on their properties. Residents who are earning more than $90,000 annually are more likely to have the intention to adopt at least one GSI practice. Also, those who own their properties and who solely decide for property development more likely intend to adopt one or more GSI practices. Those whose lawns were flooded and who believe that flooding contributes to water quality impairment are more likely to have the intention to adopt GSI practices. Lastly, those who have seen at least one GSI practice more likely intend to adopt at least one GSI practice. On the other hand, adoption barriers and their perception on GSI-related ecosystem services were found to be not statistically significant.

**Table 3**
Logit estimation results.

| Variable | Units | GSI practice | |
|---|---|---|---|
| | | Coef. | Std. Error |
| **A. Respondent's profile** | | | |
| Age | Year | −0.035*** | 0.005 |
| | 1 | omitted | |
| Gross Income | 2 | 0.219 | 0.191 |
| | 3 | 0.389* | 0.214 |
| | 1 | omitted | |
| Decision on the property | 2 | 0.343 | 0.236 |
| | 3 | 1.089*** | 0.207 |
| House flooding | 1 | 0.295 | 0.277 |
| Lawn flooding | 1 | 0.402** | 0.179 |
| Water deterioration | 1 | 0.419** | 0.166 |
| Familiarity with GSI | 1 | 0.325* | 0.183 |
| **B. Barriers to GSI adoption** | | | |
| Do not work | 1 | −0.038 | 0.199 |
| No contact | 1 | −0.026 | 0.163 |
| **C. Ecosystem Services of GSI** | | | |
| Water quality | 1 | 0.207 | 0.211 |
| Wildlife habitat | 1 | 0.166 | 0.187 |
| Flooding reduction | 1 | 0.222 | 0.197 |
| Constant | | 0.715** | 0.341 |
| Number of obs | | 865 | |
| Mean dependent var | | 0.695 | |
| SD dependent var | | 0.461 | |
| Pseudo r-squared | | 0.096 | |
| Chi-square | | 101.774 | |
| Prob > chi2 | | 0 | |
| Akaike crit. (AIC) | | 992.535 | |
| Bayesian crit. (BIC) | | 1063.976 | |

Significance levels: ***$p$ <1%, **$p$<5%, * $p$<.10 %

## 4. Discussion

The socio-demographic characteristics of the residents affect their intention to adopt certain GSI practices on their properties. Our results showed that the older population has less intention to adopt residential-based GSI practices such as rain gardens, rooftop disconnection, and rain barrels. Based on descriptive statistics, only 59 % of the older population (65 years old and above) intend to adopt one or more GSI practices as opposed to 73 % from the adult age bracket. The results of paired $t$-tests showed that the group means are statistically different, implying that preferences for adopting GSI practices are different. In a Vermont study (Coleman et al., 2018), the same pattern was observed wherein age has a negative relationship with intention to adopt diversion of roof runoff and intention to adopt at least one type of GSI practices. However, the results of the systematic literature review of Venkataramanan et al. (2020) showed that among 70 stormwater-related studies, half of them reported that age is significantly correlated with positive attitudes towards GSI. Given conflicting results in literature, relationship of age with behavior and attitudes towards GSI seems to vary depending on local preferences and conditions.

Although not statistically significant across the models, household income influences residents' level of intention to install rain gardens, as well as their intention to adopt one or more GSI practices on their properties. Households which earn more than $50,000 annually are more likely to have a higher level of intention to install rain gardens than those who are renting. On the other hand, those who earn more than $90,000 per year are more likely to have the intention to install one or more GSI practices on their properties. Brown et al. (2016) noted that low income hinders the adoption of onsite stormwater strategies, especially if the households will cover most of the installation costs. In coastal SC, only some counties (e.g., Beaufort, Horry) have existing mechanisms to incentivize households to adopt GSI practices. Aside from the stormwater utility fee (SUF) that they need to pay to their respective counties/cities, some homeowners also pay an additional fee to their Homeowner Associations (HOAs) for the maintenance of their subdivision ponds or BMPs. Since the residents typically shoulder the installation and maintenance costs of adopting GSI practices on their property, it is not a surprise that households with lower income also have a lower level of intention to adopt GSI practices. Considering that our samples' income profile is comparable with the census data, programs promoting GSI adoption should target households from these high-income brackets. For residents from lower-income groups, providing financial incentives or stormwater credits could be explored to ease the burden of adopting GSI practices.

Initially, we intended to use house ownership as one of the variables in our models. However, it has multicollinearity with property development arrangement; hence we decided to use the latter instead since it provides more information. Respondents who own their residence and are solely in charge of developing their properties are more likely to adopt rain gardens, rooftop disconnection, and one or more GSI practices in the next three years. Compared to those who are renting, homeowners have more autonomy for developing their properties (Baptiste et al., 2015; Brown et al., 2016; Gao et al., 2016). On the other hand, no significant causal relationship was recorded for homeowners who do not have the flexibility to decide solely for landscaping services. Although the coefficients were positive, this variable is not statistically significant across the models. This finding highlights the importance of providing necessary information to individual homeowners and those with organized HOAs so that they can make informed decision about GSI adoption.

Flooding-related experiences positively influence residents' intention to adopt GSI. We categorized these experiences into two types based on their severity— flooding inside the house (*House flooding*) and backyard flooding (*Lawn flooding)*. Our results showed that those who experienced backyard flooding would more likely intend to adopt either rain gardens or rooftop disconnection. For instance, those who experienced backyard flooding (n = 751) are likely to adopt rain gardens (26 %) or rooftop disconnection (31 %). However, those whose experiences were more severe since flooding entered through their houses intend to adopt a rain garden. Among the 106 respondents whose houses were flooded, 30 % expressed intention to adopt a rain garden. *House flooding* was not a significant variable though for rooftop disconnection. Shin and McCann (2018) observed that those who experienced basement and yard flooding were more likely to adopt rain garden as a solution in Columbia, Missouri. This highlights the importance of targeting individuals who have previous experiences with property flooding as they will be more open to the adoption of GSI. However, it has yet to be assessed how many people in coastal counties directly experience flooding. Although not validated in the study, the respondents' personal experience with flooding may have led them to complete the survey.

The variable *Familiarity with GSI* revealed that the residents' awareness on the prevalence of GSI in their counties could influence their intention to adopt these solutions. Those who think these practices are extremely common in their respective counties would be more likely to adopt these practices. This variable is significant across all the models. Intuitively, widespread adoption of a GSI practice probably gives individuals assurance of the effectiveness of the practice. Several studies documented that prior knowledge on GSI results in taking informed action (Brehm et al., 2013; Gao et al., 2016; Venkataramanan et al., 2020).

Although only one adoption barrier was significant in our model, five of the ten barriers we captured in the survey exhibited no statistically significant relationships with the intention to adopt GSI practices. Perceived ineffectiveness of GSI to mitigate flooding influences their decision to install rain gardens. Several studies also recorded residents' skepticism against GSI as an effective strategy to handle stormwater (Church, 2015; Turner et al., 2016). Other barriers that were not statistically significant with the intention to adopt GSI include lack of contact information or resources, perceived unattractiveness of GSI, and lack of space. These cognitive barriers are consistent with other studies' findings (Gao et al., 2016; Dhakal and Chevalier, 2017; Coleman et al., 2018). Meanwhile, the other five barriers were excluded from the models because of multicollinearity with other explanatory variables. Although not included in our models, several studies recorded that installation and maintenance costs limited residents from adopting GSI practices (e.g., Baptiste et al., 2015; Gao et al., 2016). Some studies also found that GSI suitability on residential properties (Montalto et al., 2013; Coleman et al., 2018), property rules (Montalto et al., 2013; Coleman et al., 2018), and low awareness on GSI (Turner et al., 2016; Shin and McCann, 2018; Miller and Montalto, 2019) could affect residents' behavior in adopting these practices. Therefore, while these barriers exhibited no statistical significance in our model, it still merits consideration for future studies and planning processes.

While the importance of ecosystem services has a positive relationship with the intention to adopt certain types of GSI, not all the ecosystem services that were included in the model became statistically significant. Residents who think that water quality improvement is extremely important are more likely to install rain gardens. This result suggests that although stormwater agencies promote the use of GSI because of their multiple environmental benefits, there is still a disconnect on how residents understand and value these benefits. Venkataramanan et al. (2020) noted that low awareness and knowledge on GSI and its benefits could hinder residents' positive attitude and adoption behavior toward these practices.

## 5. Conclusion and Recommendations

Green stormwater infrastructure (GSI) offers an innovative and sustainable way to manage stormwater. These practices provide multiple ecosystem services in addition to reducing floods. With the increasing need to handle more stormwater, US cities promoted the adoption of GSI both at the neighborhood and household level. However, little is known about how individual households view these practices. To address this research gap, we surveyed 1031 households in South Carolina to determine the factors affecting their level of intention to adopt GSI practices such as rain gardens, rain barrels, and rooftop (downspout) disconnection. We hypothesized that household attributes, adoption barriers, and perception of ecosystem services could influence the household's level of intention to adopt each of these practices.

Using generalized ordered logit models, we found that respondents' characteristics such as age, income, property ownership, as well as their perception and experiences of local flooding and GSI, are influencing the households' intention to adopt stormwater management practices. Although the respondents cited various adoption barriers, their perception that GSI practices are ineffective was the only statistically significant barrier in the models. Providing the household with enough information on these practices' effectiveness will likely increase their interest in adopting GSI on their properties. Meanwhile, water quality improvement is the only statistically significant ES in the analysis. This shows that residents value water quality and would likely adopt GSI that could significantly improve this benefit.

The findings of our study are helpful for stormwater professionals, practitioners, landscape developers, and planners. For stormwater educators, they could highlight the need for increased stormwater awareness and education efforts. For stormwater managers, our results show that there is a potential for household participation in stormwater management. By addressing adoption barriers, they could encourage residents to adopt GSI on their properties, especially for those who experienced property flooding. Also, helping neighborhoods understand what is allowed and not allowed in their communities might increase adoption. Considering that almost half of the property owners who answered the survey reported property rules as a constraint in adopting GSI, it would be worthwhile to assess the restrictive covenants of different HOAs in the study site.

For future studies, it would be interesting to look at the relationship of stormwater credits to the households' intention to adopt GSI practices. Since our results showed that low-income households are less likely to have intention to adopt GSI, providing financial incentives might motivate them to adopt GSI on their properties. Also, various studies recorded the importance of financial incentives in cultivating interests to adopt GSI (Green et al., 2012; Crisostomo et al., 2014; Baptiste et al., 2015; Brown et al., 2016; Gao et al., 2018). It would be interesting to know whether providing financial incentives to low-income and retired people may increase the GSI adoption or not. Currently, stormwater credits or incentives are only offered by some counties in the study site (i.e., Horry, Beaufort). Hence, our paper's results will be different in case all the households could be incentivized to adopt these practices.

Since we conducted our study in coastal counties of SC, our results might not represent upstate SC residents' intention to adopt GSI practices. It would be worthwhile to conduct a comparative study between the perception of upstate and coastal residents. Also, a comparison between different states would increase the applicability of our results and the potential for upscaling.

### 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.

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### Appendix 1 A redacted version of the questionnaire

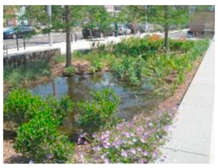
1. Where does stormwater runoff go after it leaves your property? Please select all applicable answers.
   - ☐ It flows down the road.
   - ☐ It flows to the nearest drainage.
   - ☐ It drains to the nearby creek/ stream.
   - ☐ It enters a stormwater treatment system.
   - ☐ It enters a storm sewer pipe.
   - ☐ It stays on my property and soaks into the ground.
   - ☐ I do not know.
   - ☐ Others (please specify) _______________
   - ☐ Not applicable
2. What are the pollutants that are being carried by stormwater runoff from your property? Please select all applicable answers.
   - ☐ Pet waste
   - ☐ Fertilizers/ Pesticides
   - ☐ Yard waste
   - ☐ Oil and grease
   - ☐ Others (please specify) _______________
   - ☐ None
3. Do you think flooding is a problem in your county?
   - ☐ Yes, in cities/municipalities such as: _________
   - ☐ No
   - ☐ I do not know
4. Please check all the flooding-related problems that you experienced at your primary residence?

| | Frequency of flooding | | | | Usual depth of flooding | | | |
|---|---|---|---|---|---|---|---|---|
| | After large events | Once a month | Once a year | Never | Ankle-deep | Knee-deep | Waist-deep | Not applica-ble |
| Basement or crawl space flooding | | | | | | | | |
| Flooding inside your house | | | | | | | | |
| Flooding of driveway or road to your house | | | | | | | | |
| Flooding of lawns, gardens or yards | | | | | | | | |

5. What are the impacts of flooding in your county? Please select all applicable answers.
   - ☐ Damage to properties (roads, buildings, residential houses, etc.)
   - ☐ Damage to natural resources (forest, coastal resources, etc.)
   - ☐ Reduction in water quality of streams, rivers, and coastal waters.
   - ☐ Loss of human lives
   - ☐ Temporary disruption on daily activities
   - ☐ I do not know
   - ☐ Others: _____________

6. Please rate each of the following BMPs in terms of how common they are in your county. Assign stars 5 stars to the most common BMPs and 1 star to the least. Do not check a star if you have never seen them.

RAIN GARDENS
These are small depressed areas planted with grasses, flowers, and other plants, that collect rainwater from a roof, driveway, or street and allow it to infiltrate into the ground.

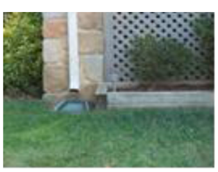


**BIORETENTION CELLS (OR BIOSWALES)**
These are larger or longer depressions that contain vegetation grown in an engineered soil mixture placed above a gravel drainage bed which slow, infiltrate, and filter runoff. They are often associated with streets and parking areas. Bioretention cells are well suited to being placed along streets and parking lots. (EPA, 2016)

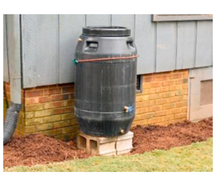
**VEGETATIVE SWALES**
These are channels or depressed areas with sloping sides covered with grass and other vegetation. They slow down the conveyance of collected runoff and allow it more time to infiltrate the native soil beneath it. These are often dry but can be wet and flooded after a rain. (EPA, 2016; Photo by Regional Plan Association and Orange County Planning Department, 2019)

**INFILTRATION TRENCHES**
These are narrow ditches filled with gravel that intercept runoff from upslope impervious or paved areas. They provide storage of water allowing additional time for captured runoff to infiltrate the into soil below. (EPA, 2016)

**GREEN ROOFS**
These are flat gardens growing on roofs. It is a soil layer laying atop a special drainage mat material that allows rainfall to percolate through soil and plants before draining off of the roof. They are particularly cost-effective in dense urban areas and on large industrial or office buildings where stormwater management costs are likely to be high. (EPA, 2016)



**Rooftop (Downspout) Disconnection**
This practice allows rooftop rainwater to discharge to pervious landscaped areas and lawns instead of directly into storm drains. You can use it to direct stormwater on your property and/or allow stormwater to infiltrate into the soil. Many homeowners can control where their downspouts flow into their landscaping. (EPA, 2016)



**Rain Barrels or Cisterns (Rainwater Harvesting)**
These are containers that collect roof runoff during storm events and can either release or re-use the rainwater during dry periods. Rain barrels are often connected to downspouts to capture rain. Cisterns may be located above or below ground (EPA, 2016; Photo by Swann and Associates Real Estate, 2016)

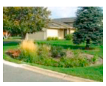
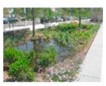
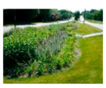
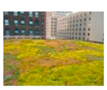
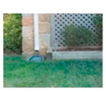
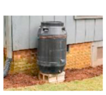
**Continuous Permeable Pavement Systems**
These are streets or sidewalks with porous concrete or asphalt mix or block pavers that allow water to flow down into water storage areas below. (EPA, 2016)

7. Are you the one making the decisions regarding management of your property? (Select one)

☐ Yes, I decide on how to develop or maintain our property
☐ No, the property manager or owner makes the decision since I am only renting this house
☐ No, the property manager and/or neighborhood decision-making body (homeowners' association) takes care of the landscaping
☐ Others (please specify) ________________

8. For the following question, please see the scale extremely unlikely (1) to extremely likely (5) that you expect to see the following (or more of the following) on your property in the next 3 years. Also, please mark 'Currently Used' if this feature is already on your property.

How likely are you to adopt the following in the next 3 years at your property? (Required)

| | Extremely unlikely (1) | Somewhat unlikely (2) | Neither likely nor unlikely (3) | Somewhat likely (4) | Extremely likely (5) | Currently used |
|---|---|---|---|---|---|---|
| Rain gardens  | ○ | ○ | ○ | ○ | ○ | ○ |
| Bioretention cells  | ○ | ○ | ○ | ○ | ○ | ○ |
| Vegetative swales  | ○ | ○ | ○ | ○ | ○ | ○ |
| Infiltration trenches  | ○ | ○ | ○ | ○ | ○ | ○ |
| Green roofs  | ○ | ○ | ○ | ○ | ○ | ○ |
| Rooftop (Downspout) disconnection  | ○ | ○ | ○ | ○ | ○ | ○ |
| Rain barrels or cisterns (Rainwater harvesting)  | ○ | ○ | ○ | ○ | ○ | ○ |
| Continuous permeable pavement systems  | ○ | ○ | ○ | ○ | ○ | ○ |

9. Please indicate whether or not you think that each of the following reasons is a barrier to you when adopting certain BMPs.

| **Reason** | **Barrier** | **Not a barrier** |
|---|---|---|
| Not enough space | ○ | ○ |
| High installation cost | ○ | ○ |
| High maintenance cost | ○ | ○ |
| Don't believe it works to lessen flooding | ○ | ○ |
| Against property rules | ○ | ○ |

(*continued on next page*)

(*continued*)

| Reason | Barrier | Not a barrier |
|---|---|---|
| Might not be suitable on my property | ○ | ○ |
| Not visually attractive or pleasant | ○ | ○ |
| Lack of knowledge about how to build or use them | ○ | ○ |
| I was unaware of BMPs before today | ○ | ○ |
| I don't know who to contact about installing a BMP | ○ | ○ |
| Other reasons (please specify): | ○ | ○ |

10. In your opinion, what is the level of importance of the following benefits provided by stormwater BMPs?

| Benefits of BMPs | Not important (1) | Slightly important (2) | Moderately important (3) | Very important (4) | Extremely important (5) |
|---|---|---|---|---|---|
| Reduce flooding | ○ | ○ | ○ | ○ | ○ |
| Improve water quality | ○ | ○ | ○ | ○ | ○ |
| Sustain stream base flow/ water supply | ○ | ○ | ○ | ○ | ○ |
| Provide erosion and sediment control | ○ | ○ | ○ | ○ | ○ |
| Treat waste | ○ | ○ | ○ | ○ | ○ |
| Reduce ambient air temperatures | ○ | ○ | ○ | ○ | ○ |
| Improve air quality | ○ | ○ | ○ | ○ | ○ |
| Reduce incidences of combined sewer overflows | ○ | ○ | ○ | ○ | ○ |
| Restore vegetation | ○ | ○ | ○ | ○ | ○ |
| Restore wildlife habitat | ○ | ○ | ○ | ○ | ○ |
| Provide pollination opportunities | ○ | ○ | ○ | ○ | ○ |
| Improve aesthetic value or scenic beauty | ○ | ○ | ○ | ○ | ○ |
| Increase revenue or property values | ○ | ○ | ○ | ○ | ○ |
| Improve recreational value (please elaborate): | ○ | ○ | ○ | ○ | ○ |
| Improve cultural benefits (please elaborate): | ○ | ○ | ○ | ○ | ○ |

11. Year of birth______
12. Gender MaleFemale Other
13. Occupation______
14. What is your highest educational attainment?
    - ☐ Less than high school
    - ☐ High school graduate
    - ☐ College degree
    - ☐ Master's degree
    - ☐ Doctorate
    - ☐ Others (please specify): ________
15. How much is your household annual gross income before taxes?
    - ☐ Less than $10,000
    - ☐ $10,000 - $29,999
    - ☐ $30,000 - $49,999
    - ☐ $50,000 - $69,999
    - ☐ $70,000 - $89,999
    - ☐ $90,000 - $149,999
    - ☐ More than $150,000
16. How many people are currently living in your household? ______
17. How long have you been residing in your county? (years)______
18. Do you own or rent your primary residence?
    - ☐ Own
    - ☐ Rent
19. What is the lot size of your primary residence?
    - ☐ Less than 1/2 acre
    - ☐ ½ to 1 acre
    - ☐ 1–2 acres
    - ☐ 3–10 acres
    - ☐ 11–100 acres
    - ☐ more than 100 acres
    - ☐ I do not know
20. How far is your primary residence from the nearest water body (e.g., river, creek, beach)?
    - ☐ Less than 1 mile
    - ☐ 1–2 miles
    - ☐ 3–4 miles
    - ☐ Greater than 4 miles
    - ☐ I do not know
21. How much of your lot do you think is covered by impervious surface (e.g., buildings, structures, driveways, parking surfaces)?

☐ Less than 10 %
☐ 10–24 %
☐ 25–49 %
☐ 50–74 %
☐ 75–90 %
☐ Greater than 90 %
☐ I do not know

22. How much do you pay annually for stormwater services? (The stormwater fee connected with your residence may come as a fee on your water bill or as a separate bill annually or monthly from your city or county. In some counties or cities, the stormwater fee is part of your annual tax bill for your county.)

☐ Less than $30
☐ $30- $60
☐ $61- $90
☐ $91- $120
☐ $121- $150
☐ Greater than $150
☐ I do not know

23. Aside from the stormwater bill from your county/ municipality, do you also pay stormwater-related fees to your Homeowners Association?

☐ Yes. Please indicate your monthly fee: USD______
☐ No
☐ I do not know
☐ Not applicable

24. Are you the one paying the water and stormwater bills in your household?YesNo

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