The Factors Affecting Residents' Willingness to Implement Green Infrastructure Strategies on Their Property.

by
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A dissertation submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

Design

Raleigh, North Carolina
2019

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DEDICATION

To my dear spouse, Ismail Dogmusoz, for his endless love and support, and giving me strength when I thought of giving up,

To my daughters, Arya and Mila, who have been my sources of inspiration,

To my mother, Gulseren Varlik for giving me encouragement during my Ph.D. journey,

To my aunt, Aynur Yanik, who passed away before I started my doctoral study.

BIOGRAPHY

Burcin Burcu Dogmusoz was born in Ankara, Turkey. She received her bachelor's degree in Landscape Architecture from Ankara University. After graduation, she earned a full scholarship from the Republic of Turkish Ministry of National Education, which funded both her master's and Ph.D. degrees in United States.

She completed her master's degree in Landscape Architecture from College of Design at North Carolina State University. During her master program, she completed the required classes and earned her certificate of Geographic Information Systems (GIS). In 2014, she started her Ph.D. journey at the same university. During her participation in the Ph.D. program, she attended various worldwide and well-known conferences such as EDRA and CELA to present papers.

ACKNOWLEDGMENTS

I would like to express my gratitude to my advisor Professor Art Rice for sharing his vision, providing me the necessary direction from the start of the research to the final phase and believing in me. I would like to thank Dr. Denis Gray, Dr. George Hess and Professor Andy Fox for being part of my advisory committee and giving me guidance in my research. I truly appreciate Dr. Denis Gray's help and guidance for the methodology and statistics portion of the dissertation.

Also, I am extremely thankful to my dear friends, Merve Yasemin Tekbudak and Secil Gonultas for their encouragement, timely help and invaluable support during the course of my Ph.D. work. I would also like to thank the Turkish Republic Ministry of National Education for their financial support granted through the doctoral education.

I would like to express my deepest appreciation to my parents, Gulseren and Cafer Varlik and my brother, Ugur Volkan Varlik for their unconditional love and encouragement. Their endless support throughout my research period has been priceless. Finally, and most importantly, I am grateful to my spouse, Ismail Dogmusoz, who has been with me through these years of doctoral study and whose love, support and care have helped me get to this point. And to my children, Arya and Mila, who have made me stronger, better and more fulfilled than I could ever imagined. I love you to the moon and back.

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ABSTRACT

DOGMUSOZ, BURCIN BURCU. The Factors Affecting Residents' Willingness to Implement Green Infrastructure Strategies on Their Property (Under the direction of Arthur Rice, Professor of Landscape Architecture).

Urbanization has resulted in more impervious surfaces, and most municipalities' stormwater infrastructure is not prepared to deal with flooding events that can be associated with the increased stormwater runoff. Cities have been looking for cost-effective, environmentally sustainable, and socially responsible solutions to deal with issues related to stormwater management. Based on this context, an increasing number of states and municipalities have been adopting green infrastructure as a supplement to the traditional stormwater management systems. When used for stormwater management, the term "green infrastructure" can be defined as strategies that infiltrate, evapotranspirate, capture and reuse stormwater on site. In order to accomplish stormwater management goals, municipalities need to both install green infrastructure on publicly owned land and also persuade residents to install green infrastructure on their private property. Previous research has investigated the factors that affect residents' willingness to install their own green infrastructure. However, very little research has investigated the barriers to that implementation in a combined manner, and social barriers mostly have been ignored. Overall, the purpose of this study is to develop a comprehensive understanding of the factors that affect residents' willingness to implement green infrastructure strategies by investigating socio-cognitive factors and other influencing factors (such as installation cost, maintenance cost, required time to maintain, health concerns, and visual appearance) in a combined manner. For this purpose, an online questionnaire was created. This questionnaire was developed based on the theory of planned behavior (Ajzen, 1991). Regression models were used to test the hypothesis, and three different regression models were created for

each type of green infrastructure in the study (rain barrel, rain garden, and porous pavement). The results indicated that self-efficacy, subjective norm, visual appearance, time required for maintenance, and general knowledge were significant predictors of a person's willingness to install green infrastructure. On the other hand, attitudes and cost, which were found to be important barriers in the literature, were not significant predictors in the current study. These findings indicate that municipalities might more effectively promote the adoption of green infrastructure on private land by providing training and by funding exemplar projects in residential neighborhoods.

CHAPTER 1: INTRODUCTION

1.1. Background

Cities have been changing over the years in many ways. One of these changes is a significant increase in impervious surfaces. Impervious surfaces can be defined as manmade structures such as buildings, roofs, roads, parking lots, sidewalks, and other land covers (Tilley & Slonecker, 2007). Two-thirds of all impervious area in the US is in the form of parking lots, driveways, roads, and highways (Water Resources Group, 1998), and the resulting loss of natural areas has led to many environmental problems (Getter &Rowe, 2006). According to Schuler et al. (2009), in the contiguous 48 states of the USA, urban impervious cover adds up to 43,000 square miles—an area nearly the size of the state of Ohio. Continuing development rapidly increases impervious surfaces by adding up to another quarter of a million acres each year (Zhou et al., 2015).

Since impervious surfaces are solid surfaces that do not allow water to penetrate, they can increase the volume and intensity of urban stormwater runoff, leading to urban flooding (Brun & Band, 2000; Weng, 2001); they also reduce water quality, degrading aquatic biodiversity and wetland ecosystems (Brabec, 2002; Goetz & Fiske, 2008). Thus, impervious cover is often used as a key indicator of environmental conditions (Arnold & Gibbons, 1996; Wu, 2014). For example, streams surrounded by less than 10% impervious cover are sensitive, vulnerable to degradation by increased development; streams surrounded by between 10%-25% impervious cover are impacted, showing clear sign of degradation and when impervious cover is over 25%,

streams are severely impacted and can no longer support a diverse stream community (Wu, 2014).

Gray infrastructures, consisting of complex underground pipes and tunnels, have been adopted as urban stormwater management strategy for many years (Kloss & Calarusse 2006). These systems, in addition to solving local problems, can also contribute to environmental problems such as water pollution and urban flooding (Kloss & Calarusse, 2006). Gray infrastructures also have high capital and maintenance costs, which cities are struggling to deal with (U.S. Environmental Protection Agency [EPA], 2008). The environmental challenges that arise as a consequence of urbanization are not simple and there are no well-defined solutions (Rosenberg et al., 2010). Urban communities are looking for new cost-effective and sustainable techniques to deal with the problems relating to urbanization (EPA, 2008).

To address these gray infrastructure limitations, green infrastructure (GI) strategies have been developed over the years to reduce the impact of impervious surface in urban areas (Carter & Jackson 2007). Green infrastructure plays a role as a supplement to traditional stormwater systems by decreasing the volume of the runoff before it gets into the water bodies (Barclay, 2016). Moreover, green infrastructure strategies provide ecosystem services and benefits to human health including reducing obesity and preventing associated chronic diseases by encouraging outdoor physical activity (Danler & Rhodaback, 2005). According to the EPA (2012), the damaging effect of urban stormwater runoff on the environment could be reduced by implementing natural systems such as trees, open green spaces and rain gardens during building or site development.

These strategies include replacing impervious paving with pervious areas, such as porous pavement, which allow stormwater to infiltrate the soil (Peng et al., 2010). Other green infrastructure options include green roofs, rain gardens, trees, rain barrels, and curbside extensions that increase stormwater storage and infiltration. Green roofs, also called vegetated rooftops, are preferred as a green infrastructure strategy because rooftops account for the most significant proportion of impervious surfaces in urban commercial areas (Peng et al., 2010). Compared with green roofs, studies of ground-level GI options are much less common and are focused mainly on the effectiveness of green infrastructure on reducing stormwater runoff. (Davis, 2005). Ground-level GI options include rain gardens, rain barrels, trees, porous pavement, and curbside extensions, in addition to bioswales in parking lots and street parking strips (Peng et al., 2010).

Despite the economic, environmental, and social benefits of green infrastructure, its implementation is not very common in the United States. As an emerging technology, several challenges exist as barriers to its implementation, and one such problem is "engendering meaningful participation from multiple stakeholders" (Montalto et al., 2013, p. 1190). Some studies revealed that by their very nature, green infrastructure strategies require engagement from a wider range of stakeholders than traditional stormwater infrastructure requires; these stakeholders include private property landowners and neighborhood residents (Hostetler et al. 2011; Keeley et al. 2013; Turner et al, 2015).

Resident participation rates in municipal green infrastructure projects have been low, even when infrastructure is provided for free or with incentives (Green et al. 2012; Mayer et al. 2012; Bos &

Brown 2015). Some studies have revealed that low participation rates are likely due to a variety of institutional and socio-cultural factors that influence residents' willingness to install and manage green infrastructure on their property (Barnhill 2012; Mayer et al. 2012; Baptiste et al. 2015). Additionally, socio-cognitive factors such as values, perceptions, and attitudes about the green infrastructure have been discussed as barriers to the adoption of green infrastructure strategies (Baptiste, 2014; Baptiste et. al., 2015; Larson et al. 2009; Turner, 2015).

The largest research gap within the stormwater management literature is the lack of research on social aspects associated with green infrastructure—in particular, the barriers to implementation in municipalities by residents. GI solutions such as rain barrels and rain gardens can be preferred by homeowners because of their "low cost and the availability of pervious surface due to low density of buildings" (Peng et al., 2010, p.5). Overall, GI options are cost-effective choices for residents to implement as a means to reduce the negative effect of impervious surfaces (Villarreal et al. 2004). However, few studies have focused on residential GI options, and the socio-cognitive factors behind the adoption have not been studied very well. This study contributes to the ongoing scholarly debate about the factors that influence green infrastructure adoption in residential neighborhoods. In this thesis, I inquire into residents' willingness to be involved in the issue of stormwater management and help determine some socio-cognitive barriers to the installation of green infrastructure strategies on residential properties.

1.2. Stormwater Management in Cities

Urban growth around the world has been increasing dramatically over the past couple of decades (Tzoulas et al., 2007). Urbanization leads to great increases in impervious surfaces, pollution,

and intensity of both urban and rural areas, and many other changes (Brander et al., 2004; Dietz & Clausen, 2008). There are many issues that are affected by increased urbanization, and one important factor is stormwater management, "especially with the threat of climate change and the increase in the area of impervious surfaces" (Sinasas, 2007, p.9).

When the rain falls in green areas, it usually is easily absorbed and filtered by soil and plants. However, more often in urban areas, rain falls on roofs, streets, and parking lots and is not as easily absorbed. This generates more stormwater runoff compared to green areas. Clar (2001) states that in vegetated areas, half of the rainwater infiltrates into the ground, about 40% returns to the atmosphere through evapotranspiration, and the other 10% is sent away through impervious surfaces into streams, rivers, or lakes. On the other hand, in urbanized areas, about 45% of rainwater is removed through impervious surfaces because the rain could not be absorbed into these surfaces (Clar, 2001). EPA (2003) estimates that the surface runoff generated by a typical city block is over five times that of a wooded area of the same size (See Figure 1-1). Overall, impervious surfaces in urban areas prevent water infiltration and create much more stormwater runoff than natural areas do.

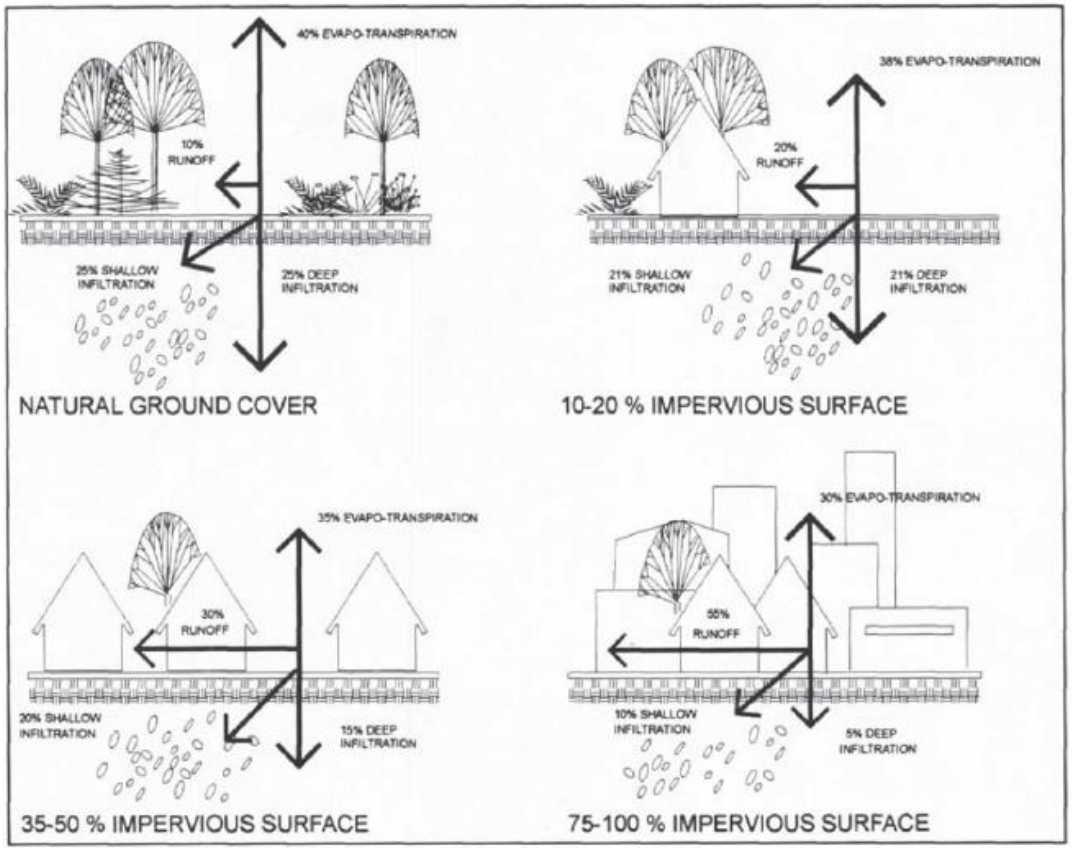


Figure 1-1. The Amount of Stormwater Runoff in Different Percentage of Impervious Surfaces (EPA,2003*).*

Stormwater runoff caused by impervious surfaces often carries hazardous pollutants. This runoff contains sediment, oil, grease from motor vehicles, viruses, bacteria, and nutrients from pet waste, and heavy metals from rooftops and streets (EPA 2010). As runoff, all these dangerous materials flow into streams, lake or other water resources. According to NRDC—Natural Resources Defense Council— (2011), nearly 10 trillion gallons a year of untreated stormwater captured from roofs, roads, parking lots, and other paved surfaces go through the stormwater management systems into rivers and waterways that are used as drinking water supplies. Beside carrying hazardous materials, increased impervious cover changes sensitive stream habitats and damages to the properties. But more importantly, this untreated runoff changes the water quality

(Hogland & Niemczynowicz,1987; Urbonas & Jones, 2002) by affecting the chemical and biological conditions of waters (Horner et al., 1995; May et al., 1997).

According to Seybert (2006), traditional stormwater management systems were implemented from the late nineteenth century to mid-twentieth century as an engineering way to control the increased amount of stormwater that occurs under current climate conditions (Wells, 2012). These engineering solutions include roof gutters, downspouts, swales, curbed gutters, sewer inlets, and sewer pipes. Most infrastructures were designed to deal with the typical 100-year and 150-year storm events, but climate change and increased impervious surfaces were not taken into consideration in the infrastructure design (Rosenburg et al., 2010). Therefore, typical gray infrastructure is not prepared to handle increased runoff and runoff from extreme weather events (Keeley et. al., 2013).

Managing stormwater is a critical municipal responsibility that has a direct impact on public health and safety, surface water quality, and wildlife habitat (San Francisco Public Utilities Commision [SFPUC], 2009). This management requires an integrated system approach to solve the various problems related to stormwater runoff, including water quality, water supply, flooding, and repairs to infrastructure (Biddle, 2012). Because traditional stormwater management is not successful in dealing with environmental problems of minimizing infiltration to groundwater and enhancing runoff via impervious surfaces that are caused by urbanization (Paul & Meyer, 2001; Arnold and Gibbons, 1996). Cities have become increasingly aware of the need to adjust their stormwater management systems to meet the demands necessary to maintain good health and quality of life (Barclay, 2016).

1.3. Limitations of Gray Infrastructures and Emergence of Green Infrastructure Strategies

Based on the common understanding of keeping floodwater out of urban areas, cities have developed strategies to cope with flooding (Benedict & McMahon, 2006). These strategies are called gray infrastructure. In some cities in the United States, these pipe systems are thousands of miles long and combine sewers and storm sewer channels (Barclay, 2016). These infrastructure systems were designed to convey rainfall or snowmelt as quickly as possible through drainage and pipes to water bodies, without treating the stormwater (Rosenberg et al., 2010). This untreated stormwater causes pollution in water bodies.

According to Kloss and Calarusse (2006), gray infrastructures are not successful in dealing with important problems such as habitat degradation, loss of ecological diversity, human health threats and swimming and fishing advisories. Single-purpose gray infrastructures were designed to move stormwater runoff away from the built environment, and environmental consequences were not taken into consideration (Kloss & Calarusse, 2006).

Maintaining gray infrastructures is also expensive. Seybert (2006) points out that agencies spend a lot of money to maintain these gray infrastructures in a good condition or to fix them when they are damaged. Despite high costs, they do not efficiently deal with water pollution and urban flooding (Seybert, 2006). This could be because “these engineered systems were usually the result of decisions made by engineers themselves without collaboration from the public and other indirect stakeholders, especially since they are highly technical, underground systems” (Barclay, 2016, p. 16-17).

Based on the limitations of gray infrastructures, cities have been looking for new solutions to stormwater management problems (Figure 1-2). The idea of "keeping flood water out" has changed to "mitigating flood risk, adaptation and increase resilience to flooding events" (Benedict & McMahon, 2006). This new idea means that cities would like to work with water instead of controlling or avoiding it. This approach requires an interdisciplinary partnership. Stormwater management issues could be handled not just from an engineering perspective, but also by using an interdisciplinary perspective to adapt the urban environment to the urban flood events (Seybert, 2006).

Figure 1-2. Gray and green infrastructure continuum (Davies et. al., 2006)

Conventional stormwater management can decrease the flow changes in streams and flooding risk in cities, but it does not help maintain the ecologically required base flow and natural flow changes that are important to maintaining a healthy aquatic environment (Thurston et al. 2003, Roy et al. 2008). In contrast, green infrastructure strategies aim at maintaining the ecologically required hydrologic functions, as well as the volume and frequency of discharges (EPA, 2010). Jaffe (2011) suggests "that green infrastructure strategies are cost effective when compared to

conventional stormwater management approaches, even when evaluated in terms of their direct costs and savings over their useful lives" (p. 357). Moreover, one of the key attractions of green infrastructure is its multi-functionality. GI can perform several functions and provide several benefits. These functions can be environmental (such as conserving biodiversity or adapting to climate change), social (such as providing water drainage or green space), and economic (such as supplying jobs and raising property values) (EPA, 2008).

1.4. Study Overview

Stormwater management is an important field for all municipalities to understand and fund. As the implementation of green infrastructure progresses, it is important to understand the factors, both technical and nontechnical, that interact to promote or hinder its implementation However, only certain types of stormwater management strategies are well researched, and residents' involvement with the issue is often ignored. The purpose of this study is to convey a comprehensive understanding of the factors affecting residents' willingness to implement green infrastructure strategies on their properties.

In Chapter II of this thesis, I examine existing literature on two major topics: (1) general review about green infrastructure including definition, goals and strategies, scales and benefits and barriers to implementation; (2) more specific review to this study including the importance of private residents in green infrastructure projects and barriers to implementation in private residential environments; (3) overview of studies relating to green infrastructure.

In Chapter III, I explain the methods of research, including a survey of residents of Raleigh, North Carolina, and why Raleigh was chosen as a study area. Chapter IV includes the results of the survey. The resulting observations and recommendations are discussed in Chapters V and VI.

CHAPTER 2: LITERATURE REVIEW

Green infrastructure covers a wide range of topics. There have been a number of research projects that have focused on green infrastructure. While some authors have focused on definitions, examples and the history of green infrastructure (Beauchamp &Adamowski, 2013; Krueger, 2008; Youngquiest, 2009), others have focused the effectiveness and the benefits of green infrastructure (Molla, 2015; Krueger, 2018; Dietz & Clausen, 2008; Anderson et. al., 2008; Yang et al., 2005) or barriers to their implementation at different scales (Keeley et. al., 2013; Barnhill & Smardon, 2012).

Green infrastructure was initially intended to be an approach to protecting and enhancing connective networks of natural and open space at the landscape or regional scale (Center for Leadership in Global Sustainability [CLiGS], 2013). The first formal mention of the term of green infrastructure was in the report released in 1999 by the President's Council on Sustainable development (CLiGS, 2013). For the six to seven years that followed, green infrastructure was discussed as a regional and landscape-scale approach to protect and connect natural features (CLiGS, 2013).

In 2007, another definition of green infrastructure, that was more restrictive and potentially competing, was announced (CLiGS, 2013). Green infrastructure was defined as a technical mechanism for improving water quality and providing other environmental benefits, especially in an urban space that lacked green or natural areas. Green infrastructure was introduced to urban planning and management as a cost-effective strategy to reduce stormwater runoff (CLiGS,

2013). Since then, studies in the field of green infrastructure have focused on comparing the effectiveness of green infrastructure strategies to gray infrastructure and on the economic and environmental benefits of green infrastructure at site scale (Yang & Li, 2013; Molla, 2015; Mayer et al., 2012; Malinowski, 2015; Michael et a.l, 2016; Pennino, 2016; Liu et al., 2015). For example, Yang and Li (2013) compared the effectiveness of a site with green infrastructure to a conventional site that includes traditional grey infrastructure and manicured lawns within the Woodlands development in Texas, USA. The subdivisions using green infrastructure had more impervious cover (32.3%) than the conventional site (13.7%). The study revealed that the site using green infrastructure, even with the greater impervious surface, generated less stormwater runoff compared to the traditionally designed site.

Another study, conducted by Dietz and Clausen (2008), compared two sites in Connecticut, USA; a traditional site with an impervious area cover of 32% and green infrastructure implemented a site with an impervious cover of 21%. The study revealed that the runoff volume increased as the amount of impervious area increased, resulting in a much higher runoff volume in the traditional site. Moreover, one EPA study compared cost estimates for conventional and green infrastructure development for new sites and found that “in most cases… significant savings were realized due to reduced costs for site grading and preparation, stormwater infrastructure, site paving, and landscaping” with savings ranging from 15% to 80% (EPA, 2007).

Although these studies revealed that green infrastructure provides economic and environmental benefits, cities have been slow to implement green infrastructure for stormwater management. Based on this, some research has been conducted to determine the barriers to implementation of green infrastructure strategies (Hammitt, 2010; Cook et al., 2012; Thurston et al. 2008; Thurston et al. 2010; Barnhill & Smardon, 2012; Green et al. 2012). Some research focused on the government side by conducting surveys, telephone interviews, or face-to-face interviews with representatives from city government, landscape architects, and engineers who have been involved in promoting or implementing green infrastructure (Faehnle, 2014; Rowe et al., 2016; Keeley et al., 2015; Elise, 2017). These studies revealed that public participation is the key factor in a green infrastructure project's failure or acceptance. For example, engagement with the public reduces the risk of dissatisfaction in green infrastructure projects (NRDC, 2015).

Based on this, recent studies have focused on the importance of public participation in green infrastructure projects and the barriers to participation. Some studies have shown that public participation can make green infrastructure projects more effective and more successful (Barclay, 2016; Benson et al, 2014; Koehler & Koontz, 2007; Randolph, 2012; Margerum, 2011). Now, cities like Philadelphia and New York City continue to highlight the need for public involvement for stormwater management. These studies highlighted the importance of public participation in the decision-making process.

Recently, some research in the United States has revealed that "private property constitutes substantially more land area in communities than public property; therefore, there are many opportunities to incorporate green infrastructure on individual private parcels as part of new

development or redevelopment" (EPA, 2015, p.7). This research implies that there is an area to investigate not just the importance of public participation in the decision process but also the importance of the residents at the implementation level. However, few studies have been focused on private parcels and which factors affect the residents' willingness to implement green infrastructure strategies on their property.

In this dissertation, I address this gap in the scholarly literature by exploring the factors that affect residents' willingness to implement green infrastructure on their own land. The first part of the literature review examines existing literature on two major topics: (1) a review of green infrastructure, including definitions, goals, strategies, objectives, tactics, scales, and benefits and (2) the importance of residents in green infrastructure projects and the barriers to implementing these strategies by residents.

2.1. LITERATURE REVIEW: GENERAL BACKGROUND OF GREEN INFRASTRUCTURE

2.1.1. DEFINITION: WHAT IS GREEN INFRASTRUCTURE?

In order to successfully study green infrastructure, it is important to understand what is meant by the phrase green infrastructure Although green infrastructure research has been rapidly developing, there are still conflicts about its definition. Some authors have defined it as a new concept that builds on existing concepts related to green space planning (MacFarlane, Davies and Roe, 2005). Each author comes up with their own definitions and emphasizes different aspects of green infrastructure. While conservationist authors emphasize the ecological and biological components of green infrastructure (e.g., Benedict & Mahon, 2006), some authors highlighted

the connectivity features linking different environmental elements at the rural and urban landscape (e.g., Keiber, 2005; Mell, 2010). Overall, there is a lack of consistency in the definition of green infrastructure. This is because green infrastructure can be defined differently, depending on the context in which it is used. Here, I investigate how various authors have defined green infrastructure and which components of green infrastructure have been highlighted in those definitions.

The term green infrastructure first came on the scene when it was in the mainstream by President Bill Clinton's Council on Sustainable Development and was identified as one of five strategic areas of sustainable community development (CLiGS, 2013). The council defined green infrastructure as "a network of open space, airsheds, watersheds, woodlands, wildlife habitat, parks and other natural areas that provide many vital services that sustain life and enrich the quality of life" (President Council on Sustainable Development [PCSD], 1999). In this definition, green infrastructure's ecological functions, connectivity, and role in promoting sustainability are emphasized. During the 2000s, green infrastructure was widely accepted, and many people attempted to define it. Benedict and Mahon (2002) emphasized not only the ecological benefits of green infrastructure but also its benefits to communities. Their definition also used by some federal agencies, including United States Department of Agriculture Cooperative Forestry.

McDonald et al., (2005) broadened the definition of green infrastructure, defining it as "interconnected network of waterways, wetlands, woodlands, wildlife habitats, and other natural areas; greenways, parks, and other conservation lands; working farms, ranches and forests; and

wilderness and other open spaces that support native species, maintain natural ecological processes, sustain air and water resources and contribute to health and quality of life" (McDonald et al., 2005, p. 7). Adding to Benedict and Mahon (2002) definition that implies ecological functions, connectivity and sustainability, McDonald et al., (2005) used the term "health." This addition gave green infrastructure a different facet, and some authors studied the health benefits of green infrastructure. In 2006, Davies et al., defined GI as follows: "Green infrastructure is the physical environment within and between our cities, towns, and villages. It is a network of multi-functional open spaces, including formal parks, gardens, woodlands, green corridors, waterways, street trees, and open countryside. It comprises all environmental resources, and thus a green infrastructure approach also contributes to sustainable resource management" (p. 2). Although this definition is broad, it does not still cover all aspects of green infrastructure; it implies connectivity, multi-functionality, and sustainability, but it does not highlight the benefits of green infrastructure to wildlife and people.

In 2007, EPA gave GI a different flavor by defining it as "technologies engineered to manage stormwater onsite, which can include both vegetated installations (e.g. green roofs, rain gardens) and non-vegetated techniques (e.g. permeable pavement, rain catchment barrels); these technologies help developers, homeowners, and cities achieve 'low-impact development,' or lessen the environmental impacts of their infrastructure." Although the concept of using green space to manage a city's sewage and water pollution dates back to mid-19th century (Olmsted's Emerald Necklace park system), the importance of green spaces in stormwater management was highlighted again. Ahern (2007) also defined GI as "a concept that is principally structured by a hybrid hydrological/drainage network that complements and links relic green areas with built

infrastructure that provides ecological functions. It is the principles of landscape ecology applied to urban environments." In the following year, EPA (2008) presented a new definition: "GI is an approach to wet weather management that uses soils and vegetation to utilize, enhance and/or mimic the natural hydrological cycle processes of infiltration, evapotranspiration, and reuse."

Based on these definitions, Dunn (2010) and Clean Water America Alliance [CWAA] (2011) defined GI as the practice of using soil and vegetation and natural processes to collect, absorb, and filter stormwater where it falls in order to reduce the negative environmental impacts of urban or suburban development. While the interpretation of GI varies from ecological conservation to health benefits, the authors most frequently show a concern for stormwater management (EPA, 2007; Chau, 2009; Novotny et al, 2010; Brown et al., 2011). GI generally defined as a cost-effective approach to stormwater management that promoted multi-functionality and connects local initiatives with state policy (Allen, 2012). The American Society of Landscape Architects (2011) defined GI as "a broad approach to sustainable development and climate change mitigation, which includes green energy, alternative transportation, habitat restoration, and stormwater management." In 2013, Roe et al. emphasized the social aspect of green Infrastructure. They highlighted that in addition to water quality improvements, green infrastructure provides social benefits that promote a sense of community, public health, and mental health.

The European Environment Agency (2014) published a report called, *Exploring nature-based solutions: The role of green infrastructure in mitigating the impacts of weather—and climate change-related natural hazards*, which built on previous definitions to demonstrate how green

infrastructure contributes to mitigating the adverse effects of extreme weather and climate-related events. In addition, the report highlighted the importance of green infrastructure and ecosystem services on global climate regulation. Moreover, Santamouris (2015) stated green infrastructure's contribution to improved air quality and reduced urban heat island effects in addition to its environmental and ecological benefits.

In 2017, the United States Agency for International Development [USAID] published a broad definition: "Green infrastructure (GI) is an engineered intervention that uses vegetation, soils, and natural processes to manage water and create healthier built environments for people and the natural resources that sustain them. GI can range in scale from small-scale technologies such as rain gardens and green roofs to regional planning strategies targeting conservation or restoration of natural landscapes and watersheds. GI approaches may be interconnected with existing and planned grey infrastructure networks to create sustainable infrastructure that can enhance community resilience to disasters and climate change as a result of increased water retention and groundwater recharge, flood mitigation, erosion control, shoreline stabilization, combatting [sic] urban heat island effect, improving water quality, conserving energy for buildings"

Green infrastructure has different meanings to different people. It can be defined differently in different disciplinary contexts such as landscape ecology, wildlife biology, landscape architecture, and civil engineering. Wright (2011) argued that a single precise meaning of GI is not possible because the concept is still evolving and has developed in response to different disciplines such as landscape ecology, wildlife biology, landscape architecture, and civil engineering. A much more specific definition can help understand which aspect of green

infrastructure will be investigated. Overall, although the idea of green infrastructure originated from two concepts: "(1) linking parks and other green spaces for the benefit of people, and (2) preserving and linking natural areas to benefit biodiversity and counter habitat fragmentation" (Benedict and MacMahon, 2007), it has been defined differently over the last decade.

After reviewing the literature, I conclude that green infrastructure definitions can generally be placed into two categories: (1) green infrastructure as a strategy for using ecological features and processes to manage urban water, namely stormwater; and (2) green infrastructure as an approach to protecting and enhancing connective networks of natural and open space at the landscape or regional scale.

For the context of this paper, the definition of green infrastructure falls under the first category, which highlights the ecological features of green infrastructure and its ability to manage stormwater. The most suitable definition for those purposes could be: "…green infrastructure can be defined as systems and practices that use or mimic natural processes to infiltrate, evapotranspire (the return of water to the atmosphere either through evaporation or by plants), or reuse of runoff on the site where it is generated." (EPA, 2008). The table below shows definitions of green infrastructure by different authors:

Table 2-1. Green infrastructure definitions in the literature by different authors

Source	Components
President Council on Sustainable Development, 1999	Connectivity, ecological components
Benedict&Mahon, 2002	Connectivity, Ecological components, multi-functionality
Mc.Donald, 2005	Connectivity, Ecological components, multi-functionality, sustainability, community health
Davies et al., 2006	Connectivity, ecological components, multi-functionality, sustainability
EPA, 2007	Stormwater management
Ahern, 2007	Hydrological/drainage network, connectivity, ecological components
EPA, 2008	An approach to wet water management, captain and infiltrate water
Dunn, 2010 CWAA, 2011	Cost effective approach to water management, multi-functionality, effects on urbanization
The American Society of Landscape Architecture, 2011	Sustainability, climate change mitigation, stormwater management, habitat restoration
Roe, 2013	Sense of community, public health
European Environment Agency, 2014	Climate change mitigation
Santamorius, 2015	Ecological components
United States Agency, 2017	Climate change mitigation, urban flooding mitigation, environmental health, stormwater management

2.1.2. GREEN INFRASTRUCTURE GOALS AND STRATEGIES

In this study, I use the following terminology:

Green infrastructure goals: The desired outcomes of green infrastructure,

Green infrastructure strategy: "the approach you take to achieve a goal" (Bell et al., 2008).

2.1.2.1. Green Infrastructure Goals

Although there are many sources about green infrastructure, it is difficult to find a source that clearly defines the goals of green infrastructure. Green infrastructure has different aspects, and there is a need to set goals based on these aspects. In this study, I will categorize the goals as social, environmental, ecological and economic goals.

Social goals: Some authors state that social goals of green infrastructure can be defined as providing social activity, improving community cohesion, developing local attachment and lowering crime levels, particularly in deprived communities (Bell et al., 2008; Weldon et al., 2007). Ahern (2007) stated that the social goal of green infrastructure is to improve opportunities for outdoor activities and recreation. Sandstrom (2002) investigated the different aspect of green infrastructure and stated that connectivity is the key element of green infrastructure so one of the main goals of green infrastructure should include creating connections between different stakeholders.

Environmental goals: Urban development has a significant impact on hydrology. Green infrastructure emerged to decrease this negative impact on water bodies. Based on this, "Forest Research" (2016) defines green Infrastructure's environmental goals to alleviate flooding and

improving water quality. Environmental goals of green infrastructure are also defined as increasing air quality, reducing the volume and pollution loading of non-point source stormwater runoff, and increasing the effectiveness of local stormwater management programs (Benedith and Mahon, 2006; the Gualala River Watershed Community [GRWC], 2007).

Ecological goals: These goals are defined as the positive impacts on water and air quality and the positive influence on biodiversity. Maintaining biodiversity is important since it promises sustainability for all life forms (Patel, 2014). Based on this, one of the main goals of green infrastructure is to increase improved habitats for wildlife (Zareba et al., 2006, Angold et al., 2006). Moreover, McDonald (2005) defines these goals as follows "Green infrastructure must include goals for the protection of ecological functions, as well as protection of working lands, and open space for human benefit" (p. 9-10).

Economic goals: EPA (2014) defined one of the economic goals of green infrastructure as the reduction both of the capital and operational costs of gray infrastructure systems such as storage tanks and pumping stations. Other goals of green infrastructure include reduced heating and cooling needs, increased land values in surrounding residential areas and job opportunities (EPA, 2014; "Forest Research", 2016; CWAA, 2010).

Table 2-2. Green Infrastructure Goals

Green Infrastructure Goals	Source
Social Goals: - Improving opportunities for outdoor activities and recreation - Improving community cohesion - Developing local attachment - Lowering crime levels	Ahern, 2007 Bell et al., 2008 Weldon et al., 2007 Sandstorm, 2002
Environmental Goals: - Alleviating flooding - Improving water quality - Increasing air quality - Mitigating and adapting to climate changes - Providing sustainability	Barriers, 2010 Benedict and Mahon, 2001 GRWC, 2007 Forest Research, 2006 Research, 2016
Ecological Goals: - Maintaining biodiversity - Improving habitats for wildlife	Angold et al., 2006 McDonals, 2005 Patel, 2014 Zareba et al., 2006
Economic Goals: - Reducing both capital and operational costs of gray infrastructure - Reducing heating and cooling needs - Increasing land values in residential areas - Increasing job opportunities	CWAA, 2010 EPA, 2014 Forest Research, 2016

Social, environmental, ecological and economic goals are the overall goals of green infrastructure. Each green infrastructure project can set up its own specific goals. For example, New Orleans, under a consent decree with the EPA and the Sewerage and Water Board of New Orleans [SWBNO], has a Green Infrastructure Plan, under which they have agreed to dedicate

$500,000 per year over the next five years to be used for green infrastructure projects and activities carried out pursuant to the Plan (U. S. Department of Housing and Urban Development [HUD], 2010). For these reasons, they focused heavily on stormwater management and the implementation of green infrastructure to meet their goals (HUD, 2010). Their green infrastructure goals are as follows (HUD, 2010):

- Reduce and eliminate runoff through innovative planning and implementation of drainage, stormwater, and wastewater management
- Implement green solutions for stormwater management including rain gardens, bioswales, pervious pavement, and green roofs
- Create an environmentally resilient region by "living with water" through the proposals illuminated in the Greater New Orleans Urban Water Plan.

Another example is that The Green Boulevard project in Pittsburg incorporated recommendations for green infrastructure throughout their final plan in order to meet their regenerative and river stabilization goals while creating new habitats and restoring natural hydrologic functions (HUD, 2010). Their green infrastructure goals are as follows (HUD, 2010):

- Improve the quality of the natural environment, including trees and other vegetation, soil, and river water
- Restore the natural hydrologic cycle and reduce the environmental impacts of stormwater runoff
- Create greater physical continuity among natural spaces,

- Reintroduce natural ecology by replacing invasive plant species with native species and creating new habitats for wildlife.

2.1.2.2. Green Infrastructure Strategies

Many different types of green infrastructures strategies that have been implemented in urban areas, including trees, permeable pavement, rain gardens and green roof.

Trees play an important role in stormwater management by reducing the amount of runoff by capturing precipitation on their leaves and branches (EPA, 2013). Trees can reduce stormwater in the following ways: evaporation of water from plant leaves (transpiration); the process of storing rain or water (interception); the shedding of excess water from leaves to the ground (reduced throughfall); the penetration of water through the ground surface into the soil (increased infiltration) and removing or neutralizing contaminants in polluted soil and water (phytoremediation) (EPA, 2013). Trees can be incorporated immediately adjacent to streets and sidewalks with the use of a structural soil, modular suspended pavement, or an underground retaining wall to keep uncompacted soil in place (EPA, 2013).

Permeable pavements help stormwater to be infiltrated rapidly, reducing the amount of rainwater carried over impervious surfaces. Since increased stormwater runoff leads to urban flooding, permeable pavement such as permeable interlocking pavers and pervious concrete are important (EPA, 2015). These strategies generally consist of a "below-ground, load-bearing stone reservoir that can store runoff." Then the stored runoff slowly filtrates and flows through the subsurface (EPA, 2015). Permeable pavements are most often used in constructing pedestrian

walkways, sidewalks, driveways, low-volume roadways, and parking areas of office buildings, recreational facilities, and shopping centers (EPA, 2015).

Figure 2-1. Permeable surface (EPA, 2015)

Rain gardens, also called bioretention or biofiltration cells, can collect and store runoff from rooftops, sidewalks, and streets. They include shallow, vegetation basins that can absorb stormwater runoff. Besides collecting stormwater, one of the main purposes of rain gardens is to improve water quality by removing pollutants in stormwater runoff ("Bioretention", 2014). Rain gardens are often located near buildings, capturing rainwater from downspouts that would otherwise be routed toward a storm drain and sewer (EPA, 2015).

Figure 2-2. Rain Garden (EPA, 2015).

Rainwater Harvesting: Cisterns or their smaller counterpart, rain barrels, are containers that capture runoff and store it for future use (EPA, 2015). Rain barrels tend to be smaller systems, less than 100 gallons. Rain barrels capture water from a roof and hold it for later use such as on lawns, gardens, or indoor plants. Collecting roof runoff in rain barrels reduces the amount of water that flows from the property. It is a great way to conserve water and it is free water for use in the landscape. Many cities and towns distribute rain barrels to residents through annual sales (EPA, 2013). Cisterns are larger systems that can be self-contained above-ground or below-ground systems, generally larger than 100 gallons. Below-ground systems often require a pump for water removal. Cisterns and rain barrels can be a useful method of reducing stormwater runoff volumes in urban areas where site constraints limit the use of other green infrastructure strategies.

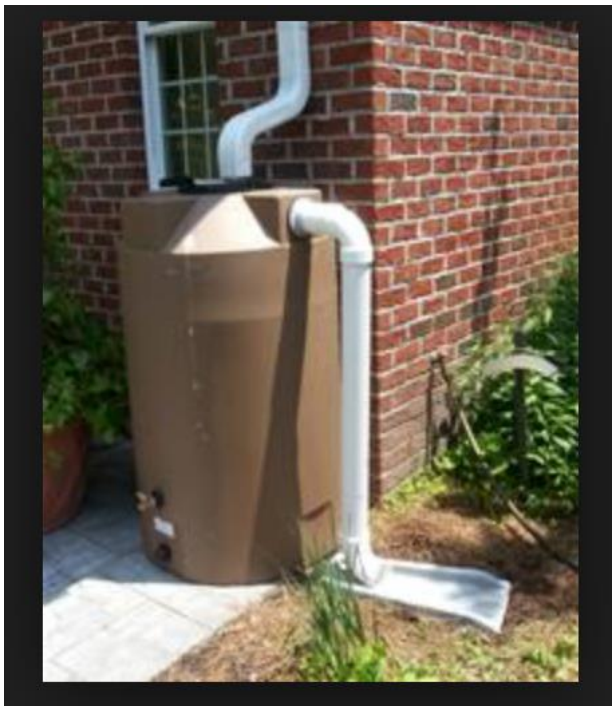


Figure 2-3. Rain Barrel (EPA, 2013).

Green Roofs are roofs covered by vegetation. Vegetation and soil act as a sponge, absorbing and filtering water that would normally goes into the gutters. In this way, less water runs off of the roof, compared to conventional roofs (EPA, 2015). This helps the address the problem of urban flooding. Typically, a green roof is part of a treatment train with the green roof draining to another stormwater control measure such as a bioretention cell, bioswale, or cistern (EPA, 2015).

Figure 2-4. Residential Green Roof

2.1.3. Green Infrastructure Implementation Scales

Green infrastructure can be implemented at different scales. Chicago Metropolitan Agency for Planning [CMAP] (2005) categorizes these scales as regional, community-level, and site scales. At a regional scale, green infrastructure interconnects natural areas and conserves landscapes for high-quality ecosystems; at the community level, green infrastructure includes smaller parks and open spaces; at site scale, green infrastructure mimics the natural water cycle for stormwater management while providing ecological services (CMAP, 2005). Allen (2012) categorize green infrastructure implementation scales into three different scales as well: Landscape-Scale Green Infrastructure, Region-Scale Green Infrastructure, and Site-Scale Green Infrastructure (Figure 5.)

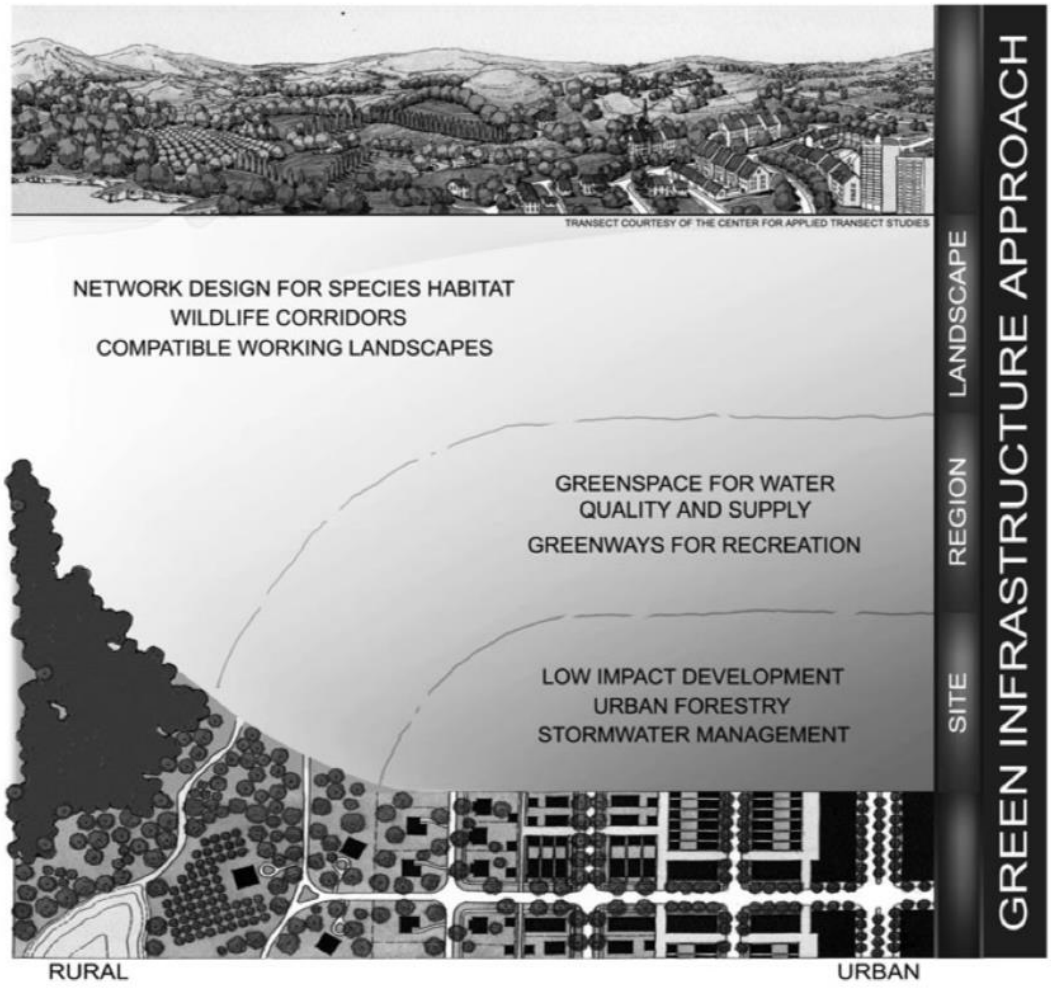


Figure 2- 5. Green Infrastructure Implementation Scales (Allen, 2012).

Landscape-scale approaches include the green infrastructure network and wildlife corridors based on landscape ecology and conservation biology principles (Dramstad et al., 1996; Forman & Godron, 1986; MacArthur & Wilson, 1967; Odum, 1983; Tewksbury et al., 2002). The green infrastructure network at landscape scale consists of core areas, corridors, and hubs (Allen, 2012). Core areas provide habitat for native wildlife and plants (Allen, 2012). These core areas are the nucleus of the green infrastructure network (Weber, 2007; Weber & Allen, 2010; Wolf et

al., 2006). Hubs are defined as natural areas that contain one or more core areas and include large protected areas, such as state and regional parks; corridors are defined as linear features that link core areas such as river and stream valley corridors and forested upland corridors (Allen, 2012). According to Allen (2012), "Implementation at landscape scale usually involves conservation land acquisition and adaptive land management by public and private landowners to support the preservation of high-quality wildlife habitat, ecological process and functions, and protection of migration corridors. Maintaining compatible working landscapes also plays a critical role in landscape-scale green infrastructure planning." (p. 21).

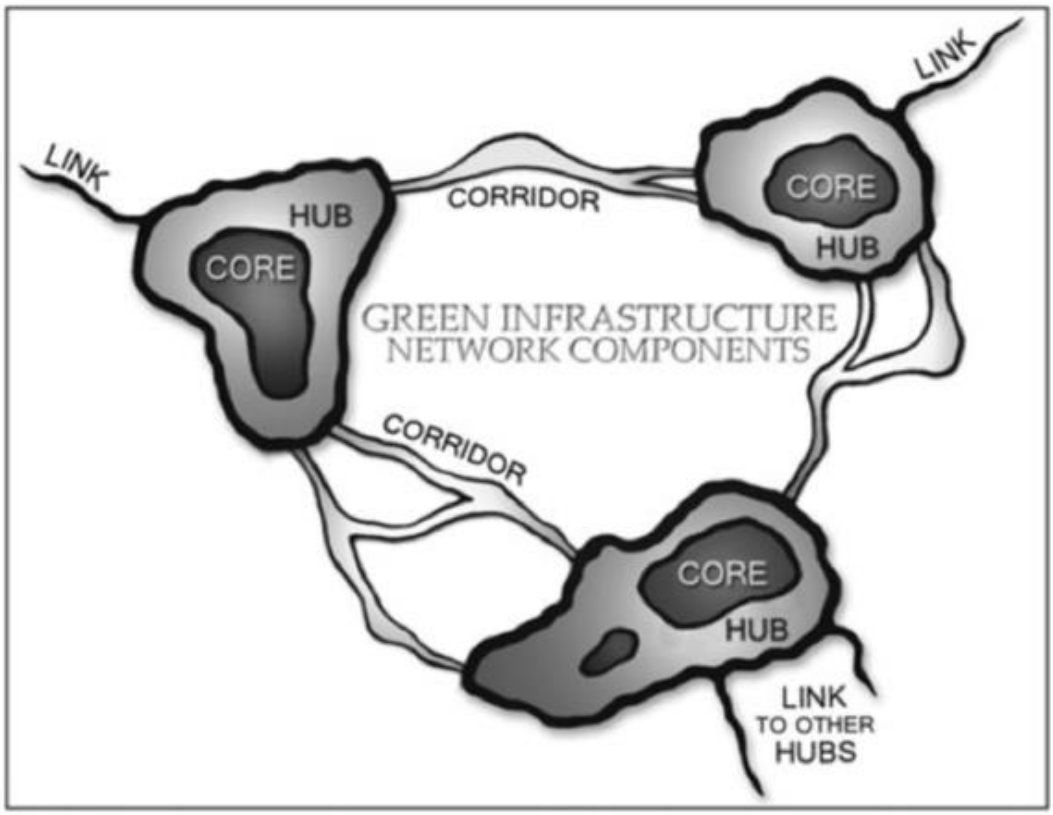


Figure 2- 6. Landscape elements of green infrastructure network design (Allen, 2012).

Region-scale green infrastructure is like a bridge between landscape-scale green infrastructure, which implies broader implementation, and site-scale green infrastructure, which focuses on individual parcels (Allen, 2012). Implementation at this scale targets land conservation and land-use and comprehensive planning in order to provide strategic open-space planning, water supply and quality management, and greenways as recreation corridors (Amundsen et al., 2009). Moreover, site-scale green infrastructure was defined by American Rivers (2010) as "a network of decentralized stormwater management practices, such as green roofs, trees, rain gardens, and permeable pavement, that can capture and infiltrate rain where it falls, thus reducing stormwater runoff and improving the health of surrounding waterways." In this dissertation, I focus on site-scale green infrastructure strategies.

2.1.4. Benefits of Green Infrastructure strategies

The benefits of green infrastructure for individuals and the wider population have been widely discussed in the academic and practitioner literature (Benedict & McMahon, 2006; City Parks Forum, 2003). Due to the multifunctional nature of the many different forms of green infrastructure, quantifying the benefits they provide has proven difficult to quantify because different functions require different forms of measurement (European Commission [EC], 2013). Providing monetary values in environmental studies are easily understood by stakeholders and the community, and this overcomes the issue of "incommensurability" (Vandermeulen et al., 2011, EPA, 2014).

However, the benefits provided by green infrastructure are also difficult to quantify in monetary units (Vandermeulen et. al., 2011). This is especially the case with cultural and aesthetic values

(Vandermeulen et. al., 2011). Naumann and McKenna (2011) states “It also appears that evidence of the benefits of GI is less easy to quantify, and more variable than costs, and are often expressed in qualitative terms” (p.7). However, various approaches have been developed in recent decades to measure a monetary value on the functions performed by GI strategies.

Various literature confirms that there are many potential social benefits provided by GI strategies, the most significant of which can be grouped into three broad categories: improvements in levels of physical activity and health; promotion of psychological health and mental well-being; and facilitation of social interaction, inclusion, and community cohesion (“Forest Research”, 2010).

Most studies confirm that the percentage of green space in a person’s living environment has a positive impact on the perceived health (Mass et al.,2015; Wodarczyk, 2007; “Forest Research”, 2010; RICS, 2011). Green infrastructure provides a high-quality environmental atmosphere that contributes to the tourism, recreation, leisure, and health sectors (SDC, 2010; Yang et al., 2005; Wodarczyk, 2007). Some studies show that improved aesthetics values and green space are related to decreased stress (Niemelä, 2009; Milwaukee Metropolitan Sewage District [MMSD], 2012). However, in contrast to other reviews, Lee and Maheswaran (2010), who examined studies investigating the health effects of green space, found only “weak” evidence for the links between urban green space and physical and mental health and well-being. The review concluded that “...most studies reported findings that generally supported the view that green space has a beneficial health effect. Establishing a causal relationship is difficult, as the relationship is complex. Simplistic urban interventions may, therefore, fail to address the

underlying determinants of urban health that are not remediable by landscape redesign" (Lee and Maheswaran, 2010, p. 212). On the other hand, after reviewing the literature on the benefits of GI for health, Ely and Pitman (2014) did not share the same concerns regarding the validity of research design and they concluded that the evidence provided very strong support for the link between GI and improved well-being. I support Ely and Pitman (2014) because studies, that support the casual relationship between GI and human health, have been increasing, compared to other studies, that have found a weak connection.

Besides social benefits, green infrastructure also provides environmental, ecological and economic benefits. Beauchamp and Adamowski (2013) state that the environmental benefits of green infrastructure include a reduction in stormwater runoff and sewer overflow events, flood protection, and efficient land use. Some studies have been done to measure quality and quantity of stormwater runoff between sites with green infrastructure strategies and the sites with traditional development (Dietz & Clausen, 2008; Yang & Li, 2005; Anderson et al., 2008). Yang and Li (2003), compared the effectiveness of a site with green infrastructure and a conventional site that includes traditional grey infrastructure and manicured lawns within Woodlands development in Texas, USA. Only two subdivisions in Woodland were designed using green infrastructure because of complaints about the poor aesthetics associated with the bioswales and rain gardens. The rest of the sites in Woodland development site were designed using gray infrastructure. The subdivisions using green infrastructure had more impervious cover (32.3%) than the conventional site (13.7%). The studies about the effectiveness of green infrastructure revealed that even if the site using green infrastructure had more impervious cover, less stormwater runoff was generated compared to the traditionally designed site.

Moreover, studies show that green roofs, street trees, and increased urban green spaces make individual buildings more energy efficient by reducing heating and cooling demands (Banking on Green, 2012). Heisler (1986), analyzed the effect of green infrastructure on cooling and heating costs, and showed cooling cost reductions of 20—50% and heating cost reductions of 10—15% for residential allotments with trees. Similarly, a study in Chicago has shown that increasing tree cover in the city by 10% may reduce the total energy for heating and cooling by 5—10% (Haq, 2011).

Ecological benefits of green infrastructure include providing habitats for a wide range of flora and fauna ("Forest Research", 2010). Haq (2011) shows that in green spaces that have good connectivity and act as wildlife corridors or function as urban forests can maintain viable populations of species that would otherwise disappear from built environments. A study conducted by Okunlola (2013) demonstrated that the combination of mowed turf, trees, and natural areas provides a diverse environment for people and wildlife and that preserving these green spaces improves the environmental quality of the entire community.

The economic benefits provided by green infrastructure can be categorized as water-related, energy-related, air-quality related, and climate-change related (EPA, 2014). Moreover, EPA (2010) states that "some environmental benefits of green stormwater infrastructure include flood protection, reduction in sewer overflow events, and efficient land use. An example of a social benefit is enhanced livability through attractive streetscapes. In the previous paragraph, poor aesthetics value associated with green infrastructure strategies were mentioned. Although

residents think that green infrastructure strategies beautify the neighborhood, they have some concerns related to their look in winter time or if they poorly maintain.

Lastly, some economic benefits include increase in land value, reduction in the cost of traditional infrastructure, and encouragement of economic development." In 2013, EPA approved a plan by the Metropolitan Sewer District of Greater Cincinnati to control combined sewer overflows stemming from the Lower Mill Creek service area using green infrastructure, along with strategic sewer separation and other methods. This approach, which uses both gray and green infrastructure, is projected to save $150 million compared to the city's original plan to construct a deep tunnel stormwater storage area—even before considering other potential economic benefits.

A body of literature has discussed the effect of green infrastructure strategies on property value (Wolf, 2005; Plant, 2006; Bolitzer & Netusil, 2000; Donovan & Butry, 2010). In a variety of studies, the presence of trees has been found to increase the selling price of a residential unit from 1.9% (Dombrow et al., 2000) to 3–5% (Anderson and Cordell, 1988) to 9% in a study examining Philadelphia's rejuvenated suburbs (Wachter and Gillen, 2006). In addition, commercial areas with green spaces and trees in excellent condition were correlated with significant increases in home values (Plant, 2006).

While the literature I reviewed comes from many different fields, it provides evidence for the many benefits of green infrastructure, including physical and mental health, community, economic, climate modification, water management, and ecologic benefits. However, although

green infrastructure has such benefits, its implementation is still low. In the next section, I discuss barriers to the implementation of green infrastructure.

Table 2-3. Green Infrastructure benefits

Environmental	• Improve air quality • Efficient land use • Improve human health • Flood protection • Drinking water source protection • Reduce sewer overflow events • Reduce stormwater runoff amount
Economic	• Reduce gray infrastructure construction costs • Increase land values • Reduce heating and cooling demands • Encourage economic development
Social	• Enhance livability through attractive streetscapes • Provide health benefits • Provide opportunities for recreation • Improves safety • Promotes community identity
Ecological	• Protect and restore wildlife habitat • Provide connectivity act as wildlife corridors • Maintain population of species

2.1.5. Green Infrastructure Implementation Challenges

The concept of green infrastructure and its benefits to communities and cities are increasingly being recognized by planners and practitioners, but the transition from traditional stormwater management systems to green infrastructure strategies requires overcoming significant barriers. Although green infrastructure has proven social, economic, and environmental benefits, its implementation is not very common. Green infrastructure strategies are more complex than traditional stormwater infrastructure strategies because green infrastructure strategies require engagement from a wide range of stakeholders. Residents, business owners, community-based organizations, and other stakeholders are important to the implementation of green Infrastructure. This collaboration can help create sustainable communities, which is one of the main goals of green infrastructure strategies.

Some authors focus on the barriers at the government level (Westerlund, 2010; Dobson, 2010; Hill, 2010; Spencer, 2010; Hammit 2010). These studies reveal that "a resistance to change" is the first barrier to implementation of green infrastructure at the government level. The reason why local governments resist change is that they believe that past practices (gray infrastructure) fulfill the government priorities for stormwater management, including efficacy, safety, reliability, and predictability (Hammit 2010). A second barrier within the government is uncertainty about green infrastructure strategies for use in stormwater management because of insufficient and inaccessible information about green infrastructure and its benefits. Moreover, the lack of design standards for GI strategies creates a barrier to its acceptance at the government level (Dobson, 2010). According to Spencer (2010), another barrier to implementation of GI at the government level is the lack of expertise in city staff to design, implement, and maintain GI

strategies. Westerlund (2010) states that if the cities are planning to adapt GI as a stormwater management strategy, they need to hire staff with expertise in green infrastructure planning and implementation.

The final obstacle is "interagency coordination." For example, Seattle Green Factor, administered by the Department of Planning and Development, encourages the installation of GI facilities by private developers in the public right-of-way, which falls within the realm of the Department of Transportation (Hammit, 2010). In this case, it may take time to have coordination between agencies. For example, Tracy Tackett, one of the engineers who developed the SEA streets design in Seattle, experienced obstacles with interagency coordination. She maintained "endless discussions with the Department of Transportation's street designer on how to balance all the multiple demands of street spaces" (Tackett, 2010). After several years and persistent diplomacy, the Seattle Right-of-Way Improvements Manual ("City of Seattle", n.d.) finally contains GI and natural drainage systems in its "Streetscapes Design Manual." (Hammit, 2010).

Similar to government support, green infrastructure strategies also require public support (Shandas et al, 2010). Benedict (2016) states "even though green infrastructure initiative may begin as a government-led effort, the most successful results are achieved when the greater community is brought into the process" (p. 85). First, public participation is important in order to incorporate sustainability in infrastructure projects (Natural Resource Defence Council [NRDC], 2015). Sustainable communities are those that balance their economic assets, natural resources, and social priorities so that residents' diverse needs can be met now, and in the future (Shandas

et al, 2010). Secondly, engagement with the public reduces the risk of dissatisfaction in green infrastructure projects (NRDC, 2015). Dissatisfaction may decrease the willingness for next projects, so it is important to engage the community in the process.

Finally, public support is important because, in contrast to hidden grey infrastructure, green infrastructure strategies affect the look and feel of a neighborhood (Shandas et al., 2010). According to EPA (2002), people will be more satisfied if they are involved in deciding process where green infrastructure strategies will be installed and what they will look like. Dobson (2010) states "typically, if you are just doing underground work, you don't involve the public that much except to tell them about the construction. I think there is a real recognition now that because these facilities are at the surface... we want people to know what they are and not abuse them, and in fact to adopt them and take care of them."

However, there are some barriers to the adaption of green infrastructure at the public level. Lack of public awareness is a barrier to the adaption of green infrastructure strategies. The public may not be aware of the benefits of green infrastructure to cities and water bodies (Hammit, 2010). Another barrier is that the public may not perceive that stormwater is a problem and may think that it is already taken care of by government (Keeley et al. 2013). Hammit (2010) states that the visibility of poorly maintained plantings, which negatively affect the public's perception of green infrastructure is a barrier to the adaption of green infrastructure. Finally, sociocultural factors such as social status and norms can affect the adaption (Turner, 2015). These barriers can be overcome by generating public understanding and potential support and by conducting education and outreach.

Table 2- 4. Green infrastructure challenges at government and public level

Implementation Challenges	**Source**
Challenges at government level: • Resistance to change • Uncertainty about green infrastructure strategies (insufficient and inaccessible information) • Lack of design standards • Lack of expertise in city staff • Lack of interagency coordination	Dobson, 2010 Hammit 2010 Hill, 2010 Spencer, 2010 Westerlund, 2010
Challenges at public level: • Lack of public awareness to the benefits of green infrastructure • Lack of knowledge about stormwater problems • Negative perception toward green infrastructure • Sociocultural factors	EPA, 2002 Hammit, 2010 Keeley et al., 2013 Turner, 2015

Another group in green infrastructure projects is private residential landowners, who are the target of this study. In the next chapter, the importance of residents in green infrastructure studies and barriers to its adaption among residents will be deeply discussed.

2.2. LITERATURE REVIEW: FOCUS OF THIS STUDY

Green infrastructure is a decentralized approach to stormwater management, whereas traditional stormwater infrastructure is centralized (Barclay, 2016). The main purpose of the traditional stormwater infrastructure is "keeping flood water out." However, this idea has changed to "mitigating flood risk, adaptation and increased resilience to flooding events" with the emerge of green infrastructure (Benedict & McMahon, 2006). It means that cities would like to "work with water instead of controlling or avoiding it" (Benedict & McMahon, 2006). This approach requires interdisciplinary partnership, in which all disciplines related to stormwater management should work together to successfully implement green infrastructure strategies (Seybert, 2006).

The key point to the success of green infrastructure projects is to acknowledge that everyone can play a part in maintaining, enhancing, and restoring green infrastructure in urban, suburban, and rural areas—from business owners to community-based organizations to local planners to engineers to large private landowners (Biddle, 2006; Marsalek & Chocat, 2002; Parkinson, 2003; Rauch et al, 2005; Ryan & Brown, 2001). This collaboration can provide sustainable communities, which is one of the main goals of green infrastructure strategies. Moreover, according to Turner (2014), high participation rates in green infrastructure projects break the connections between impervious surfaces, and this disconnection leads to improved water quality and ecological function in the streams that receive stormwater runoff. However, there are some barriers to the implementation of these strategies.

Some authors investigated the barriers to the adoption of green infrastructure strategies at the government level. Some focused on the barriers to the adoption of green infrastructure strategies

by the public. Yet, little scholarly work has investigated the role of private residential landowners in green infrastructure projects and the barriers that influence residents' participation. My dissertation addresses this gap in green infrastructure literature. This part of the literature review examines (1) the role of private residential landowners in green infrastructure projects and (2) barriers to the implementation of green infrastructure strategies in municipalities targeting residential landowners.

2.2.1. THE ROLE OF PRIVATE RESIDENTIAL LANDOWNERS IN GREEN INFRASTRUCTURE PROJECTS

When green infrastructure planning first emerged in urban areas, it often focused on open space, city parks or other parcels where the installation of green infrastructure strategies would not conflict with residential, commercial, or industrial land use (Dreher, 2009; Pataki et al., 2011). However, as cities grow, open-spaces have been decreasing and may not be enough to deal with stormwater after heavy storms (Thurston et al., 2012). In suburban areas, most impervious surfaces, roofs, driveways, and sidewalks, are connected to stormwater infrastructure, and lawns may not allow for enough stormwater to infiltrate after heavy storms (Thurston et al., 2012). For these urban and suburban areas, small-scale green infrastructure strategies may be the most practical approach to increasing the efficiency of green infrastructure, which in turn provides storm-water detention capacity (Thurston et al., 2012).

In green infrastructure projects, private landowners are one of the important stakeholders in the implementation of these strategies. Installing green infrastructure strategies solely on public land,

including rights of way, parkland, or buildings, would not be enough to meet cities' goals for stormwater management ("NewYork City", 2017). For example, In NewYork City, stormwater runoff and sewer overflows are the largest sources of water pollution. Billions of gallons of untreated sewage flow each year into waterways such as Flushing Bay, the Bronx River, the Hudson River, the East River, Newtown Creek, and Jamaica Bay, where New Yorkers kayak, fish, and swim ("NewYork City", 2017). Based on this, the City, through its Department of Environmental Protection (DEP), committed in 2012 to a hybrid plan to reduce sewer overflows, using gray infrastructure in combination with green infrastructure that captures storm runoff before it reaches water bodies ("NewYork City", 2017). Over the last six years, DEP has focused on building GI on streets, sidewalks, and other public property. But more than 50 percent of the land area that the City has targeted for GI projects is in private hands, and it is not possible to reach their target without getting support from private landowners ("NewYork City", 2017).

As mentioned in the background section, the majority of land in cities is in private residential ownership and implementing green infrastructure techniques on private lands could increase the effectiveness of green infrastructure strategies. EPA (2015) states that "private property constitutes substantially more land area in communities than public property; therefore, there are many opportunities to incorporate green infrastructure on individual private parcels as part of new development or redevelopment" (p. 7). In 2014, Partners for Places—with matching support from the Community Foundation for Greater Buffalo—funded a community engagement campaign about stormwater management and green infrastructure. The goals of the program were to: "(1) work with residents to shape effective stormwater management messaging; (2) mount a multi-faceted education campaign about overflow issues; (3) motivate residents to act

(from rain barrels to rain gardens); and (4) establish/report on community-wide performance measures and impacts" (Urban Sustainability Directors Network [URDN], 2017, p. 2.). At the end of the program, 1,279 rain barrels were implemented by residents, and 168,800 gallons of stormwater were prevented from entering the combined sewer system. These results were provided by increasing awareness of residents and encouraging them to install these strategies.

Thurston et al. (2012) conducted a six-year study in Shepard Creek, Ohio. In 2007 and 2008, they encouraged private residential landowners to install one rain garden or up to four rain barrels on their property through a reverse auction. Reverse auction is "a type of auction in which several sellers offer their items for bidding and compete for the price which a buyer will accept" ("Dictionary", n.d.). At the end of two rounds of reverse auctions, 176 rain barrels and 83 rain gardens were installed on private property. Residents were provided the incentive of free rain gardens and rain barrels, three years of free maintenance and a one-time payment of the bid amount. After the six-year observation, this study revealed that the installation of 83 rain gardens and 176 rain barrels onto private residential properties altered the overall discharge regime and contributed to ecosystem services such as flood protection, water supply, and water infiltration; provided benefits to the local residents; and reduced the need for a larger, expensive, centralized retrofit.

However, it is not an easy process to install green infrastructure strategies on private lands. "NewYork City" (2007) states "whereas installing GI for an indefinite duration on public property is simply a matter of changing policy and reallocating public funds, to do so on private property a city must undertake the more difficult tasks of aligning public and private objectives

with respect to assets located on private property, and creating a mechanism to redirect public money to private actors for the installation and maintenance of those assets" (p. 9). Although institutional barriers have been removed, residents may not be willing to implement these strategies on their property (Turner, 2015). In the next chapter, barriers to the implementation of green infrastructure by residents will be discussed.

2.2.2. IMPLEMENTATION CHALLENGES IN RESIDENTIAL ENVIRONMENTS

Resident participation rates in municipal green infrastructure projects have been low, even when infrastructure is provided for free or with incentives (Green et al. 2012; Mayer et al. 2012; Bos & Brown 2015). Low participation rates are likely due to a variety of institutional and socio-cultural factors that influence residents' willingness to install and manage green infrastructure on their property (Barnhill 2012; Mayer et al. 2012; Baptiste et al. 2015).

It is important for municipalities to understand how much environmental knowledge private residents have, and plan to increase their knowledge if knowledge is lacking (Faehnle et al., 2014). Studies examining environmental knowledge have found that the residents are not aware of the environmental benefits of green infrastructure and could not make a connection between green infrastructure and stormwater management, so they do not take concrete actions (Barnhill & Smardon 2012; Keeley et al. 2013; Baptiste 2014; Baptiste et al. 2015). Hammit (2004) conducted interviews with city officials in her study, and Executive Director Becky Rice of Minneapolis's Metro Blooms states that "people are just not aware that the rainwater that goes off their yard and down the storm sewer system is the number one cause of pollution in urban

waters. However, once people know about what's happening, they are willing to make a change."

Increasing residents' knowledge about stormwater management and green infrastructure strategies may increase residents' willingness to implement green infrastructure (Faehnle et al., 2014). Baptiste (2014, 2015) state that even if a small number of residents attend education programs, there is a potential that they may spread this knowledge to their neighbors. Shelton et. al. (2015) found that residents who attended workshops that aimed to increase knowledge about green infrastructure show more willingness to implement green infrastructure on their property. Results indicated that over 70% of all participants of the workshops planned on implementing the infrastructure on their own property This study states that residents are interested in learning more about green infrastructure and this learning may affect their willingness to implement green infrastructure on their property in a positive way. On the other hand, Turner (2015) and Heimlich and Ardoin (2008) studies revealed that educational activities do not necessarily motivate the participation.

In summary, although knowledge is often a major social barrier in the implementation of green infrastructure on private properties (Babtiste 2014; Babtiste et al., 2015, Huang, 2013; Barnhill), some studies stated that there is no relationship between knowledge about stormwater management and green infrastructure adoption (Turner, 2015; Robinson et. al., 2008).

Sociodemographic factors have been discussed as a potential barrier to the implementation of green infrastructure strategies. Many studies state that sociodemographic characteristics are not

related to “willingness to adopt green infrastructure” (Barr, 2007; Noor et al., 2012; Stern, 2000). However, Baptiste (2014) revealed that there is no relationship between sociodemographic factors and willingness to implement, except age. Older people show more willingness to implement green infrastructure strategies. On the other hand, other studies show that actual adoption of GI generally happens in high-income areas (Heynen et al. 2006; Ando & Freitas 2011; Locke & Grove 2016). For example, a study by the Atlanta Regional Commission [ARC] revealed that high-income residents were more willing to implement Green infrastructure strategies on their property or street (ARC, 2008).

The appearance of green infrastructure strategies has been found to be a barrier to the implementation of green infrastructure strategies at the resident level. These studies state that people show more willingness to implement landscapes that have high “aesthetic” value (Apostalaki et al. 2006; Bryne et al. 2015; Baptiste, 2014). Baptiste’s study revealed that aesthetic appeal plays an important role in implementation factors, rather than cost or health concerns. Some residents in subdivisions are not likely to install bioretention swales and rain gardens because they often view naturalized features as “messy” (Yang & Li, 2013). People often prefer manicured grass and do not understand the environmental benefits of vegetated areas (Yang & Li, 2013). Winkelman (2010) supports these findings by stating that the unmaintained rain gardens which look messy and weedy, affect residents’ willingness to implement these strategies on their property. One of the city officials, with whom Hammit (2014) conducted an interview, stated that “unsuccessful or unsightly green infrastructure projects actually do more harm than good.” Part of the problem is that people are not aware of the benefits of adding native plantings on their property, benefits such as managing stormwater more effectively and bringing local wildlife into their yards (Hammit, 2004). Cost is also identified as a major barrier to the

implementation of green infrastructure at the resident level (Anderson et al., 2009; LaBadie, 2010; Barnhill & Smardon 2012). Barnhill and Smardon (2012) found through focus group research in Syracuse, NY, that respondents identified "up-front individual costs" as a dominant barrier to their decision to implement GI around their home. Another study conducted by Baptiste (2014) indicated that residents considered stormwater options too expensive and would only implement them on their properties if the infrastructure was provided to them for free. Recently, studies removed "cost" barrier and investigated how willing residents would be if green infrastructure strategies were provided for free or by offering savings on their bill (Mayer et al., 2012; Baptiste et al., 2015; Turner, 2015; Green et al. 2012; Foley, 2012). According to Sinasas (2007), two unrelated reasons might explain why respondents show resistance to spending money on stormwater green infrastructure: (1) respondents do not have the money to spend on this infrastructure or (2) respondents have the money, but they are not willing to spend it on this infrastructure.

Mayer et al. (2012) found that an economic incentive greatly increased the number of residents who were willing to install rain gardens and rain barrels on their property. Mayer et al. (2012) found that the majority of residents in Shepard Creek, Ohio, would not be willing to pay for rain barrels or rain gardens. They responded by offering rain barrels and rain gardens for free to residents. Residents were surveyed again the following year and the percentage of residents who stated that they would not pay for rain barrels or rain gardens had decreased from 16% to 9%, (Mayer et al., 2012). Unfortunately, while Mayer et.al. (2012)'s study inquired into residents' willingness to pay for green infrastructure, it did not inquire residents' ability to pay for this infrastructure. Consequently, for this study, it is difficult to determine whether residents'

decision about installing of green infrastructure is influenced by an unwillingness to pay or an inability to pay.

Moreover, health concerns related to green infrastructure have been defined as a barrier to the implementation of green infrastructure strategies. Traver (2009) states that there are misconceptions regarding green infrastructure, especially related to disease vector habitat for mosquito populations. Foley (2012) conducted a study in Syracuse, NY which revealed that "potential health risk" concerns have a significant influence on residents' willingness to implement GI strategies on their property. Hammit (2014)'s study supports these results by stating that residents think GI strategies "won't infiltrate and will be mosquito traps." On the other hand, Baptiste (2014) study showed that health concerns with GI strategies had a low influence on their implementation compared to the cost and aesthetics factors.

Next, maintenance has been identified as a major barrier to implementation (Baptiste, 2014). In Baptiste (2014)'s study, residents were less willing to implement porous driveways because they require more maintenance. Moreover, Hammit (2004) states that there is a perception that the future costs of green infrastructure maintenance are relatively unknown compared to gray infrastructures. Western (2010) supports this statement by adding that there was no guide that gives clear information about the cost of maintenance and that makes it unknown for the long-term maintenance, repairs, replacements, etc. Since there is an uncertainty, the residents do not want to take the responsibility for maintenance and so show less willingness to implement.

Additionally, Foley (2014)'s study found that the perceived barriers of "maintenance cost" have a high influence on the implementation of green infrastructure. In some studies, maintenance was

investigated under two topics: “maintenance cost” and “required time for maintenance” (Baptiste, 2014; Baptiste, 2015; Mayer et al. 2012; Sinasas, 2007). This result suggests that participants view the time required for maintenance as a potential barrier to the installation of green infrastructure on their properties. On the other hand, Mayer et al. (2012) found that available time is not a barrier to the installation of green infrastructure on residential properties.

Other barriers to the implementation of green infrastructure have been discussed in the green infrastructure literature. Barnhill and Smardon (2012) reported that “lack of control over property” is a barrier to GI implementation. Depending on the agreement between landowner and renter, the landowner may not have control over the property. Sinasas (2017)’ s study revealed that “site suitability” is another barrier to the implementation of green infrastructure for property owners. Matthew et al. (2015) states that biophysical factors such as soils, slopes, or other environmental characteristics are barriers to the implementation of green infrastructure strategies.

Table 2-5. The factors affecting willingness to implement green infrastructure discussed in the literature

Lack of knowledge Authors agree: Barnhill & Smardon, 2012; Baptiste, 2014; Baptiste et al., 2015; Faehnle et al., 2014; Huang, 2013; Keeley et al., 2013. Authors disagree: Ardoin, 2008; Robinson et al., 2008; Turner, 2015.	**Maintenance** Authors agree: Baptiste, 2014 (required time and cost); Baptiste et al., 2015 (required time and cost); Foley, 2014 (cost); Hammit, 2014 (cost); Sinasas, 2007 (required time and cost); Western, 2010 (cost). Authors disagree: Mayer et al., 2012 (required time)
Sociodemographic factors Ando & Feritas, 2011 (income); ARC, 2008 (income); Barr, 2007; Baptiste, 2014(age) Heynen et al.,2006 (income); Noor et al., 2012 Stern, 2000.	**Other barriers** Barnhill & Smardon, 2012 (lack of control over the property); Sinasas, 2017 and Matther et al., 2015 (site suitability)
The appearance of green infrastructure Apostalaki et al., 2006; Bryne et al., 2015; Baptiste, 2014; Hammit, 2004; Yang & Li, 2013	**Cost (installation)** Anderson et al., 2009; Barnhill & Smardon, 2012; Baptiste, 2014; Baptiste et al., 2015; Green et al., 2012; Foley, 2012; LaBadies, 2010; Mayer et al., 2012; Turner, 2015.
Health concerns **Authors agree** Foley, 2012; Hammit, 2014; Traver, 2009 Authors disagree Baptiste, 2014.	

Little is known about residents' values, attitudes, social norms, and other perceived cognitive barriers toward green infrastructure and how those factors influence their willingness to implement these strategies on their property. Sinasac (2017) revealed that attitudes toward green infrastructure did not contribute much to the residents' intention to implement green infrastructure strategies on their property. However, if study participants felt social pressure to install green infrastructure options on their property, then they were much more likely to express intention to do it. On the other hand, Turner (2014) demonstrated that attitudes and perceptions strongly influenced participation.

2.2.3. OVERVIEW OF STUDIES

Based on the issues identified earlier, the literature can be divided into two large categories: cognitive factors (knowledge, attitudes, values, and awareness) and other influencing factors (cost, maintenance, aesthetics, physical space and health). Some studies have concentrated on the cognitive factors that affect the implementation of green infrastructure strategies (Barnhill & Smardon, 2004; Baptiste, 2014; Baptiste, 2015; Foley, n.d.; HuangQ, 2013, Turner, 2015; Robinson et al, Heimlich & Ardoin, 2008) while others have focused on other influencing factors (Apostaloki et al., 2006; Bryne et al, 2015; Baptiste, 2014; Yang & Li, 2013). However, very few studies have investigated these factors in a combined way.

Overall, some studies found out that willingness to implement is associated with knowledge, attitudes, sociodemographic factors, cost, aesthetics and health (Barnhill & Smardon, 2012; Keeley et al., 2013; Baptiste, 2014; Baptiste et al., 2015). On the other hand, other studies could not find an association or found a weak association between some of those variables and

willingness to implement (Turner, 2015; Heimlich & Ardoin, 2008; Mayer et al., 2012). These contrasting views imply that more discussion related to factors that affect residents' willingness to implement green infrastructure strategies on their property is needed. My study will contribute to this discussion by investigating these factors and will also fill a gap by investigating them in a combined way.

CHAPTER 3: CONCEPTUAL FRAMEWORK

3.1. THEORETICAL BACKGROUND

3.1.1. Theory of Planned Behavior

3.1.1.1. Early development of theory of planned behavior: The Theory of Reasoned Action

The Theory of Reasoned Action, introduced by Fishbein in 1967, provides clues to the development of the Theory of Planned Behavior. The Theory of Reasoned Action (TRA) suggested that a person's behavior is determined by their intention to perform the behavior and that this behavior intention is in turn a function of two factors: 1) their attitude toward the behavior (AAct) and 2) his/her subjective norm (SN) (Ajzen & Fishbein, 1980). Attitude generally refers to the favorability of an individual toward certain behaviors, while a subjective norm involves perceived social pressure or acceptance of that behavior (Ajzen & Fishbein, 1980).

Ajzen and Fishbein (1980) state that in general individuals will intend to perform a behavior when they evaluate it positively and when they believe important "others" think they should perform it. However, the theorists acknowledge the relative weights of attitude and subjective norm vary based on the intent, and also vary from person to person (Ajzen & Fishbein, 1980).

The Theory of Reasoned Action has worked in a variety of settings (Eagly & Chaiken, 1993). However, Aiken (2002) states "there are questions about its generality and the operation of certain variables in the equation, and the model does not explain the research findings that the best predictor of future behavior is past behavior." The model also did not make reference to the

perceived behavioral control. This deficiency led to Ajzen's (1988) updated extension to the model, called the Theory of Planned Behavior.

3.1.1.2. Theory of Planned Behavior

Ajzen (1991) revised TRA by incorporating another variable into the model that accounts for an individual's ability to have control over the behavior. This additional variable is referred to as perceived behavioral control (PBC). PBC reflects two dimensions: (a) an individual's external conditions that may augment or moderate his or her ability to adopt certain behavior and (b) an individual's perceived ability to carry out the behavior (Oom Do Valle et al., 2005, p. 367).

The Theory of Planned Behavior (TPB) is a popular choice of theoretical models for research into the prediction of an individual's environmental behavior (Chao, 2012; Wauters et al., 2010). This model has been used by different disciplines to investigate behaviors such as leisure choice (Aizen and Driver, 1992), driving violations (Parker et al., 1992) and dishonest actions (Beck & Aizen 1991) and recyling (Chan, 1998; Cheung et al., 1999; Davies et al., 2005; Taylor & Todd, 1995; Terry et al., 1999; Wan et al., 2012). When compared to other similar theoretical frameworks—for example, the model of responsible environmental behavior (Hines et al., 1986/87)—TPB is found to have stronger predictive ability in regard to explaining behavioral intention (Chao, 2012).

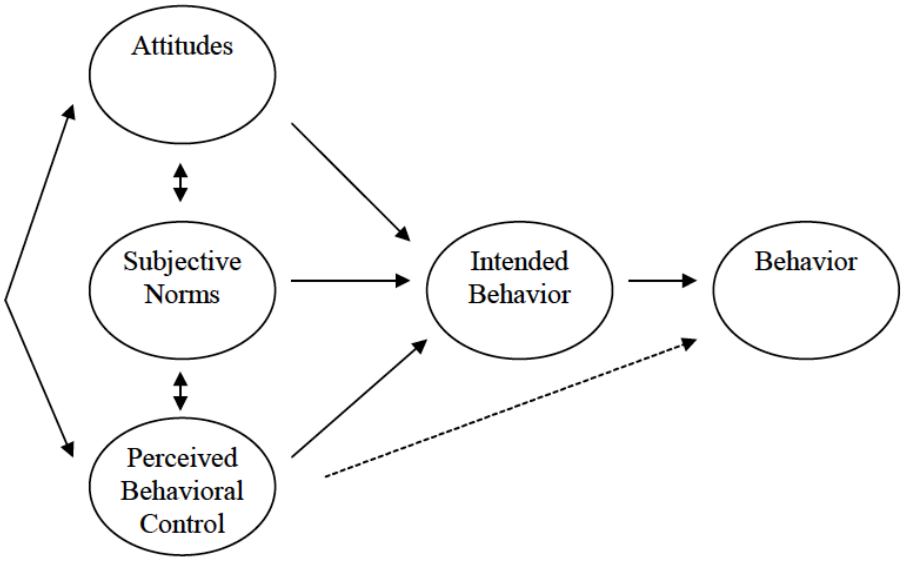


Figure 3-1. Theory of Planned Behavior Model (Ajzen. 1991).

According to TPB, beliefs influence attitude, norms and perceived behavioral control, which then influence behavioral intent, which in turn influences behavior (Figure 7.). Beliefs, attitude, norms, and perceived behavioral control can all be barriers to the intent and actual behavior.

Although there are extended usages of the Theory of Planned Behavior model, there are concerns that it does not explain behavior and that additional variables should be included within the model (Boldero, 1995; Cheung et al., 1999; Davies et al., 2002; Tonglet et al., 2004; Davies et al., 2005; Macey & Brown, 1983; Terry et al., 1999). Davies et. al. (2005) stated that external factors such as personality, demographic characteristics, and past experience may also influence the behavior. Based on the other researchers' explanations, TPB allowed for adding variables that contribute to explaning behavior (Ajzen, 1991; Gadiraju, 2016).

3.1.2. Knowledge-Attitude-Behavior Model

Another important modification to the Theory of Planned Behavior is the addition of knowledge as a variable. Though psychologists often consider knowledge a necessary predictor to attitudes, it is not explicitly included in Ajzen's original model. Researchers such as Kaiser et al. (1999) have added it to their adapted theory of planned behavior. Kaiser et al. (1999) states "Because attitude includes not just the evaluation of a certain outcome but also the estimation of the likelihood of this outcome, salient information or factual knowledge is a necessary precondition for any attitude" (p. 3). This research provides the theoretical grounding for the use of a conceptual model that combines knowledge, attitudes, and behavior (often referred to as a KAB model) in a single framework.

Some studies imply that environmental knowledge is important to informing or affecting positive environmental attitudes and positive environmental behaviors. (Frick, Kaiser, & Wilson, 2004; Fraj-Andrés & Martínez-Salinas, 2007). Several studies have found a positive association between increased environmental knowledge, a positive environmental attitude, and behavior changes to protect the environment (Coyle, 2005; Koupal & Krasny, 2003). Hines et al. (1986/87), reported that "the positive correlation coefficient indicates that those individuals with greater knowledge of environmental issues and/or knowledge of how to take action on those issues were more likely to have reported engaging in responsible environmental behaviors than were those who did not possess this knowledge" (p. 2).

Some environmental knowledge studies use survey questionnaires related to basic environmental facts and measure whether these questions were answered correctly or not (Coyle, 2005; Mancl, Carr, & Morrone, 2003; McDaniel & Alley, 2005). On the other hand, Frick, Kaiser and Wilson

(2004) divide the environmental knowledge questions into three different categories: system knowledge (having a basic understanding of problem), action-related knowledge (knowing what can be done about a problem), and effectiveness knowledge (knowing about the benefit of environmentally responsive actions). They suggest that understanding all three areas may help promote pro-environmental behavior. Moreover, Barber et al. (2009) have used two main approaches to analyze the environmental knowledge: objective and subjective knowledge. Objective knowledge is defined as how much a person knows about an issue or object. Subjective knowledge refers to how much a person thinks he/she knows (Dodd et. al, 2005).

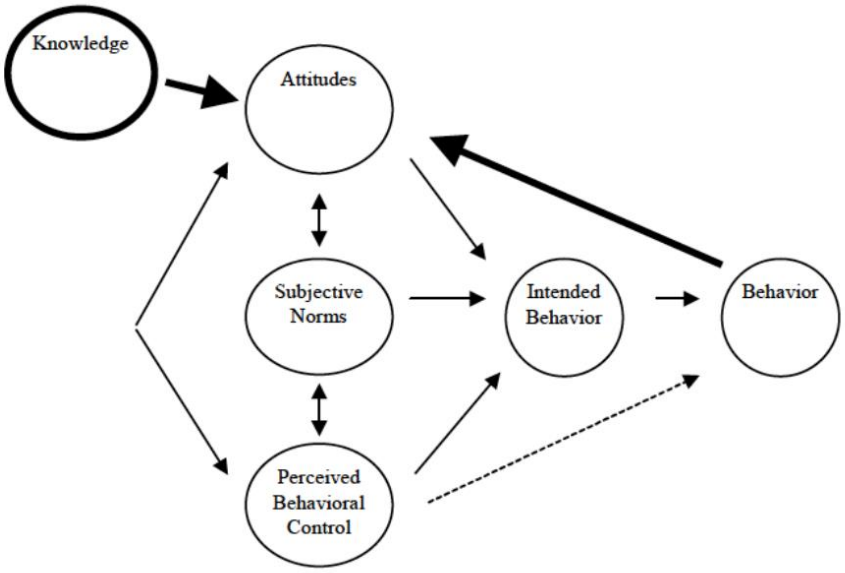


Figure 3-2. Addition of Knowledge to TPB Model (Kaiser et al, 1999)

Literature shows that theoretical knowledge seems to play an important role in pro-environmental behavior, but the empirical evidence tells the opposite (Kaiser and Fuhrer, 2003; Laroche et al., 2001; Zsóka et al., 2012). Some studies could not find any relationship between environmental knowledge and pro-environmental behavior (Bartiaux 2008; Laroche et. al. 2001). On the other hand, some studies show that a deeper knowledge of environmental issues and how to solve them increases the likelihood of pro-environmental behavior (Kaiser and Fuhrer, 2003; Mobley et. al, 2010). These studies indicate that understanding the environmental problems and causes to environment may motivate the individuals to take concrete actions.

Some research show that behavior is related to attitude (Burgess et al., 1998). Environmental attitude is defined "as a systematic value about environmental issues and behavioral intention to improve environmental quality" (Sudarmadi et al., 2001). A great deal of research has been done in different disciplines to understand how attitudes vary across time and individuals, and how environmental attitudes affect behavior (Rauwald and Moore, 2002).

The Theory of Planned Behavior is a rational approach to determining the predictors of intentions (Ajzen, 2011). It uses behaviors that are "under volitional control of people to interpret human judgements and behaviors" (Sinasac, 2017, p. 29). It has been criticized in the past for not relying on external variables, such as emotions. However, in response it was argued that human emotion acts as a background factor that can influence how individuals evaluate situations under their control and that therefore an individual's mood can affect results from TPB (Ajzen, 2011). Overall, the Theory of Planned Behavior has been widely used in many fields such as recycling, health care, nutrition, exercise, etc., and it is very popular in the literature.

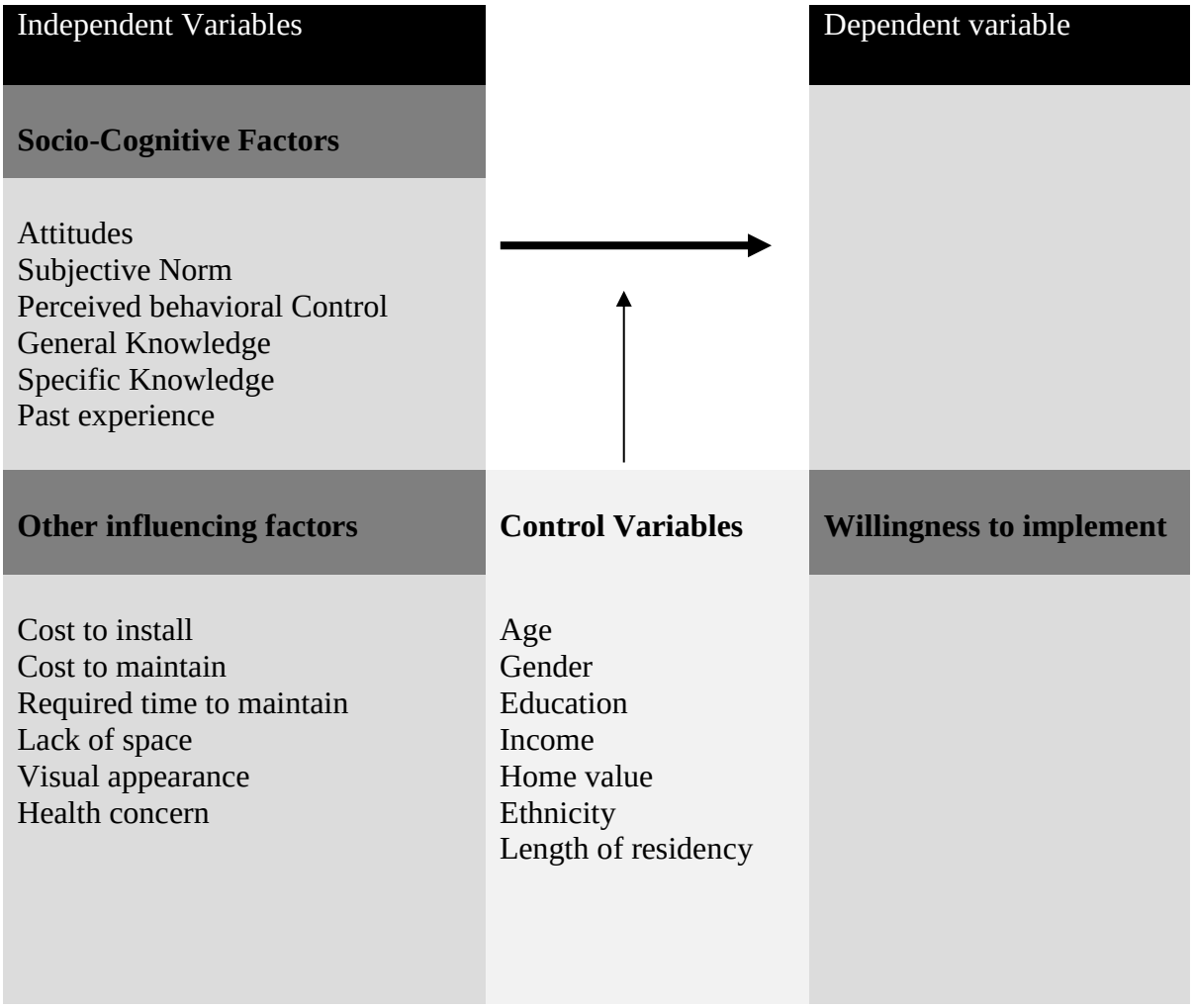
3.1.3. Conceptual Framework

The largest gap in the stormwater management field is the lack of research on social aspects associated with green infrastructure. While some studies have investigated the social and economic barriers to implementation, most studies ignore these issues and focus on the engineering and planning side of green infrastructure. This study will fill this gap by investigating which factors most affect residents' willingness to implement GI strategies on their property and the role of cognitive factors in combination with other influencing factors in the decision process by addressing these questions: (1) Are there any socio-cognitive barriers to the implementation of green infrastructure strategies by private residents within municipalities? What are these barriers? Which of these barriers are the most important ones? The expected barriers are knowledge, attitude, social norms, and personal self-efficacy. (2) Are there any other influencing barriers to the implementation of green infrastructure strategies by private residents? What are these barriers? Which of these barriers are the most important ones? Expected barriers are visual appearance, initial cost, maintenance cost, required maintenance, health concerns, and the size of green infrastructure. (3) Do demographic variables have a significant impact on willingness? These questions were answered in the discussion section of this dissertation.

Social-psychological theories are often used as the theoretical basis that informs questions for social sciences questionnaires. In support of the current research, several social-psychological theories were studied to determine which one would be most appropriate for this research. These theories include the Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1975), the model of environmental behavior (Hines et al., 1986/87), the attitude-behavior theory (Triandis, 1980), the protection motivation theory (Rogers, 1983), and the value-belief-norm model (Stein, 2000).

The TPB was chosen as the theoretical framework to support questionnaire development for the current research because it reflects the crucial processes that can explain individuals' intentions and behaviors (Ajzen, 1991). Moreover, due to its popularity in literature and well-researched results in past studies, the TPB was used for the creation of the questionnaire used in the current research. Ultimately, the TPB was chosen as the theoretical framework for the current research because it is well-grounded in research and theory and has been used successfully in many social studies of behaviour. For example, TPB has been used in several studies that investigate recycling behavior (see, e.g., Boldero, 1995; Chan, 1998; Cheung et al., 1999; Davies et al., 2002, Tonglet et al., 2004; Davies et al., 2005; Taylor & Todd, 1995; Terry et al., 1999; Wan et al., 2012). In the context of this research, the TPB will be used to enlighten social-psychological factors associated with implementation of green infrastructure in private residential environments. The conceptual framework underlying this research is illustrated below:

Table 3-1. Conceptual Framework



3.1.4. Research Questions and Hypothesis

Within the conceptual framework of this study, the following research questions and hypothesis are formulated:

RQ1. Is there an association between socio-cognitive factors and willingness to implement Green infrastructure strategies on private properties? To answer the research question, the following hypothesis were formulated:

There will be a significant prediction of willingness to implement green infrastructure by…

H1. … attitudes toward green infrastructure strategies.
H2…...subjective norm.

H3……perceived behavioral control.

H4. ….general stormwater knowledge and specific knowledge about green infrastructure strategies.

H5. …..past experience.

RQ2. Is there an association between other influencing factors (cost, maintenance, appearance, health concerns) and willingness to implement green infrastructure strategies on private properties? To answer the research question, the following hypothesis were formulated:

There will be a significant prediction of willingness to implement green infrastructure by…

H6…. visual appearance of green infrastructure.
H7…..installation cost.

H8…..maintenance cost.

H9…...required time to maintain.

H10…..health concerns related to green infrastructure strategies.

H11…..lack of adequate space.

RQ3. Does the inclusion of demographic variables help predict willingness to implement green infrastructure?

CHAPTER 4: METHODOLOGY

4.1. Research Design

The aim of this research is to discover the determinants that explain residents' willingness to implement green infrastructure on their properties in Raleigh. Various independent variables that influence willingness to implement green infrastructure have been discussed in the literature. Theory of planned behavior (TPB) was chosen as a theoretical framework. As in the most of TPB research studies, a survey instrument was developed to test the efficacy of the theory. Recent studies using the TPB support this decision to use quantitative analysis when applying the theory (Ajzen, 2006). Quantification makes it easier to aggregate, compare and summarize the data and allows for statistical analyses.

TPB variables and the other additional variables (discussed in the literature) were chosen for inclusion within the conceptual model. In this study, willingness to implement green infrastructure is considered as the dependent variable. This behavioral intention to the implementation of green infrastructure can directly predict actual behavior if the behavior is under volitional control (Ajzen, 1991). Each of these variables, attitude, subjective norm, perceived behavioral control, past experience, general stormwater knowledge, specific knowledge, other influencing factors (cost, maintenance, required time, appearance, lack of adequate space, health concerns) and demographic factors (age, education, income, ethnicity, gender, market value of house, length of residency) were considered as independent variables in statistical analyses. All the independent variables were assumed to be directly proportional to behavioral intention. A hierarchical regression analysis was applied in order to determine the

relationship between willingness and the independent variables. The hypotheses were tested with data collected by means of an online survey.

4.2. Study Area

Raleigh, also known as the city of Oaks, is the capital of the state of North Carolina. Raleigh has 143 square miles of land with an estimated population of 464,000. Raleigh is one of the fastest-growing cities in the United States with a growth rate of about 3.4% per year. According to the most recent American Community Survey [ACS], there are 194,768 households in the city, with an average size of 2.43 people per household. The median house value is $225,000 and, the median income for households in City of Raleigh is $61,505. The overall median age is 33.1 years, 31.9 years for males, and 34.1 years for females. For every 100 females, there are 93.4 males. According to ACS, racial composition of Raleigh is 59% white, 28.9% African American and 12.1% others (Figure 4-1). Education level is mostly bachelor's degree (31.9%) and graduate degree (18.2%) (Figure 4-1).

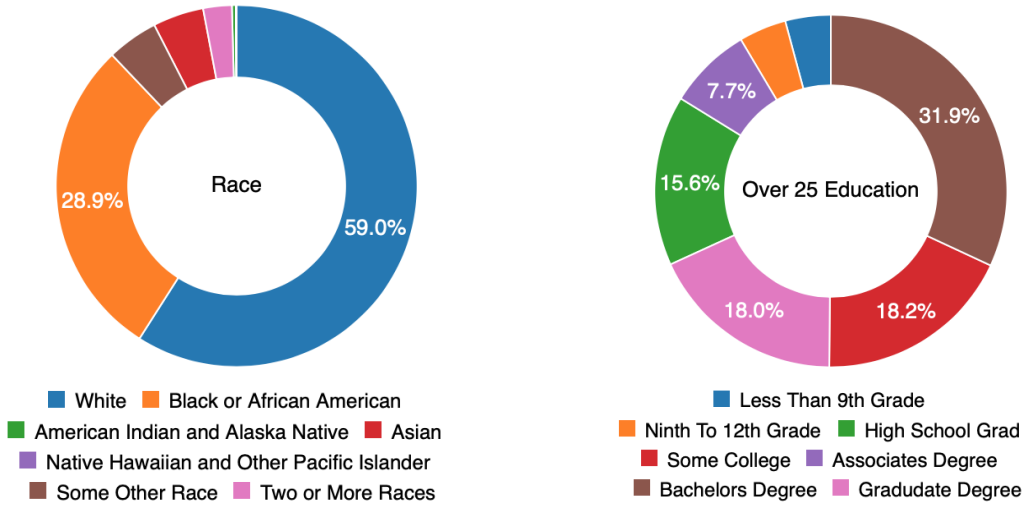


Figure 4-1. Raleigh demographics

The reason we have considered Raleigh is that it has been emerging as a leader in the use of green stormwater infrastructure (GSI). The City Council committed to improving the health of local streams and the Neuse of River by promoting green infrastructure strategies in the early 2000s. That commitment took a decade to be converted into action by the city. In 2013, the City of Raleigh began the process of developing a GSI plan, which was facilitated by Tetra Tech. The first phase of the plan was to educate staff and learn about potential barriers within the city to successfully implementing GSI. This was a critical step in truly integrating GSI into the basic mechanisms of a city – city staff at all levels and all departments need to see how GSI strategies can aid their work rather than be a burden.

Raleigh began implementing its green stormwater infrastructure strategic plan in September 2017. The new plan included revision of the City's Unified Development Ordinance (UDO) to remove barriers and the development of an incentive program for private developers to use green stormwater infrastructure in new and redevelopment. Then, the city of Raleigh started Rainwater Rewards Program, also known as our Stormwater Quality Cost Share Program. The city of Raleigh stated, "This program provides funding for stormwater quality projects that capture and clean rainwater before it goes into storm drains and local waterways. These projects are good for the environment because they mimic nature and absorb pollution from impervious surfaces, like roofs and driveways, that impact the water quality of streams and lakes". Anyone who owns a property and pays the city's stormwater utility fee can participate in this program. However, many residents seem unaware of the advantages of green infrastructure and few residents seem to have already implemented green infrastructure on their properties. There are

many potential barriers that could be associated with the instalment of green infrastructure in private properties.

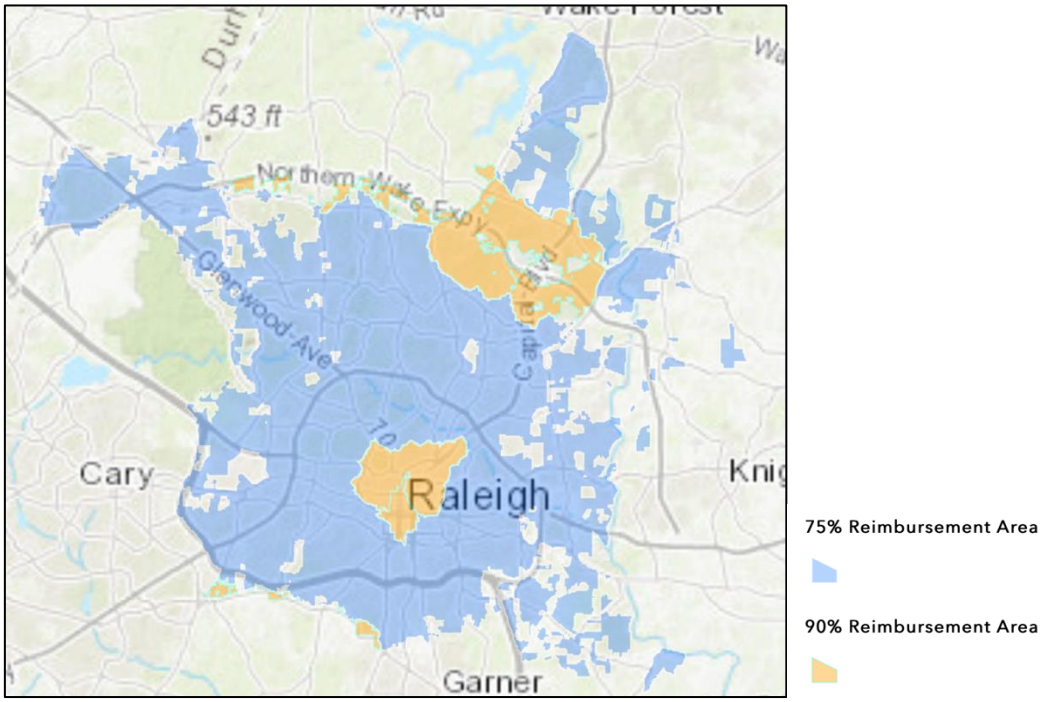


Figure 4-2. Raleigh rainwater rewards reimbursement map

In the context of Rainwater Rewards Program, the areas shown in the map (Figure 4-2) above with orange color, are target areas for the city of Raleigh's program, and 90% reimbursement for the implementation cost of GSI is provided to the residents who live in those areas. The properties that are eligible for 90% reimbursement are located within the watersheds of streams that have been identified by NCDEQ as impaired and are a target for water quality improvements. These are Perry Creek and Pigeon house branch watersheds (see Figure 4-3). In addition, there is a highly urbanized area downtown that has also been delineated as a target area due to the percentage of impervious surface. The areas shown in the map below with blue color are provided %90 reimbursement for the cost by the city of Raleigh.

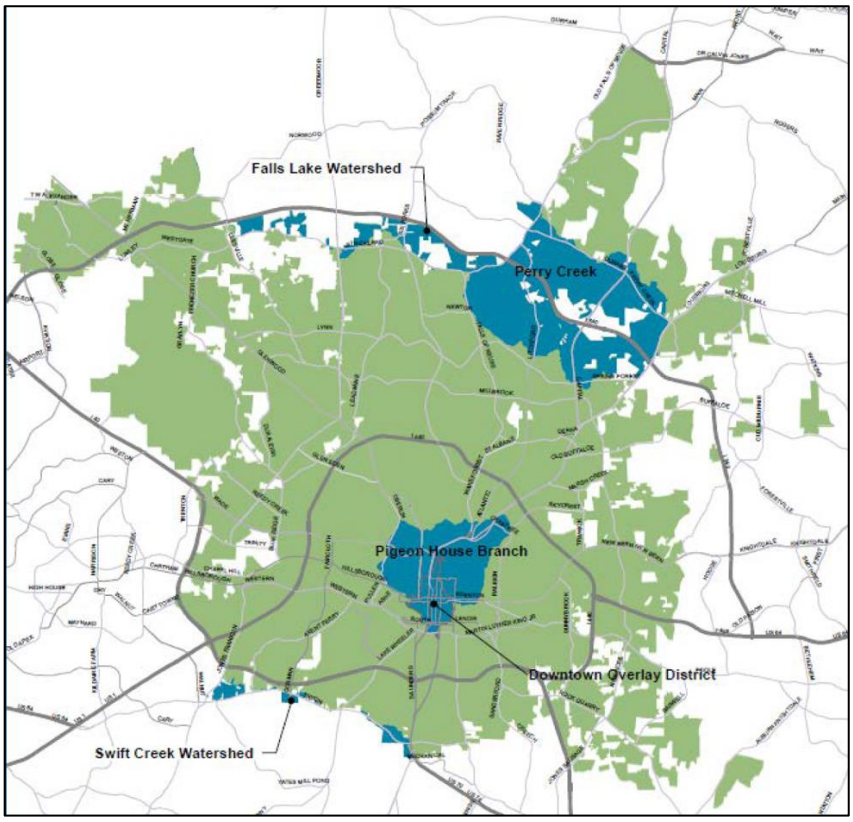


Figure 4-3. Perry Creek and Pigeon house branch watersheds (shown with blue color) which are targets for water quality improvements.

4.3. Questionnaire Design

Poorly designed questionnaires or ineffective survey methods can lead to low participants rates, which make it difficult to obtain statistically significant results (Dillman and Christian, 2005; Hoddinott and Bass, 1986; Czaja and Blair, 2005). Therefore, prior to disturbing the survey to participants, questionnaire designs and survey methods were investigated to maximize participant response rates. The questionnaire focused on barriers to implementation such as knowledge, attitude, subjective norm, perceived behavioral control and other influencing factors such as finances, and time availability. A demographics section, at the end of the questionnaire,

was included to understand if demographic variables were related to willingness to implement green infrastructure. All questions, except for those within the demographics section and the questions to determine participants' level of stormwater and green infrastructure knowledge, were designed using a four-point Likert scale, in order to allow for quantitative analysis of all answers. For knowledge questions, respondents were asked to indicate if the statements are true or false. The writing process for the questionnaire followed the steps outlined in Designing Surveys by Czaja and Blair (2005). The steps are organized as follows: writing and organizing the questions and testing the questions.

4.3.1. Writing and organizing the questions

Writing the questions is the first step in designing a questionnaire. According to Sinasac (2017), every question must contribute to the research questions and the researcher should avoid content that does not provide answers to the research questions. In the beginning of this process, a minimum of ten questions were written for each construct of the theory of planned behavior and other influencing factors that may affect the dependent variable (willingness). Then, these questions were discussed with the committee members in order to ensure that each question showed a close relationship with its section of cognitive factors and other influencing factors. The questions were written after thorough review of previous green infrastructure studies (Babtiste, 2014; Babtiste et al., 2015; Keeley et al., 2013, Sinasac, 2017). Specific wording for questions in each section of the TPB was determined based on Fishbein and Ajzen (2010) who indicate how to word questions so that they clarify the required content.

The questions were organized into sections consistent with the theoretical constructs in Ajzen's (1991): TPB measures (attitude, perceived behavioral control, subjective norm) and additional

variables such as general stormwater knowledge questions, specific green infrastructure knowledge questions, other influencing factors, behavioral intention question (willingness) and demographics.

4.3.2. Testing the questions: Pilot study

In general, a survey should not be used without adequate pre-testing, because results from a pilot survey can provide insights into the effectiveness of the survey method and help determine whether the questions are appropriate. Moreover, a pilot study can inform researcher whether the required time to complete the questionnaire is too long. If only a small number of questionnaires are returned or the questions are consistently left unanswered, the researcher should consider modifications to the survey method, the design of the questions, and the length of the questionnaire. A pilot survey can also be used to estimate the expected response rate and required sample size to achieve statistically significant survey results.

All aspects of the surveys used in this research were tested including question content, wording, sequence, instructions and question difficulty. Protocol and pretesting were conducted to demonstrate the accuracy and completeness of the surveys. The pilot test served two purposes: (i) to fix any unforeseeable problems with the survey, and (ii) to gain feedback from the participants. The pilot test was conducted with the actual software and circumstances of the final survey, as recommended by Fink and Kosecoff (1998). This allowed participants to provide feedback concerning the clarity of the questions. The goal the pilot study was to learn as much as possible from a small diverse sample. Firstly, the individuals read through the questionnaire and

identified confusing or poorly worded questions. Then, they provided feedback on which questions to omit, and what concepts were missing from the questionnaire.

Next, the pilot test questionnaire was performed in Raleigh. An online survey link was sent via email with a completion date indicated on the survey invitation. Then, two follow-up surveys were sent as reminders to individuals who did not fill out the questionnaire online. Revisions were made based on the feedback from participants, making sure that the questions were precise, and the variables reliably generated the data. A few changes were recommended by the participants in this pilot study. These included clarifications in wording, reduction of redundant questions and other suggestions to make the questionnaire shorter.

4.4. Questionnaire

The online survey was created and distributed using the "Qualtrics" survey tool. The survey used closed-ended questions and was divided into multiple sections to determine knowledge (both general and specific), theory of planned behavior measures (attitude, self-efficacy, subjective norm), influence factors affecting willingness to implement green infrastructure strategies and demographic characteristics of respondents. The survey was reviewed and approved by the NC State University Institutional Review Board for research involving human subjects (Protocol #16642).

The first page of the survey explained that clicking the "next" button was an indication of consent to participate in the survey for the purpose of the author's dissertation research. Each of the questions on the survey did not require a response before participants could proceed through to the next page of questions. If a question was skipped, an error message was sent, requesting a

response to the skipped item(s). The participants had the option of skipping the error message and proceeding through the instrument. At any time, the participants could exit the survey prior to completing all the items which resulted in their responses being labeled “partial”.

The survey questionnaire had seven different parts (see Appendix B). The questions in Part 1 asked respondents to indicate if they had green infrastructure on their property or not. The answers were: “yes I installed”, “yes, the previous owner installed” and “no”. In Part 2, respondents were asked to indicate their level of agreement or disagreement with the following statement: “How likely are you willingness to implement rain barrel, rain garden or porous pavement?”. A four-point Likert scale was used, where 1=extremely unlikely, 2=somewhat unlikely, 3=somewhat likely, and 4= extremely likely. The higher the score, the more likely a respondent was willing to implement green infrastructure strategies.

In Part 3, general stormwater knowledge was determined by asking respondents if the following statements were true or false: (i) Rainfall that flows over the ground surface, which is called stormwater runoff, can be a large source of pollution in local water bodies; (ii) Stormwater runoff flowing from impervious surface can negatively affect water bodies etc. These questions were used to determine respondents’ level of knowledge related to stormwater management. In Part 4, specific knowledge questions related to green infrastructure strategies were asked. Rain barrel, rain garden and porous pavement each had two statements. Respondent were asked if the following statements were true or false: (i) Porous pavement can allow water to infiltrate into the soil; (ii) Rain garden can absorb the pollutants carried in stormwater runoff; (iii) Rain barrel can capture water and hold it for later use on lawns and gardens etc. Specific knowledge questions

were used to determine whether a person was knowledgeable about the use of green infrastructure strategies to control stormwater.

In Part 5, respondents were asked to indicate their level of agreement or disagreement with the following statements: (i) If my neighborhoods were to install green infrastructure on their property, I would be more likely to install it on my property; (ii) I am confident that I could learn the skills required to install or maintain GI on my property; (iii) I support the adoption/implementation of Green infrastructure on my property. A four-point Likert scale was used, where 1=extremely unlikely, 2=somewhat unlikely, 3=somewhat likely, and 4=extremely likely. These statements were used to measure the respondents' self-efficacy, subjective norm and attitudes toward green infrastructure strategies. Higher scores indicated higher levels of self-efficacy, subjective norm and attitudes regarding the implementation of green infrastructure strategies.

In Part 6, respondents were provided with other influencing factors to determine the extent to which these factors affected their decision to implement green infrastructure strategies. Specifically, these influence factors were considered as the perceived barriers for implementation. The factors included cost to install, cost to maintain, required time to maintain, visual appearance, lack of adequate space and health concerns. Respondents were asked to indicate their level of agreement or disagreement for each type of green infrastructure separately. This was measured on a five-point Likert scale, where 1=no influence, 3=don't know, and 5=great influence. Higher scores indicated a higher level of influence on implementing green infrastructure strategies. Part 7 included demographic questions. Respondents were asked to

answer questions about gender, age, education, home value, income and the years lived in Raleigh. The raffle entry on the last page of the survey was optional and if participants chose to click past it, their surveys were still coded as “completed”.

4.5. Data collection procedure

Due to its usefulness and efficiency, an online mode of survey administration was used to collect data for this study. The survey questionnaire was built in the online survey tool, Qualtrics. This tool generated a customizable link distributed via email to residents. The researcher reached the email address via Citizen Advisory Council (CAC) in Raleigh. The city of Raleigh has 19 CACs, each representing a different geographic region of the city. Each CAC elects its own officers and decides its own activities and priorities. All CAC meetings held once a month and open to everyone. Each CAC has a chairperson, co-vide chairperson/persons and secretary. The researcher emailed to each CAC members to ask if they distributed the survey link to the residents in their regions. Moreover, the researcher made presentations to introduce the survey in CAC’s monthly meetings. While some CAC members accepted to participate in, some did not. Overall, 232 surveys were ready to analyze.

4.6. Data Analysis Strategies

Several statistical analyses were employed in this study: descriptive statistics, factor analysis, bivariate correlation and regression. All statistical analyses were conducted with SPSS software program with an *a priori level* of significance of 0.05. Following sections provide a detailed information about the statistical methods used in this study.

4.6.1. Descriptive Statistics

Descriptive statistics offer a summary and basic description of the sample data through quantitative information. In descriptive statistical analysis, data are typically described in two ways. One involves measures of central tendency (mean, mode, median) and other is related to distribution or dispersion of scores (variance, range, standard deviation, percentages). In my study, mean values, standard deviations and percentages were calculated to summarize characteristics of our data. I also employed chi-square tests to examine relationships between willingness and the other variables.

4.6.2. Exploratory factor analysis (EFA)

Factor analysis is used to reduce a set of correlated variables into a smaller number of unrelated factors to describe the phenomenon of interest. In exploratory factor analysis (EFA), data is simply explored, and it provides information about the number of factors required to represent the data. All measured variables in exploratory factor analysis are related to the corresponding latent variable. Overall, the main goals of the factor analysis are: (i) to reduce the number of variables and (ii) to detect structure in the relationships between variables.

In this study, an exploratory factor analysis was conducted to test how well the measured variables represent the number of constructs. The main purpose here was to test whether the data fit a hypothesized measurement model (theory of planned behavior) and to assess the quality of individual items before establishing the internal consistency and reliability of scores (Cronbach's alpha).

4.6.3. Correlation and Regression Analysis

This part of the statistical analyses includes investigating bivariate correlations, building multiple regression models and running a hierarchical regression model as the final step. Bivariate correlation is a statistical technique that examines the existence of a relationship between two variables. This is used to determine whether the two variables are significantly correlated. This step is required to see what variables should be included in multiple regression models. As an analysis technique, regression can be followed by the correlation analysis. It helps researchers to assess the strength of relationship between variables and to predict the level of the dependent variable based on the behavior of independent variables.

Hierarchical regression can be roughly considered as a combination of different regression models at one step. This is another way to show if variables explain a statistically significant amount of variance in dependent variable after accounting for all other variables. Several regression models are built by adding variables to a previous model at each step. The main interest is to determine whether newly added variables show a significant improvement in R^2 (the proportion of total variation explained in the dependent variable).

In this study, we examined associations to understand whether the independent variables (attitudes, subjective norm, self-efficacy, knowledge, cost to install, cost to maintain, required time to maintain, visual appearance, health, demographics) and the dependent variable (willingness to implement) were associated. The variables that were found to be significantly correlated with stated willingness to implement were then included in regression analysis within their domain (generic variables, specific variables and demographics). The independent variables which were still significant in multiple regression models, were then added to a hierarchical

regression model. We reported the coefficients of determination (R^2) to investigate how much of the total variation in willingness were explained by the independent variables in each model. The regression coefficients were also interpreted.

4.7.Study Variables

The dependent variable for the study was "willingness to implement". However, since there were three types of green infrastructure strategies in the context of this study, three different models were created to measure participants' willingness to implement each type of green infrastructure. The dependent variables were, respectively, willingness to implement rain barrel, willingness to implement rain garden and willingness to implement porous pavement. Note that our models included the outcome (willingness) as a scale variable.

Independent variables (Table 4-1) can be categorized as: generic variables (produced based on the results of factor analysis), dependent variable-specific variables (measure specific knowledge on each green infrastructure strategy), and demographic variables.

Table 4-1. Study variables

Independent variables	Dependent variable (DV)
1. Generic variables - Theory of planned behavior measures (subjective norm, self-efficacy and attitude) - General knowledge - Past experience	***Willingness to implement*** (rain barrel, rain garden and porous pavement)
2. DV-specific variables - Specific knowledge - Other influencing factors (Cost to install, cost to maintain, required time to maintain, visual appearance the lack of adequate space, health concerns)	
3. Demographic variables - Gender, age, income, education level, income, home value, ethnicity, the years lived in Raleigh	

CHAPTER 5: ANALYSIS RESULTS

5.1. Descriptive Statistics

A total of 359 people responded to the survey. Of those, 127 did not complete the questionnaire properly; hence, both non-responses and incomplete responses were omitted to avoid inaccuracy. The demographic characteristics were investigated for the remaining 232 respondents. Many of the participants live in North Raleigh (25.9%), and in Five Points (25.9%), while 11.9% of the participants are from Glenwood. The remaining respondents live in Hillsborough (6.9%), Northwest Raleigh (6.9%), West Raleigh (6.5%), and other areas (16%) in Raleigh (see Figure 5-1).

Figure 5-1. Citizen Advisory Councils (CACs) map

More females (64.7%) than males (35.3%) in this study. The results indicated that 31.5% and 37.1 % of the participants were of working age (30-49) and late middle age (50-64), respectively. The youngest age group of 18-29 years made up the smallest proportion (0.4%) of the sample. It can be easily seen that people over the age of 50 contributed more (68.1%) to the study. One reason might be that individuals in late middle age and older age groups are more likely to answer the survey due to an increased interest in stormwater management practices. Another reason could be that older retired people have more time to fill out surveys compared to those in younger age groups. Our results for the age groups were in keeping with the results of Baptiste (2014) indicating that a large proportion of respondents within the higher age groups completed the survey. More than half of the total participants (52.6%) earned a professional degree and 38.8% of the participants graduated from a four-year program. There were 218 participants (94%) who identified themselves as White, whereas 1.7% were African-American/Black, 1.7% were Asian, and 2.6% of the respondents were from other ethnic groups. The demographics results show that majority of respondents (56.5%) reported that their household income was over $90,000 per year. About 31% of homeowners reported that the market value of their house was between $400K and $600K, while almost one-third of homeowners reported a market value either in range of $250,000 - $399,000, or more than $600K. In terms of length of residency, the largest group contained 77 participants (33.2%) who lived in Raleigh more than 20 years, while second largest group contained 51 individuals (22.0%) with a time period of 1-5 years for residency.

Table 5-1. Frequencies for the demographic variables

		Count (n)	Percentage (%)
Gender	Male	82	35.3
	Female	150	64.7
Age	18-29 years	1	0.4
	30-49 years	73	31.5
	50-64 years	86	37.1
	over 65 years	72	31.0
Education	Less than high school	0	0.0
	High school graduate	3	1.3
	Some college	13	5.6
	2-year	4	1.7
	4-year	90	38.8
	Professional	122	52.6
Income	< $30,000	8	3.4
	$30,000-$49,999	12	5.2
	$50,000-$69,999	27	11.6
	$70,000-$89,999	54	23.3
	> $90,000	131	56.5
Ethnicity	White	218	94.0
	Black or African American	4	1.7
	American Indian or Alaska Native	0	0.0
	Asian	4	1.7
	Native Hawaiian or Pacific Islander	0	0.0
	Other	6	2.6
Market value of the house	< $100,000	0	0.0
	$100,000-$249,999	23	9.9
	$250,000-$399,999	69	29.7
	$400,000-$600,000	71	30.6
	> $600,000	69	29.7
Length of residency (in years)	< 1	8	3.4
	1-5	51	22.0
	6-10	32	13.8
	11-15	43	18.5
	16-20	21	9.1
	> 20	77	33.2

5.2. Variables of the Study

5.2.1. Existing of Green Infrastructure

Participants were asked if they currently had rain barrels, rain gardens and/or porous pavement on their properties. When asked, 31.9% of the participants reported that they installed rain barrels, while 13.8% of those installed rain gardens and 11.6% of those installed porous pavements on their properties (Table 5-2). Only 2.6%, 3%, and 6.9% of the respondents indicated that previous owners installed rain barrels, rain gardens, and porous pavements, respectively.

Table 5-2. Frequencies for the green infrastructure strategies

		Count (n)	Percentage (%)
Rain barrel	Yes, I installed	74	31.9
	Yes, previous owner installed	6	2.6
	No	152	65.5
Rain garden	Yes, I installed	32	13.8
	Yes, previous owner installed	7	3.0
	No	193	83.2
Porous pavement	Yes, I installed	27	11.6
	Yes, previous owner installed	16	6.9
	No	189	81.5

5.2.2. Specific Knowledge of Green Infrastructure Strategies

Specific knowledge regarding the use of each type of green infrastructure was measured by six statements (two statements per GI technique) on a 0 to 1 scale, where 0=false and 1=true. The aggregate scores for specific knowledge were calculated and recoded into a binary variable, where 0 denoted a low level of knowledge and 1 denoted a high level of knowledge on GI techniques. The mean scores for knowledge on rain barrels, rain gardens, and porous pavements

were 0.96, 0.98, and 0.91, respectively. These results suggested that respondents were most knowledgeable about rain gardens as a stormwater control strategy, followed by rain barrels. They were less knowledgeable about porous pavements compared to the other two techniques. Overall, respondents were high knowledgeable about all green infrastructure strategies. Internal consistency was measured by Cronbach's Alpha of .68 for rain barrel, .197 for rain garden and .169 for porous pavement. Low reliability scores are usual in this kind of measure with only a few items.

5.2.3. Influencing Factors

The participants' thoughts for the barriers were determined by asking whether any of the following factors could influence their decision to implement GI: installation cost, maintenance cost, required time for maintenance, visual appearance, lack of adequate space, and health concern. This was measured on a five-point Likert scale, where 1=no influence, 3=don't know, and 5=great influence. Installation cost was the top barrier for all three green infrastructure practices (Table 5-3). Maintenance costs and time were consistently among the top three barriers. For rain barrels, health concerns (M=2.81) were also among the top three barriers. Likewise, for rain gardens, the highest mean score 3.34 indicated that installation cost had a medium-to-high level of influence on participants' decisions, which was followed by the factor of required time for maintenance (M=3.31). As in the other two GI techniques, installation cost (M=4.24, SD=1.07) was found to be the most influencing factor for implementing porous pavements. Maintenance cost (M=3.12) were also among the top three barriers to implement porous pavements. Participants reported that they believed potential health risk (M=1.98) of porous pavements had a low level of influence on their decision to implement. An internal consistency

was measured by Cronbach's Alpha .826 for rain barrel, Cronbach's Alpha of .726 for rain garden and Cronbach's Alpha of .746 for porous pavement.

Table 5-3. Descriptive statistics for perceived barriers to implement GI strategies (ranking from high influence barrier to low influence barrier)

		Mean	Standard deviation
Rain barrel	Cost to install	2.83	1.35
	Health concern	2.81	1.51
	Required time for maintenance	2.66	1.44
	Visual appearance	2.66	1.39
	Lack of adequate space	2.55	1.41
	Cost to maintain	2.42	1.41
Rain garden	Cost to install	3.34	1.32
	Required time for maintenance	3.31	1.33
	Cost to maintain	3.07	1.32
	Visual appearance	2.76	1.44
	Lack of adequate space	2.73	1.41
	Health concern	2.57	1.41
Porous pavement	Cost to install	4.24	1.07
	Cost to maintain	3.12	1.38
	Required time for maintenance	2.92	1.40
	Visual appearance	2.88	1.44
	Lack of adequate space	2.43	1.43
	Health concern	1.98	1.31

5.2.4. General Knowledge of Stormwater Control

General knowledge on stormwater control was assessed by six statements and on a 0 to 1 scale, where 0=false of and 1=true. The aggregate scores for knowledge on stormwater control were calculated and recoded into a binary variable, where 0=low level of knowledge and 1=high level of knowledge. Overall, the mean response for knowledge was 0.87 (SD=0.133) indicating that

the sample had a high level of knowledge about the negative effects of excessive stormwater runoff.

5.2.5. Willingness to Implement GI Strategies

Willingness to implement was only independent variable of this study for each model. It means that three different models were created for each type of green infrastructure. Respondents were asked to indicate their level of agreement or disagreement with the following statement: How likely would it be for you to install rain barrels, rain gardens and/or porous pavement on your property in the next 5 years? A 4-point Likert scale was used where 1= extremely unlikely, 2= somewhat unlikely, 3=somewhat likely, 4= extremely likely. The higher score, the more likely a respondent was willing to implement. I code the questions as different variable, for example, the likelihood an individual installs rain barrels are RB_likelihood, the likelihood an individual installs rain gardens are RG_likelihood and the likelihood an individual installs porous pavement is PP_likelihood. Based on the Table 5-4, respondents were more likely to install rain barrel and rain garden, compare to porous pavement.

Table 5-4. Frequencies for willingness to implement GI strategies

		Count (n)	Percentage (%)
Rain barrel	1=extremely unlikely	32	13.8
	2=somewhat unlikely	58	25
	3=somewhat likely	93	40.1
	4=extremely likely	49	21.1
Rain garden	1=extremely unlikely	34	14.7
	2=somewhat unlikely	57	24.6
	3=somewhat likely	109	47.0
	4=somewhat likely	32	13.8
Porous pavement	1=extremely unlikely	81	34.9
	2=somewhat unlikely	73	31.5
	3=somewhat likely	62	26.7
	4=extremely likely	16	6.9

5.3. Factor Analysis: Developing a New Scale for the Theory of Planned Behavior Measures

Studies related to theory of planned behavior were examined and some of the questionnaire questions were adapted from those studies (Sinasas, 2017; Gadijaru, 2016; Turner, 2015). The questions were modified based on the purpose of our study. Other questions were created by the researcher after reviewing related literature. Since this measure involved the creation of new multi-item scale, a series of psychometric scale development steps were undertaken to confirm the structure and internal consistency of these measures. These steps included: examining the characteristics of individual items; subjecting the items to exploratory factor analysis to create scales or subscales; evaluation of the scales based on internal consistency analysis. The exploratory factor analysis was conducted on the following survey items to identify attributes of theory of planned behavior.

The participants' responses were measured on a 4-point Likert scale, where 1= strongly disagree, 2= somewhat disagree, 3=somewhat agree, and 4= strongly agree. Note that the items 10 and 11 were reverse coded. The first step was to check whether the sample size was adequate to reliably extract factors before conducting EFA. The Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) was 0.715, which indicated that the sample size was large enough to identify factors. The second step was to look at the correlation structure between these variables. As can be seen in Table, most items were correlated with each other, ranging from r=-0.133 to r=0.604. This indicated that the inter-correlated items could be split into underlying factors. The Bartlett's sphericity test results (X^2=610.96, p=0.000) also showed that the correlation coefficients between the items were significantly different from zero meaning that the factor analysis was an appropriate approach.

Table 5-5. Theory of planned behavior measures items

Item 1	If my neighbors were to install Green Infrastructure on their property, I would be more likely to install it on my property.
Item 2	When considering whether to install Green Infrastructure, I consider what my friends may be thinking.
Item 3	If the people in my life whose opinions I value agreed that I should install Green Infrastructure on my property, I would be more likely to install.
Item 4	I am confident that I could learn the skills required to install or maintain GI on my property.
Item 5	I feel that I could decrease the level of pollution entering local water bodies through the implementation of green infrastructure on my property.
Item 6	I feel that the expense related to maintaining Green Infrastructure on my property would not be a burden.
Item 7	I feel that the amount of time required to maintaining Green Infrastructure on my property would not be a burden.
Item 8	I support the adoption/implementation of green infrastructure on my property.
Item 9	I believe that green infrastructure strategies are easy to learn and implement.
Item 10	I believe that installing Green Infrastructure on my property would not reduce the amount of polluted runoff going into local streams and rivers.
Item 11	I believe that green infrastructure at the resident level does not help improve the quality of water bodies.

Table 5-6. Correlation Matrix

	1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***
Item 1	1										
Item 2	**.38**	1									
Item 3	**.54**	**.39**	1								
Item 4	.06	.03	-.06	1							
Item 5	**.22**	.11	.09	**.19**	1						
Item 6	**.14**	-.01	.12	**.28**	**.21**	1					
Item 7	.03	-0.2	-.04	**.33**	**.23**	**.60**	1				
Item 8	.22	-.07	.05	.19	**.37**	**.37**	.37	1			
Item 9	.03	-.07	.02	**.48**	**.25**	**.40**	**.47**	**.46**	1		
Item 10	.00	**-.17**	**-.12**	-.08	**.23**	.06	.05	**.18**	.02	1	
Item 11	-.08	**-.26**	-.13	.05	.20	.15	.09	**.27**	**.15**	**.41**	1

After checking prerequisites for the analysis, EFA was conducted on these items using principal component analysis extraction and Varimax rotation. Table 5-7 shows the eigenvalues associated with factors and the total variance explained by each factor. The factors were extracted by using the cut-off criterion that eigenvalues were greater than 1. In this case, there were three eigenvalues accounted for 58.6% of the variability. Factor 1 explained 26.5% of total variance, Factor 2 explained 18.7% of the variance, and Factor 3 explained 13.4% of the variance.

Table 5-7. Eigenvalues and total variance explained

	Eigenvalues		
Factors	Total	% of Variance	Cumulative %
1	2.919	26.540	26.540
2	2.052	18.657	45.196
3	1.479	13.448	58.645

The optimal number of the factors was also confirmed by graphing the total variance explained against the factor number. The scree plot in Figure 5-2, displays the number of eigenvalues that are greater than 1. The factors at the elbow joint and below were eliminated. Only the first three factors were retained in the study.

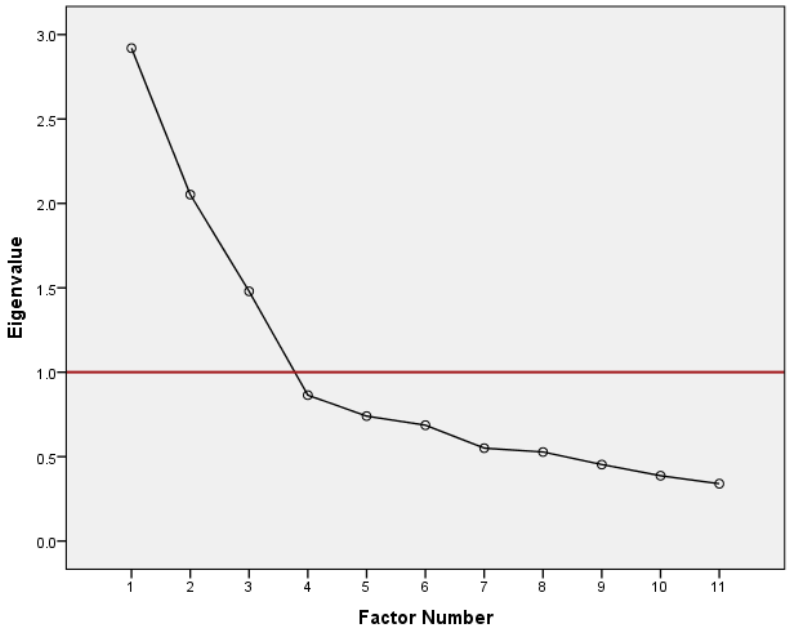


Figure 5-2. Scree Plot

The rotated component matrix reports factor loadings for each variable onto each factor. In other words, each number in this matrix represents the correlations between the item and the corresponding factor (i.e., the correlation between Item 1 and Factor 2 is 0.834). The reason that the matrix did not contain all loadings was, because factor loadings less than 0.4 were considered as low correlation values and suppressed to make interpretation easier.

Based on a series of psychometric analysis steps above, these questions were organized into three subscales: self-efficacy, subjective norms, and attitudes. There were five items (4, 6, 7, 8, 9) that loaded highly on Factor 1. This factor measured an individual's perceived ability to install and maintain green infrastructure on his/her property and was labeled self-efficacy. Three items (1, 2, 3) that loaded strongly onto Factor 2 were all related to an individual's perceived social pressure or acceptance of implementing green infrastructure in his/her property; hence, Factor 2 was labeled as "subjective norm". Three items (5, 10, 11) loaded onto Factor 3 were related to an

individual's attitude toward effectiveness of green infrastructure strategies; therefore, Factor 3 was labeled as "attitudes".

Table 5-8. Rotated component matrix

	Component		
	1	**2**	**3**
Item 1. If my neighbors were to install Green Infrastructure on their property, I would be more likely to install it on my property.		.834	
Item 2. When considering whether to install Green Infrastructure, I consider what my friends may be thinking.		.686	
Item 3. If the people in my life whose opinions I value agreed that I should install Green Infrastructure on my property, I would be more likely to install.		.801	
Item 4. I am confident that I could learn the skills required to install or maintain GI on my property	.687		
Item 5. I feel that I could decrease the level of pollution entering local water bodies through the implementation of green infrastructure on my property			.495
Item 6. I feel that the expense related to maintaining Green Infrastructure on my property would not be a burden.	.713		
Item 7. I feel that the amount of time required to maintaining Green Infrastructure on my property would not be a burden.	.781		
Item 8. I support the adoption/implementation of green infrastructure on my property.	.547		.477
Item 9. I believe that green infrastructure strategies are easy to learn and implement.	.786		
Item 10. I believe that installing Green Infrastructure on my property would not reduce the amount of polluted runoff going into local streams and rivers.			.790
Item 11. I believe that green infrastructure at the resident level does not help improve the quality of water bodies.			.735

Finally, Cronbach's alpha reliability coefficient was computed for each factor to examine internal consistency of the items. For our data, Cronbach's alpha coefficient was 0.77 for Factor 1 (self-efficacy) and 0.70 for Factor 2 (subjective norm). Both values presented a good level of internal consistency. Furthermore, item-total correlations ranged from 0.42 to 0.63 for the self-

efficacy latent variable and ranged from 0.44 to 0.56 for the subjective norm variable, meaning that the items were coherent and measured the same construct.

However, for Factor 3 (attitudes), Cronbach's alpha was 0.54, indicating a low level of reliability. The item-total correlation results show that, except for Item 5, the correlations ranged from 40% to 42% in this scale. Item 5 had a correlation coefficient of 0.26, which was less than 0.30. This item was problematic. Additionally, the last column (Cronbach's alpha if item deleted) in Table 5-9 gave us the revised Cronbach's alpha coefficients if we removed each item from the survey. If Item 5 was deleted, the reliability score would go up to 0.57. Even though this score was still low, removing Item 5 would make the questionnaire more reliable. Hence, Item 5 was deleted based on item-total correlation results. Factor 3 (attitudes) contained only two items for the rest of the analysis.

Table 5-9. Item-total statistics

	Corrected item-total correlation	Cronbach's alpha if item deleted
Item 1	.560	.556
Item 2	.436	.704
Item 3	.562	.551
Item 4	.416	.762
Item 5	.260	.574
Item 6	.574	.711
Item 7	.629	.687
Item 8	.459	.748
Item 9	.620	.697
Item 10	.419	.335
Item 11	.407	.368

The results in the table below indicated that participants, on average, had high positive attitudes (M=3.40) toward effectiveness of green infrastructure and high self-efficacy score (M=3.16). Contrast to these results, they had low mean score (M=2.00) for subjective norm. It means that the participants would not take into consideration others' opinions about green infrastructure.

Table 5-10. Mean values and standard deviations for TPB variables

	Self-efficacy	Subjective norm	Attitudes
Mean	3.16	2.00	3.40
Standard deviation	.49	.70	.63

5.4. Results for Correlation and Regression Analysis

The analysis strategy used in this study is called "trimming strategy". In this strategy, variables were eliminated before putting them into a final regression model**.** The elimination was done via bivariate correlation and multiple regression analyses. Overall, this strategy was used to increase the power of the final model. The following steps were applied to answer the research questions and hypotheses:

Step 1 (simple bivariate correlation): testing all relevant predictors for simple bivariate relationships,

Step 2 (multiple regression): testing the independent variables that were found to be significant in Step 1 within their variable domains (demographics, generic variables, specific variables),

Step 3 (final full regression): any predictor that was still significant at the domain level would be tested in one final full regression. This strategy was employed to the each of green infrastructure types: rain garden, rain barrel and porous pavement.

5.4.1. Rain Barrel

The correlation between willingness to implement rain barrels and gender was 0.12 (p=0.047), indicating that there was a weak positive relationship between the variables (Table 5-11). This

means that females were more likely to implement rain barrels compared to males. Required time to maintain (r=-0.167, p=0.002), visual appearance (r=-0.209, p=0.000), lack of adequate space (r=-0.143, p=0.009), health concerns (r=-0.184, p=0.001) and existence of rain barrels (r=-0.218, p=0.000) were negatively correlated with respondents' willingness. The p-values for the correlation between willingness and the other independent variables were all more than the significance level of 0.05, indicating that correlation coefficients were not significant. Based on these results, we concluded that the residents who already had rain barrel on their properties were less willing to implement rain barrels. Additionally, the participants who believed that implementation of rain barrels had potential risks for health and, also it could require a certain amount time were less willing to implement.

Next, multiple regression analysis was run to predict willingness to implement rain barrels. The variables, which were found significant in the correlation analysis, were tested within their domain variables (generic variables, DV-specific variables and demographic variables). Since there was just one significant variable (gender) from the set of demographic variables, it was directly added to the final full model. Multiple regression analysis was run for the required time to maintain, visual appearance, lack of adequate space, health concern and existing rain barrels.

Table 5-11. The relationship between independent variables and willingness to implement rain barrels

Variables	Correlation Coefficient (r)	p-value
Gender	0.120	0.047*
Age	-0.092	0.107
Education	0.078	0.182
Income	-0.045	0.431
Market value of house	-0.102	0.068
Length of residency	-0.032	0.557
Cost to install	-0.013	0.812
Cost to maintain	-0.042	0.447
Required time to maintain	-0.167	0.002*
Visual appearance	-0.209	0.000*
Lack of adequate space	-0.143	0.009*
Health concern	-0.184	0.001*
General knowledge	-0.067	0.269
Specific knowledge	-0.043	0.477
Existing rain barrels	-0.218	0.000*

*p < .05. **p < .05

Table 5-12. Multiple regression for DV-specific variables (rain barrels)

	β	***Std. Error***	***p-value***
(Constant)	3.641	0.197	0.000*
Required time to maintain	-0.039	0.050	0.429
Visual appearance	-0.117	0.055	0.034*
Lack of adequate space	.0.007	0.054	0.900
Health concern	-0.047	0.051	0.356
Existing rain barrels	-0.182	0.068	0.008*
Adjusted R^2	.09		
F-statistic for the model	5.661		
p-value of F statistic	0.000*		

*p < .05. **p < .01.

According to the results given in Table 5-12, visual appearance (β=-0.117, p=0.034) and existing rain barrels (β=-0.182, p=0.008) were significant variables to predict respondents' willingness to implement rain barrels. Afterwards, we applied a hierarchical multiple regression analysis. The variables were included in the regression model in an order by the theoretical framework of this

study. The first block contained the gender variable. The second block contained the significant DV-specific variables, visual appearance and existing rain barrels. The third block included the generic variables, self-efficacy, subjective norm and attitudes.

The results are summarized in Table 5-13. In the final full model, the effect of visual appearance (β=-0.141, p=0.001) was significant and its coefficient was negative indicating that the higher levels of concern about the visual appearance of rain barrels were related to decreasing willingness to implement. Existing rain barrels (β=-0.208, p=0.002) had a significant effect on participants' willingness to implement rain barrels. The direction of the relationship was negative, meaning that the participants' who already had rain barrels installed on their properties were less willing to implement a rain barrel. Self-efficacy (β=0.131, p=0.029) had a positive relationship with willingness. Thus, the higher levels of ability to succeed in installing and maintaining rain barrels were associated with higher levels of willingness. Next, subjective norm (β=0.060, p=0.011) was found a significant variable to predict willingness to implement rain barrels. It means that residents who felt social pressure from others show more willingness to implement green infrastructure. We also concluded that about 14% of total variation in willingness were explained by the model.

Table 5-13. Hierarchical regression for rain barrel

	Block 1			***Block 2***			***Block 3***		
	β	***Std. Error***	***p***	***β***	***Std. Error***	***p***	***β***	***Std. Error***	***p***
(Constant)	2.244	0.224	0.000*	3.177	0.285	0.000*	3.149	0.285	0.000*
Gender	0.268	0.131	0.042*	0.229	0.125	0.068	0.241	0.126	0.057
Visual appearance				-0.149	0.044	0.001*	-0.141	0.043	0.001*
Existing rain barrels				-0.202	0.065	0.002*	-0.208	0.066	0.002*
Self-efficacy							0.131	0.060	0.029*
Subjective norm							0.153	0.060	0.011*
Attitudes							0.020	0.061	0.741
Adjusted R^2	0.014			0.105			0.138		
F-statistic for the model	4.200			9.989			7.188		
p-value of F statistic	0.042 *			0.000*			0.000*		

5.4.2. Rain Garden

As shown in Table 5-14, there were weak but significant relationships between willingness to implement rain gardens and installation cost (r=-0.163, p=0.003), maintenance cost (r=-0.242, p=0.000), required time to maintain (r=-0.284, p=0.000), lack of adequate space (r=-0.124, p=0.023) and existence of rain barrels (r=-0.241, p=0.000). The direction of these relationships was negative. We observed the respondents who believed that installation and maintenance cost were high showed less willingness to implement rain gardens on their properties. Moreover, as the respondents' space concern was increased, they felt less willing to implement rain gardens. The residents who already had rain gardens installed were less willing to implement rain gardens. On the other hand, neither the socio-demographic variables nor visual appearance, health concerns, and knowledge had had influence on residents' willingness.

Table 5-14. The relationship between independent variables and willingness to implement rain gardens

Variables	Correlation Coefficient (r)	p-value
Gender	0.117	0.055
Age	-0.015	0.799
Education	-0.048	0.413
Income	-0.110	0.055
Market value of house	-0.078	0.168
Length of residency	-0.041	0.453
Cost to install	-0.163	0.003*
Cost to maintain	-0.242	0.000*
Required time to maintain	-0.284	0.000*
Visual appearance	-0.067	0.223
Lack of adequate space	-0.124	0.023*
Health concern	-0.060	0.277
General knowledge	0.023	0.703
Specific knowledge	0.001	0.989
Existing rain gardens	-0.241	0.000*

*p < .05. **p < .01.

The variables, installation cost, maintenance cost, required time to maintain, lack of adequate space, and existing rain gardens were than included in a regression model to predict willingness. Based on the results shown in Table 5-15, required time to maintain (β=-0.178, p=0.005) and existing rain gardens (β=-0.216, p=0.011) were significant variables to predict respondents' willingness to implement rain gardens. In the hierarchical regression model, the first block contained required time to maintain and existing rain gardens as independent variables. The second block contained the generic variables, self-efficacy, subjective norm and attitudes.

The results are summarized in Table 5-16. The effect of required time to maintain (β=-0.156, p=0.001) was significant and its coefficient was negative indicating that, as the respondents believed implementation would require more time, they showed less willingness to implement

rain gardens. Existing rain gardens (β=-0.188, p=0.022) had a significant effect on participants' willingness to implement rain gardens. The direction of the relationship was negative, meaning that the participants' who already had rain garden installed on their properties were less willing to implement another one. Self-efficacy (β=0.143, p=0.016) was positively associated with willingness. Thus, the higher levels of ability to succeed in installing and maintaining rain gardens were associated with higher levels of willingness. We also observed that about 18% of total variation in willingness were explained by the model.

Table 5-15. Multiple regression for DV-specific variables (rain gardens)

	β	***Std. Error***	***p-value***
(Constant)	3.856	0.246	0.000*
Cost to install	0.025	0.062	0.683
Cost to maintain	-0.036	0.079	0.647
Required time to maintain	-0.178	0.064	0.005*
Lack of adequate space	-0.021	0.042	0.615
Existing rain gardens	-0.216	0.085	0.011*
Adjusted R^2	0.144		
F-statistic for the model	7.594		
p-value of F statistic	0.000*		

*p < .05. **p < .01.

Table 5-16. Hierarchical regression for rain garden

	Block 1			***Block 2***		
	β	***Std. Error***	***p***	***β***	***Std. Error***	***p***
(Constant)	3.838	0.234	0.000*	3.621	0.246	0.000*
Required time to maintain	-0.200	0.043	0.000*	-0.156	0.046	0.001*
Existing rain gardens	-0.214	0.082	0.010*	-0.188	0.082	0.022*
Self-efficacy				0.143	0.065	0.016*
Subjective norm				0.105	0.054	0.055
Attitudes				0.083	0.056	0.139
Adjusted R^2	0.142			0.184		
F-statistic for the model	18.922			10.167		
p-value of F statistic	0.000*			0.000*		

*p < .05. **p < .01.

5.4.3. Porous Pavement

The results in Table 5-17 shows that the correlation coefficient of 0.128 (p=0.035) indicated there was a weak positive relationship between willingness to implement porous pavements and gender. This means that females were more likely to implement porous pavements than males. Installation cost (r=-0.124, p=0.031), maintenance cost (r=-0.133, p=0.015), required time to maintain (r=-0.112, p=0.041), and existence of porous pavements (r=-0.201, p=0.001) were negatively correlated with participants' willingness. This suggests that respondents showed less willingness as they thought installation and maintenance of porous pavements required time and budget. Additionally, participants who had a high level of knowledge about stormwater control felt less willing to implement porous pavements.

Table 5-17. The relationship between independent variables and willingness to implement porous pavements

Variables	Correlation Coefficient (r)	p-value
Gender	0.128	0.035*
Age	-0.038	0.508
Education	0.027	0.644
Income	-0.017	0.771
Market value of house	0.024	0.672
Length of residency	0.010	0.855
Cost to install	-0.124	0.031*
Cost to maintain	-0.133	0.015*
Required time to maintain	-0.112	0.041*
Visual appearance	-0.088	0.108
Lack of adequate space	-0.093	0.092
Health concern	-0.048	0.396
General knowledge	-0.136	0.026
Specific knowledge	0.002	0.975
Existing rain gardens	-0.201	0.001*

*p < .05. **p < .01.

The variables, installation cost, maintenance cost, required time to maintain, and existing porous pavements were than included in a regression model to predict willingness. Based on the results

shown in Table 5-18, only existing porous pavements (β=-0.282, p=0.002) was significant to predict respondents' willingness to implement rain gardens. In the hierarchical regression model, the first block contained the gender variable. The second block included existing porous pavements. The third block contained the generic variables, self-efficacy, subjective norm and attitudes, along with general knowledge on stormwater control.

Table 5-18. Multiple regression for DV-specific variables (porous pavements)

	β	***Std. Error***	***p-value***
(Constant)	3.182	0.339	0.000*
Cost to install	-0.020	0.061	0.747
Cost to maintain	-0.069	0.073	0.348
Required time to maintain	-0.023	0.071	0.748
Existing porous pavements	-0.282	0.092	0.002*
Adjusted R^2	0.061		
F-statistic for the model	3.710		
p-value of F statistic	0.000*		

*p < .05. **p < .01.

Table 5-19. Hierarchical regression for porous pavement

	Block 1			***Block 2***			***Block 3***		
	β	***Std. Error***	***p***	***β***	***Std. Error***	***p***	***β***	***Std. Error***	***p***
(Constant)	1.603	0.221	0.000*	2.399	0.335	0.000*	3.366	0.509	0.000*
Gender	0.275	0.129	0.034*	0.255	0.127	0.045*	0.250	0.128	0.052
Existing porous pavements				-0.283	0.091	0.002*	-0.245	0.091	0.007*
General knowledge							-0.553	0.214	0.010*
Self-efficacy							0.090	0.060	0.136
Subjective norm							0.094	0.060	0.115
Attitudes							0.104	0.062	0.094
Adjusted R^2	0.019			0.060			0.114		
F-statistic for the model	4.569			7.223			4.841		
p-value of F statistic	0.034*			0.001*			0.000*		

*p < .05. **p < .01.

The results are summarized in Table 5-19. Existing porous pavements (β=-0.245, p=0.007) had a significant effect on participants' willingness and its coefficient was negative indicating that the participants' who already had porous pavement installed on their properties were less willing to implement another one. General knowledge on stormwater control (β=-0.553, p=0.010) was negatively associated with willingness. Thus, the higher level of knowledge was related to lower willingness to implement porous pavements. We also observed that about 11% of total variation in willingness were explained by the model.

CHAPTER 6: DISCUSSION

This chapter summarizes the results and discusses how they support or differ from the theoretical positions and relevant literature findings. Moreover, a summary of limitations and strengths that are related to sampling, methodology and analysis are discussed and suggestions for future research studies are provided.

6.1. Summary of Major Findings

Hypotheses that were formulated to answer research questions were tested for each type of green infrastructure strategy. Overall, Table 6-1 shows the hypotheses that were supported or not supported based on the results of final full regression model.

In the Table 6.1, the + symbol indicates positive association between variables and willingness to implement and similarly the - symbol indicates negative association. The following section discusses in detail how the results are supported by or differ from relevant literature findings.

Table 6.1. Hypotheses that were not supported or were partially supported (+: positive association, -: negative association)

Hypotheses not supported	Hypotheses partially supported
• Attitudes • Specific green infrastructure knowledge • Installation cost • Maintenance cost • Health concern • Lack of space • Demographics	For rain barrel: • Subjective norm + • Self-efficacy + • Visual appearance - • Past experience - For rain garden: • Self-efficacy + • Required time to maintain - • Past experience - For porous pavement: • General knowledge - • Past experience -

6.2. Hypothesis Discussion

The results suggest that attitudes were not a significant predictor of willingness to implement green infrastructure strategies. In the current study, attitudes were defined as a person's beliefs about the consequences that result from the performance of a behavior and the person's affective response to those consequences (Ajzen, 1991). The theory of planned behavior (TPB) proposes that a person's intention to perform a behavior will increase as his or her attitudes toward a behavior become more favorable. I used attitude in an attempt to estimate intentional behavior. Models of environmental attitude and behavior in academic literature indicate that attitude is a contributing variable to actual behavior (Guagnano et al. 1995; Fransson and Gärling 1999; Rauwald and Moore 2002). Therefore, based on the resulting high attitude scores, I estimate moderately high levels of green infrastructure implementation.

The results related to attitudes in this study support Sinasac (2016)'s study, which indicates that attitude (beliefs about the impacts of green infrastructure) had no effect on residents' overall intention to install green infrastructure on their properties. In other words, participants' beliefs about the efficacy of green infrastructure (such as reduced pollution and/or reduced flooding), did not affect their willingness to install green infrastructure.

On the other hand, my results contradict with Turner (2015)'s study, which examines the West Creek Ecosystem Restoration Project in Parma, Ohio, a suburb of Cleveland. That project implemented a green infrastructure demonstration site for a new regional stormwater management program, and residents were offered free installation of green infrastructure (such as rain gardens, right-of-way bioretention, and rain barrels) on their property. Overall, Turner's study suggests that attitudes most strongly influenced residents' participation. The difference

between my findings and other research on attitudes towards GI could be a result of 1) the different measures used, or 2) location of the study, or 3) the low variance between survey participants. It is important to note that the measures used in other studies of environmental attitudes are often different from the multidimensional attitude measure towards a specific environmental action (such as GI implementation). Another reason might be that green infrastructure strategies were provided free to the residents in Turner's study area in the context of the West Creek Ecosystem Restoration Project. Therefore, residents' free access to green infrastructure may positively affect their attitudes toward green infrastructure and, in turn, their willingness to implement. In the current study area, the City of Raleigh also provides reimbursements to the residents who want to install green infrastructure, but residents must pay the installation cost. Moreover, residents must agree with the city to be responsible for taking care of the green infrastructure. Therefore, although residents have highly positive attitudes toward green infrastructure, they still may be concerned about cost, maintenance, and other factors. Finally, non-significant results might be caused by the low variance between survey participants; participants' responses on attitude scale were strongly skewed, with a high mean score (M=3.40). The effect of attitudes on behavioral intention might be more evident if there were high variance between respondents.

The subjective norm in this study, which relates to how much pressure the resident feels to perform the behavior, was a significant predictor for installation of rain barrels. According to Theory of Planned Behavior, attitude, subjective norms, and perceived behavioral control influence behavioral intention, which in turn influences behavior. This idea has been supported by studies like recycling behavior (Boldero, 1995; Chan, 1998; Cheung et al., 1999; Davies et al.,2002, Tonglet et al., 2004; Davies et al., 2005; Taylor & Todd, 1995; Terry et al., 1999; Wan

et al., 2012). Sinasas (2016)'s study of green infrastructure also suggests that subjective norms play a significant role in residents' intention to install green infrastructure. The difference between the results of Sinasac (2016)'s study and the current study may be caused by the fact that Sinasac's study focused on "green infrastructure" as a whole rather than on specific types of green infrastructure. In the current study, three different types of green infrastructure were defined, and willingness to implement each was measured separately. For rain gardens, the subjective norm was marginally significant (p=.055). It is possible that the relationship between subjective norm and willingness might become more robust with a larger sample size.

Another measure of the Theory of Planed Behavior is perceived behavioral control, which was also discussed as an independent variable in the current study**.** Perceived behavioral control (PBC) concerns individuals' own judgment about their capabilities to engage in a particular behavior (Ajzen, 1991). In the current study, perceived behavioral control is named as self-efficacy. Self-efficacy was found to be a significant predictor of willingness to implement rain barrels and rain gardens, but not for implementing porous pavement. These results support some studies (Moan and Rise, 2011; Mullan et al.'s, 2013), which indicated that perceived behavioral control was the strongest predictor of intention. This result is also similar to the study of Baptiste et. al (2012)'s study, which suggests that self-efficacy is one of the key factors affecting residents' willingness to implement green infrastructure.

On the other hand, studies in different fields suggest that perceived behavioral control is a weak indicator of intention. Wauters et al. (2010) studies adoption of soil conversation practices and found that perceived behavioral control did not contribute to behavior. Nigbur et al.'s (2010) also

used of the TPB to predict recycling and provided similar results to Wauters et al.'s (2010), with a poor predictive effect of perceived behavioral control on intention and behavior. It can be expected the using TPB yields different results for different fields of research, because individuals are motivated by different factors when making decisions based on safety, health, or environmental conservation. In the green infrastructure field, there are also different results regarding the effectiveness of self-efficacy on the installation. This may be caused by using different scales to measure self-efficacy.

Knowledge was also discussed as an independent variable to predict willingness to implement green infrastructure. Hines et. al. (2013) states that "the positive correlation coefficient indicates that those individuals with greater knowledge of environmental issues and/or knowledge of how to take action on those issues were more likely to have reported engaging in responsible environmental behaviors than were those who did not possess this knowledge" (p. 2). In the current study, general stormwater knowledge was not a predictor of willingness to implement green infrastructure, except for porous pavement. But there was a negative association, which means that a higher level of knowledge was related to lower willingness to implement porous pavements. However, there was no significant association between general stormwater knowledge and willingness to implement rain barrels and rain gardens. The results for rain barrel and rain garden align with the Turner (2015) and Heimlich and Ardoin (2008) studies, which revealed that educational activities do not necessarily motivate the participation in green infrastructure projects. However, the results of the current study conflict with other studies in green infrastructure field.

When we look more closely at scales used to measure the level of knowledge in other studies, those scales may not be effective for making conclusions that participants have high or low knowledge. Foley's (2012) study suggested that residents' knowledge about the problem was a significant positive contributor to an individual's self-reported behavioral intention to implement green infrastructure. However, in Foley (2012)'s study, the level of knowledge was measured with just two statements: (1) "There already exist enough ways to handle storm water run-off in Syracuse" and (2) "There are many things that I can do to help minimize storm water run-off". These statements may not directly measure the level of knowledge. The first statement measures residents' "awareness" of the stormwater management problem in Syracuse, and the second statement measures their perceived ability to deal with this problem. Baptiste et. al. (2014)'s study used the same scale to measure the level of knowledge and found that knowledge does influence implementation. Baptiste et. al. (2014) used the second statement to measure personal efficacy, not to measure the level of knowledge. In this case, level of knowledge about stormwater management was measured with just one statement in Baptiste et. al.'s study ("There already exist enough ways to handle storm water run-off in Syracuse").

Moreover, specific knowledge about green infrastructure strategies was not a predictor of willingness to implement in this study. It was not significant for each type of green infrastructure (rain garden, rain barrel and porous pavement). This result also conflicted with other studies in the field of green infrastructure. Foley (2012) also measured the specific green infrastructure knowledge and found that it is a significant predictor of implementation. However, Foley (2012) measured the knowledge by using just one statement for each type of green infrastructure: "Rain barrels will help to reduce storm water run-off/ Rain gardens will help to reduce storm water run

off". However, these statements may not directly measure the specific knowledge for each type of green infrastructure. Overall, the difference in results between the current study and the other studies in green infrastructure field may be caused by the use of different scales to measure the level of knowledge.

The literature has suggested that engaging in a certain behavior will increase the likelihood of repeating the same kind of behavior in the future. In this study, existing green infrastructure was a predictor of willingness to implement further green infrastructure. However, compared to other studies, there was a negative association. Residents who already had green infrastructure on their properties showed less willingness to implement additional green infrastructure. This might be caused by the possibility that (1) residents had a bad prior experience so they did not want to install more or (2) they might think that one green infrastructure element is enough or (3) they might not have enough space for another element. Further investigation is required to make a clear conclusion.

In addition to socio-cognitive factors related to willingness to implement, other influencing factors were also investigated. Visual appearance was a possible barrier that could limit a resident's willingness to implement green infrastructure. Studies in the literature suggest that people show more willingness to implement landscapes that have high "aesthetic" value (Apostalaki et al. 2006; Bryne et al. 2015; Baptiste, 2014). The current study indicates that visual appearance is not a predictor of implementing a rain garden or porous pavement, but that is a predictor of implementing a rain barrel. The reason why visual appearance of a rain barrel was important might be that participants mostly like the appearance of a rain garden or porous

pavement compared to a rain barrel. Because of that, the visual appearance of porous pavement and rain garden may not influence that participants' decisions to implement those strategies.

These results for rain garden and porous pavement conflicts with other studies in green infrastructure field. Baptiste et. al. (2014)'s study revealed that aesthetic appeal played an important role in implementing green infrastructure. In that study, statements like "Rain gardens add beautification to property" were used to measure participants' aesthetics evaluation. However, there were no statements related to rain barrel even though rain barrel was in the concept of the study. At the end of the study, aesthetics was found a predictor of willingness to implement green infrastructure. However, specific types of green infrastructure were not evaluated separately. Overall, it could be said that different aesthetic scales were used in studies, and this may explain the difference between my study and other studies in the green infrastructure field.

Another reason for the difference in studies may be because of the pictures used to introduce green infrastructure strategies. Some of the participants may evaluate aesthetics on the basis of those pictures. The background of the picture, color, or other factors may influence participants' aesthetic evaluation for the same green infrastructure types. For example, there are different types of rain garden. Some are more planted with colorful flowers and some look plain. If the researcher picks a rain garden picture with more colorful flowers, participants may be more likely to think that a rain garden can beautify their garden.

Installation cost was discussed as another barrier to the implementation of green infrastructure. Because previous research has identified cost as a major barrier to green infrastructure implementation (Anderson et al. 2009; LaBadie 2010; Barnhill and Smardon 2012), the researcher had expected "cost" to have a high influence on implementation. Contrary to expectations, installation cost was not a significant predictor of willingness to implement any of the three types of green infrastructure in the current study.

Barnhill and Smardon (2012) found through focus group research in Syracuse, NY, that respondents identified "up-front individual costs" as a dominant barrier to their decision to implement GI around their home. Mayer et. al. (2012) found that an economic incentive greatly increased the percentage of residents installing rain gardens and rain barrels on their property. The difference in results between the current study and the other studies in green infrastructure field may be because (1) respondents in the current study have high income, so they do not consider cost as a barrier or (2) the city of Raleigh provided reimbursement (75-90%) to the residents, and most of the participants may know about this campaign. However, for porous pavement, although the cost to install has a high score (mean=4.26), it was not significant in the model. A possible reason for this nonsignificant result might be that residents' responses were strongly skewed, with a high mean score. In other words, there was less variance among residents in term of "cost to install" porous pavement.

In the current study, cost was investigated under two topics: installation cost and maintenance cost. Most studies in the literature have focused on the installation cost, and maintenance cost has been ignored. Since "cost" has been identified a barrier to the implementation in those

studies, I expected “maintenance cost” would also be a barrier to the installation. However, in the current study, maintenance cost was not significant for any of the three types of green infrastructure. The results support Foley (2012)'s study, which indicated that “maintenance cost” did not influence a respondent’s decision to implement green infrastructure. The reason why maintenance cost was not a significant predictor in the current study might be that (1) respondents in the current study have high income, so they do not consider cost as a barrier or (2) participants may think that Raleigh’s rainwater reward program offsets the maintenance cost.

In the current study, required maintenance time was a significant predictor only for rain garden; it was not significant for rain barrel and porous pavement. The result for rain garden supports the Baptiste (2014, 2015), which suggest that participants view the required time for maintenance as a potential barrier to the installation of green infrastructure on their properties. On the other hand, Sinasac (2017) and Mayer et. al. (2012) found that available time is not a barrier to the installation of green infrastructure on residential properties. The difference in the literature may be a result of the employment status of the participants. The surveys mostly ask if they perceive “required time” as a barrier, but do not ask about their employment status (working or retired). Residents who are still in the work force may have less time to maintain a green infrastructure option and show less willingness to implement green infrastructure. In the current study, the participants perceived “required time to maintain” as a barrier to the implementation for rain garden but not for porous pavement and rain barrel. Participants may think that taking care of porous pavement will require a professional help so they may not need to spend time, and they may think that rain barrels would not require maintenance very often.

Moreover, health concerns related to green infrastructure have been defined as a barrier to the implementation of green infrastructure strategies (Traver, 2009; Hammit, 2014; Foley, 2012). In the current study, health concerns were not a predictor of installing green infrastructure. This result supports Baptiste (2014)'s study, which indicated that health concerns with green infrastructure strategies had no influence on their implementation. No significant association was found between lack of space and the willingness to implement, so the hypothesis was not supported. The reason why it was not a significant predictor may be that participants (53.4%) of the survey reside in high value houses (over $400,000), so they may have enough space.

Finally, sociodemographic factors have been discussed as a potential barrier to the implementation of green infrastructure strategies. Many studies state that sociodemographic characteristics are not related to "willingness to adopt green infrastructure" (Barr, 2007; Noor et al., 2012; Stern, 2000). In the current study, none of demographic variables were found to be significant. This result is supported the studies in the literature. However, in the current study, the reason for non-significant results might be that there was less variance between respondents. They were mostly white and had high income, high home value, and high education level. With a different sample, more accurate results related to socio-demographics might be obtained.

6.3. Supplemental Analyses

Upon the completion of the analysis as presented, further examination raised some questions regarding the potential impact of how a specific variable (past experience) was treated. The individuals who previously installed various forms of green infrastructure strategies were included in the main analysis. However, two other ways treating this data were considered. One

of them is to eliminate participants who already installed green infrastructure strategies, and the other is to recode the residents' responses (who already installed green infrastructure) as 5 on 4-point scale (1=strongly disagree to 4= strongly agree and 5= actual behavior) (See Appendix C). The same strategy that was adopted in the main analysis was also adopted in the supplemental analyses (See Appendix C). Regarding the variables that were significant, the following table (Table 6-2) shows how these different analyses were affected.

Table 6-2. Analysis models with significant predictors and adjusted R^2 value

	Main analysis	Supplemental analysis	Supplemental analysis_2
Rain Barrel	• Visual appearance • Past experience • Self-efficacy • Subjective norm	• Gender • Self-efficacy • Subjective norm	• Health concerns • Self-efficacy
Adjusted R^2	0.138	0.118	0.118
Rain Garden	• Time to maintain • Past experience • Self-efficacy • Subjective norm (marginally significant)	• Time to maintain • Self-efficacy • Subjective norm	• Income • Time to maintain • Self-efficacy
Adjusted R^2	0.184	0.174	0.212
Porous Pavement	• General Knowledge • Past experience	• Self-efficacy • Attitudes	• Cost to install • Self-efficacy • Attitude
Adjusted R^2	0.114	0.036	0.065

The supplemental analysis for rain garden and rain barrel reinforced the notion that "self-efficacy" and "time to maintain" were critical with regard to a person's willingness to implement green infrastructure. With regard to porous pavement, self-efficacy reappeared as a significant predictor in supplemental analyses, but no clear conclusion can be developed by comparing these supplemental analyses to the main analysis**.**

6.2. Strength and limitations of the study

This study used a well- accepted theoretical framework, the Theory of Planned Behavior (TPB). Survey questions were designed based on TPB measures. Some limitations associated with the TPB were removed by the researcher. TPB has been criticized in the past because it did not account for other variables that factor into the behavioral intention and motivation. Therefore, additional variables such as economic factors, which are indicated as an important variable in the green infrastructure literature, were added to the TPB model. Additional variables can make the theory of planned behavior a more integrated model.

Hierarchical regression was used to analyze the survey questions using the TPB as a theoretical framework. Hierarchical regression is a strong tool for the analysis of theoretical framework, and it is also useful for evaluating the contributions of predictors above and beyond previously entered predictors, both as a means of statistical control and for examining incremental validity. In hierarchical regression, the order of variable entry into the analysis is based on a theory. Instead of letting a computer software algorithm "choose" the order in which the variables enter the order is determined by the researcher based on a theory and past research. Overall, a trimming strategy was adapted in the current research. The variables that had a significant

association with willingness to implement (the dependent variable) were added to the model. This helped strengthen the statistical power of the model.

In the literature, the research related to green infrastructure has mostly focused on socio-cognitive factors (attitude, knowledge and social norms) or other influencing factors (such as cost and appearance). However, in the current study, socio-cognitive factors and other influencing factors were examined in a combined way. This may provide more comprehensive information about the factors that affect residents' willingness to implement green infrastructure. Another strength of the current study is that three different statistical models were created for each type of green infrastructure (porous pavement, rain barrel, and rain garden). This allowed the respondents to separately evaluate both their willingness to implement and the factors affecting the implementation. Since there are different types of green infrastructure types, it is difficult to draw conclusions about the factors affecting green infrastructure implementation by asking only questions that are related to a single type of green infrastructure. In the current study, different factors were determined for each type of green infrastructure (rain barrel, rain garden, and porous pavement).

The minimum sample size estimation was conducted through using G power analysis (with the desired statistical power at 0.80, effect size 0.20 and alpha of 0.05). The minimum required sample size was calculated to be 136. In total, there were 360 responses in the study. When missing data was removed, the total sample size was 232. Therefore, meeting with the minimum required sample size was not a limitation of the study.

Although current research has strengths, some limitations are worth mentioning. One of the limitations of this study is the use of self-reported surveys to gather data through asking participants about their willingness to implement green infrastructure and about the factors affecting their decision to implement. The survey tool was used because of its convenience, its ability to describe characteristics of a large population, and its cost-effectiveness. One of the limitations of online surveys is that respondents may not feel encouraged to provide accurate, honest answers. However, since the current survey was conducted anonymously (the beginning of the survey clearly states that survey answers will remain completely confidential), respondents may provide more honest and unambiguous responses. Moreover, respondents in questionnaire style surveys might interpret the questions individually, which can lead to different responses among participants (Armitage and Conner, 1999).

Distributing a web survey has the risk of "coverage error" (that is, not including people who have no internet access). A further limitation can be defined as self-selection bias. Although the survey link was sent to all Citizen Advisory Councils (CAC)' leaders so that they could distribute the link to the residents, only the CAC regions who volunteered to participate took part in the study. Therefore, there is no evidence although all CAC regions were invited to participate in, there is no evidence that this sample is representative of the population, and self-selection bias might inhibit the ability to generalizable the survey results. One of the main limitations of this study is the lack of variance between samples. In the literature, this type of sample is called a WEIRD (White, Educated, Industrialized, Rich, and Democrat) sample. This is a threat to external validity and limits the generalizability.

Another limitation is the use of a new scale, which has not been previously tested. The new scale was established by adapting the existing scales in the literature. Exploratory factor analysis with a reliability coefficient was conducted. Based on the exploratory factor analysis, two items were loaded on attitude scale. Because of the small number of items on the attitude scale, the coefficient score for this component was low compared to other components, although it has a moderate score.

6.3. Future Research

There are opportunities for future research. Future research can broaden the sample size, and a larger sample size enables research to focus more specifically on demographic factors. Other research on green infrastructure could ask residents about their willingness to pay for green infrastructure on their property. From my research, cost was not a significant predictor of willingness to implement and this could possibly be because of the city of Raleigh's Rainwater Rewards Program. However, although cost is identified as a barrier to the implementation in most studies, those studies did not indicate a monetary amount the residents are willing to pay. It would be beneficial to researchers and policy makers to know the monetary threshold for residents. Future research could also focus on other specific types of green infrastructure that were not included in this study, such as trees, green roofs and others.

Moreover, although surveys are a great tool to collect quantitative data, future research should have follow-up interviews with the respondents in order to gain a deeper understanding of their reasons for implementing or not implementing green infrastructure.

CHAPTER 7: CONCLUSION

With the respect to the growing green infrastructure literature, this work addresses the gap in literature by examining the factors that affect residents' willingness to implement specific forms of green infrastructure on their property. The results indicate that for both rain barrels and rain gardens, self-efficacy has a significant effect on residents' intention. Additionally, for just rain barrels, visual appearance is a significant predictor and for just rain gardens, time to maintain is a significant variable. These two observations are also confirmed by supplemental analyses. For porous pavement, general stormwater knowledge has an effect on residents' intention.

Stormwater green infrastructure on private properties can help reduce the amount of polluted stormwater runoff that is flowing into local water bodies. Residents need encouragement from their municipalities to help them overcome the perceived barriers that negatively affect their decision. The results from this research can inform municipal policy-makers in their decisions about what social constructs to target, if they want to encourage implementation of residential green infrastructure.

In the literature, the variable of self-efficacy has not been found to be as an important variable as attitude, knowledge, cost and other variables. The most critical thing that distinguishes the results of this study from other work is the emphasis on the importance of self-efficacy (in other words, a person's perceived ability to install and maintain green infrastructure strategies), which could increase that person's willingness to implement green infrastructure. A city has to do more than just educate its residents on what the green infrastructure features are; it must actually, provide

training so that people can develop the level of self-efficacy necessary to adopt. Required maintenance time is also a significant predictor for installation of a rain garden. The City of Raleigh provides reimbursement for installation, but not for maintenance. The city might provide reimbursement for maintenance as well.

Overall, green infrastructure strategies are more than a group of plants or the systems that infiltrate stormwater into the ground. They are sustainable solutions to water quality and flooding problems, urban heat island problems, and climate change problems. To achieve these goals, it is important to install green infrastructure strategies at all scales.

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APPENDICES

APPENDIX A. INFORMED CONSENT FORM FOR ONLINE SURVEY

North Carolina State University
INFORMED CONSENT FORM FOR ONLINE SURVEY

Title of Study: The factors affecting Green infrastructure implementation on private residential environments

Principal Investigator: Burcin Burcu Dogmusoz Faculty Sponsor (if applicable): Art Rice

Introduction
You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time without penalty. The purpose of research studies is to gain a better understanding of a certain topic or issue. You are not guaranteed any personal benefits from being in a study. Research studies also may pose risks to those that participate. In this consent form you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. If at any time you have questions about your participation, do not hesitate to contact the researcher(s) named above.

Purpose of this study
The main purpose of the study to convey a comprehensive understanding of the factors affecting residents' willingness to implement
green infrastructure strategies on their properties.

Procedures
If you agree to participate in this study, you will be asked to fill in the online survey. You'll be asked different types of questions such as knowledge about green infrastructure and stormwater management, attitudes and perceptions toward green infrastructure strategies and lastly demographic questions. Please fill out all questions to the best of your ability. Some questions may seem similar to others, but they are all important for determining patterns of behavior and intention. The survey will take approximately 10 minutes to complete.You may omit any question you prefer not to answer, and you may withdraw from the study at any time.

Risks
There are no known or anticipated risks to participation in this study.

Benefits
There is no direct benefit from being involved in the study. However, the answers that you provide may help build a more sustainable future for the City of Raleigh. Raising the residents (including participants of this research) awareness toward stormwater management and green infrastructure will be an indirect benefit.

Confidentiality
The information in the study records will be kept confidential to the full extent allowed by law. Your name will not appear in the final research paper and your data will be grouped with other participants' data. The data collected through this study will be kept for a period of one year in a secure location and then destroyed. The following precautions have been taken to minimize any risk to confidentiality: (1) data will be stored securely, (2) the researcher will be the only person to have access to data, (3) data will be protected by a password and data access will be done from the researcher's own device, which is also password protected (4) no reference will be made in oral or written reports, which could link you to the study.

Compensation
For participating in this study, you will be included in a raffle to win $10.00 value gift cards (10 participants will have a chance to win $10.00 gift cards). Quality of your responses will not affect the drawing; however, you must complete the surveys AND provide your email address in order to enter the drawing. At the end of survey, you will be asked to provide your email address. This information is needed for a reason: The recipients of the survey compensation will be contacted by email. Email addresses will be destroyed after prize distribution.

If you are a NCSU student?
Participation in this study is not a course requirement and your participation or lack thereof, will not affect your class standing or grades at NC State.

If you are a NCSU employee?
Participation in this study is not a requirement of your employment at NCSU, and your participation or lack thereof, will not affect your job.

If you have questions about this study
If you have questions at any time about the study or the procedures, you may contact the researcher, Burcin Burcu Dogmusoz, at bbdogmus@ncsu.edu, or 984-218-8880.

If you have questions about your rights as a research participant
If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Deb Paxton, Regulatory Compliance Administrator at dapaxton@ncsu.edu or by phone at 1-919-515-4514.

"I have read and understand the above information. I may print a copy of this form if I wish. I am over the age of 18 and I agree to participate in this study with the understanding that I may choose not to participate or to stop participating at any time without penalty or loss of benefits to which I am otherwise entitled. I understand that by clicking to "agree" I will proceed with the study and agree to consent to these terms or by clicking "disagree" I will exit the study and I disagree to consent to these terms."

Agree
Disagree

APPENDIX B. ONLINE SURVEY

Dear Residents,

My name is Burcin Dogmusoz and I am a current Ph.D student in the College of Design at the North Carolina State University. I will be sending this online questionnaire as part of my graduate research. I would very much appreciate if you could take the time to fill out the following questionnaire in order to help me understand the factors that help or hinder the installation of Green Infrastructure on private properties.

To take participate in the study, you must be **over the age of 18 and own a house in Raleigh**. You will find more detailed information about the survey in the consent form. If you agree with the consent form, just click "agree" to proceed with the study or if you "disagree" with consent form, just click disagree to exit.

If you complete the survey and provide your email address, you will be included in a raffle to win $10.00 value gift card. There will be approximately 200 participants, and 10 participants will have a chance to win the prize.

Thank you for your time,

Burcin Burcu Dogmusoz

PhD Candidate
College of Design
North Carolina State University

Here are the definitions of the terms in this questionnaire:

Green infrastructure: Green infrastructure (GI) is a cost-effective, resilient approach to managing wet weather impacts that uses vegetation, soils and other elements and practices to restore some of the natural processes required to manage water and create healthier urban environments.

Stormwater runoff: Stormwater runoff is defined as the water that washes over a developed area (rooftops, roadways, parking lots, etc.) after a precipitation event.

Impervious surface: Impervious surfaces are mainly artificial structures—such as pavements like roads, sidewalks, driveways and parking lots that are covered by impenetrable materials such as asphalt, concrete, brick, stone and rooftops.

Rain barrel: Rain barrel is a large storage barrel that can connect to your downspout in order to collect rainwater. Rainwater can be reused from the barrel to water the garden.

Rain gardens: A type of garden that is planted within low lying areas in order to absorb more rain water than traditional gardens.

Porous paving: An alternative to asphalt that allows rainwater to pass through it into the ground below.

1. Rain garden

2. Rain Barrel

3. Porous pavement

Question 1: Do you currently have rain barrels, rain gardens and/or porous pavement on your property?

	YES	NO
Rain Barrels		
Rain Gardens		
Porous pavement		

Question 2: If yes, which were installed by the previous owner (1) or the current owner (2)? If no, you can just skip this question.

	1	2
Rain Barrels		
Rain Gardens		
Porous pavement		

Question 3: How likely would it be for you to install rain barrels, rain gardens and/or porous pavement on your property in the next 5 years?

	Extremely Likely	Somewhat Likely	Somewhat Unlikely	Extremely Unlikely
Rain Barrels				
Rain Gardens				
Porous pavement				

Question 4: Why or why not?

Question 5: Please indicate whether the following statements are true or false.

	TRUE	FALSE
Rainfall that flows over the ground surface, which is called stormwater runoff, can be a large source of pollution in local water bodies.		
Stormwater runoff flowing from impervious surfaces can negatively affect water bodies.		
Stormwater runoff can lead to flooding problems. Reduced impervious cover can lead to an increase in stormwater runoff amount.		

In general, more water pollution is generated by industrial facilities than stormwater runoff from cities.

Question 6: Please indicate whether the following statements are true or false.

	TRUE	FALSE
Porous pavement can allow water to infiltrate into the soil.		
Porous pavement can lead to flooding.		
Rain gardens can absorb the pollutants carried in stormwater runoff.		
Rain gardens can improve the quality of water bodies.		
Rain barrels can increase the volume of stormwater runoff going into the water bodies.		
Rain barrels can capture water and hold it for later use on lawns or gardens.		

Question 7: From where do you get most of your information on Green Infrastructure? Please check all that apply.

popular press (newspapers, TV, radio, magazines)

worldwide research reports

scientific research reports

research conferences

neighbors

other

Question 8: Please indicate whether you strongly agree, somewhat agree, somewhat disagree or strongly disagree with the following statements.

	Strongly Agree	Somewhat Agree	Somewhat Disagree	Strongly Disagree
If my neighbors were to install Green Infrastructure on their property, I would be more likely to install it on my property.				
When considering whether to install Green Infrastructure, I consider what my friends may be thinking.				
If the people in my life whose opinions I value agreed that I should install Green Infrastructure on my property, I would be more likely to install.				

Question 9: Please indicate whether you strongly agree, somewhat agree, somewhat disagree or strongly disagree with the following statements.

	Strongly Agree	Somewhat Agree	Somewhat Disagree	Strongly Disagree
I am confident that I could learn the skills required to install or maintain GI on my property.				
I feel that I could decrease the level of pollution entering local water bodies through the implementation of green infrastructure on my property.				
I feel that the expense related to maintaining Green Infrastructure on my property would not be a burden.				
I feel that the amount of time required to maintaining Green Infrastructure on my property would not be a burden.				

Question 10: Please indicate whether you strongly agree, somewhat agree, somewhat disagree or strongly disagree with the following statements.

	Strongly Agree	Somewhat Agree	Somewhat Disagree	Strongly Disagree
I support adoption/implementation of Green infrastructure on my property.				
I believe that Green infrastructure strategies are easy to learn and implement.				
I believe that installing Green Infrastructure on my property would not reduce the amount of polluted runoff going into local streams and rivers.				
I believe that green infrastructure at the resident level does not help improve the quality of water bodies.				

Question 11: To what extent would any of the following factors influence your decision to implement green infrastructural practices? (1= no influence on 5= great influence).

	Rain Barrels	Rain Gardens	Porous pavement
Cost to install			
Cost to maintain			
Required time to maintain			
Visual appearance			
Lack of adequate space			
Health concerns (mosquito etc.)			

Question 12: Is there any "out of your control" factors that influence your decision to implement Green Infrastructure strategies?

HOA requirements

Soil condition

Lack of space

Other

Question 13: What is your gender?

Male

Female

Question 14: What is your age?

18-29 years

30-49 years

50-64 years

over 65 years

Question 15: What is your educational level?

Less than high school

High school graduate

Some college

2-year degree

4-year degree

Professional degree

Doctorate

Question 16: How much is your annual household income?

Less than $30,000

$30,000-$49,999

$50,000-$69,999

$70,000-$89,999

more than $90,000

Question 17: What is your ethnicity?

White

Black or African American

American Indian or Alaska Native

Asian

Native Hawaiian and Pacific Island

Other

Question 18: How much is the market value or your house?

Less than $100,000

$100,000-$249,999

$250,000-$400,000

More than $400,000

Question 19: How many years have you lived in Raleigh area?

Less than 1 year

1-5 years

6-10 years

11-15 years

16-20 years

More than 20 years

Question 20: If you would like to enter a raffle for the chance to win a prize, please provide your email address (your email address will not be linked to your answers).

THANK YOU!

APPENDIX C. SUPPLEMENTAL ANALYSES

Table C-1. Frequencies for willingness to implement

		Count (n)	Percentage (%)
Rain barrel	1=extremely unlikely	25	10.8
	2=somewhat unlikely	44	19
	3=somewhat likely	61	26.3
	4=extremely likely	22	9.5
	5=actual behavior	80	34.5
Rain garden	1=extremely unlikely	31	13.4
	2=somewhat unlikely	53	22.8
	3=somewhat likely	91	39.2
	4=somewhat likely	18	7.8
	5=actual behavior	39	16.8
Porous pavement	1=extremely unlikely	73	31.5
	2=somewhat unlikely	62	26.7
	3=somewhat likely	44	19
	4=extremely likely	10	4.3
	5=actual behavior	43	18.5

Table C-2. Results for rain barrel

	Block 1			***Block 2***		
	β	***Std. Error***	***p***	***β***	***Std. Error***	***p***
(Constant)	2.127	0.310	0.000*	2.171	0.312	0.000*
Gender	0.455	0.152	0.003*	0.428	0.152	0.006*
Self-efficacy				0.153	0.079	0.050*
Subjective norm				0.175	0.073	0.018*
Attitudes				0.105	0.072	0.149
Adjusted R^2	0.069			0.118		
F-statistic for the model	6.564			5.036		
p-value of F statistic	0.002*			0.000*		

Table C-3. Results for rain garden

	Block 1			***Block 2***			***Block 3***		
	β	***Std. Error***	***p***	***β***	***Std. Error***	***p***	***β***	***Std. Error***	***p***
(Constant)	3.678	0.327	0.000*	4.675	0.345	0.000*	4.417	0.341	0.000*
Income	-.0179	0.075	0.017*	-0.144	0.070	0.039*	-0.161	0.068	0.018*
Time to maintain				-0.346	0.056	0.000*	-0.247	0.060	0.000*
Self-efficacy							0.294	0.078	0.000*
Subjective norm							0.112	0.072	0.123
Attitudes							0.140	0.074	0.058
Adjusted R^2	0.020			0.155			0.212		
F-statistic for the model	5.734			22.165			13.447		
p-value of F statistic	0.017*			0.000*			0.000*		

Results C-4. Results for porous pavement

	Block 1			***Block 2***		
	β	***Std. Error***	***p***	***β***	***Std. Error***	***p***
(Constant)	3.486	0.385	0.000*	3.306	0.384	0.000*
Cost to install	-0.228	0.088	0.010*	-0.186	0.088	0.035*
Self-efficacy				0.220	0.094	0.019*
Subjective norm				0.043	0.092	0.644
Attitudes				0.250	0.092	0.007*
Adjusted R^2	0.024			0.065		
F-statistic for the model	6.729			5.042		
p-value of F statistic	0.010*			0.001*		