PLACE-BASED SOCIAL-ECOLOGICAL INQUIRY IN URBAN GREEN STORMWATER INFRASTRUCTURE SYSTEMS: A COMPARISON OF ECOLOGICAL AND SOCIAL OUTCOMES ACROSS THREE PORTLAND NEIGHBORHOODS

by

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DISSERTATION ABSTRACT

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Title: Place-Based Social-Ecological Inquiry in Urban Green Infrastructure Systems: A Comparison of Social and Ecological Outcomes in Three Portland Neighborhoods

With the anticipated escalation in extreme weather events due to climate change, urban areas are increasingly managing stormwater through the use of green infrastructure, designed facilities which share an emphasis on the use of soil and plants to store and infiltrate stormwater. In addition to its primary hydrologic functions, green infrastructure is recognized for its multifunctionality in providing numerous bioecological and sociocultural benefits. In this context, in addition to serving as functional hydrological amenities, green infrastructure networks can be interpreted as "social-ecological systems," systems of integrated human-environment relationships which are both adaptive and complex.

There is a growing recognition in both natural science and social science disciplines that the most pressing challenges of the 21st century involve both social and biophysical elements as well as their interactions. To address the intertwined challenges of creating socially and environmentally just and ecologically resilient contemporary cities, planners, policymakers, and designers must increasingly consider the ecological and social outcomes of their decisions as a complexly integrated whole. "Place-based" modes of inquiry have emerged across disciplines out of a recognition of the critical importance of understanding unique contextual factors in both knowledge acquisition and application. This integrated understanding of physical conditions, contextual variation, and human experience have made place-based approaches an appealing mode of inquiry in the study of human-environment relationships.

This dissertation uses Portland, Oregon's network of publicly managed streetside green infrastructure facilities (Green Streets) to demonstrate how social and ecological processes co-create urban ecosystems and to explore how policy and design shape these emergent social-ecological systems. I center three

neighborhood communities in both ecological and social examinations, using the concept of place to inform both social and ecological study design. In employing a place-based approach to the study of urban green infrastructure landscapes, this dissertation both advocates for the critical role of place-based methods in landscape architecture research and asserts their particular utility for exploring the complexity of human-environment relationships in interdisciplinary landscape studies.

This dissertation includes unpublished coauthored material.

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For my family, biological and chosen

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CHAPTER I

INTRODUCTION: GREEN INFRASTRUCTURE AND THE STUDY OF HUMAN-ENVIRONMENT RELATIONSHIPS

Research Context and Approach

With the anticipated escalation in extreme weather events due to climate change, urban areas are increasingly turning to green infrastructure solutions for managing stormwater. The 2019 Water Infrastructure Improvement Act (2019) enacted by the U.S. Congress defines "green infrastructure" as "the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspirate stormwater and reduce flows to sewer systems or to surface waters." Green infrastructure encompasses a variety of stormwater management strategies such as eco-roofs, bioswales, and stormwater planters, which share an emphasis on the use of soil and plants to store and infiltrate stormwater.

In contrast to traditional pipes and drains, green infrastructure installations slow, cool, and clean water before it enters rivers and streams, helping to prevent combined sewer overflows, regulate water temperatures, and reduce flooding (U.S. EPA, n.d.). Accompanying these primary hydrologic functions, green infrastructure is increasingly recognized for its multifunctionality in providing numerous bioecological benefits including carbon sequestration, urban heat island mitigation, pollutant degradation, and the provision of biodiversity-fostering habitat (Blecken, et al., 2009, Clark et al., 2010, Kavehei et al., 2019, Kazemi et al., 2011, Lucke & Nichols, 2015, Read et al., 2008., Zhang & Chui, 2019). Furthermore, these small instances of urban nature may improve the health, safety, comfort, aesthetics, and livability of neighborhoods and communities for humans (Dill et al., 2010, Kondo et al., 2015).

This dissertation explores the City of Portland, Oregon's public streetside stormwater planters ("Green Streets"), considering the role of design, planning, and management decisions in shaping both the ecological community structure and human community response to these green infrastructure installations across three neighborhoods. As landscape features embedded in the fabric of designed urban spaces, it is apparent that urban green infrastructure facilities are more than simply hydrological systems but are rather integrated systems of bioecological and sociocultural factors and processes; this makes them an ideal case study for considering the epistemology of human-environment relationships[1] in landscape architecture.

Given the global impacts of anthropogenic climate change, there are few contemporary ecosystems that can be understood ecologically without considering human factors. Unlike traditional ecological studies which have typically focused on "undisturbed" or "natural" ecosystems, the relatively new field of urban ecology embraces the fundamental inextricability of humans and the environment in its scientific investigations (Alberti et al., 2003, Pickett et al., 2005). Simultaneously, the growth of environmental and climate justice scholarship demonstrates how addressing the uneven distribution of environmental risks and amenities is critical to the pursuit of equity and social justice within our communities (Pellow, 2018, Taylor, 2000). To address the intertwined challenges of environmental justice and ecological resilience in contemporary cities, planners, policymakers, and designers must increasingly consider the ecological and social outcomes of their decisions as a complexly integrated whole, or a social-ecological system.

The concept of social-ecological systems (SES) arises from systems theory more broadly and in particular the concept of Complex Adaptive Systems (CAS). Complex systems are systems of interacting components whose behaviors cannot be fully understood using standard analytical models due to a set of shared attributes including non-linearity, emergence, uncertainty, scale, and self-organization (Berkes, Colding, & Folke, 2003). Complex Adaptive Systems are a special class of complex systems, of which social-ecological systems are an example. CAS are set apart from complex systems in general by the term "adaptive," which refers to the ability of the system to change—through self-organization or learning—in response to conditions (Norberg & Cumming, 2008). Social-ecological systems, then, are systems of

[1] My use of the term human-environment relationships is specific to this project; this term is used to broadly indicate the idea that sociocultural and bioecological process work in concert with one another. The concept of systems with interacting biophysical and sociocultural components has emerged across fields and owes its conceptual foundation to the study of complex systems, as outlined above. While this idea is often discussed in terms of "social ecological systems" (SES) or "coupled human and natural systems" (CHANS), these terms originated in natural resource contexts at the nexus of ecology and economics and therefore may carry discipline-specific meanings in some literature. To avoid confusion, I preference the term human-environment relationships when specifying these ideas outside of a discipline-specific discussion.

integrated human and biophysical elements, which are both adaptive and complex. This study utilizes the clearly articulated definition of social-ecological systems outlined by Redman et. al (2004). This definition, which emphasizes the coequal weighting of social and ecological components, includes four key qualities:

1. A coherent system of biophysical and social factors that regularly interact in a resilient, sustained manner;
2. A system that is defined at several spatial, temporal, and organizational scales, which may be hierarchically linked;
3. A set of critical resources (natural, socioeconomic, and cultural) whose flow and use is regulated by a combination of ecological and social systems; and
4. A perpetually dynamic, complex system with continuous adaptation (p. 163)

Recognizing that the most pressing problems of the 21st century involve both social and biophysical elements as well as their interactions, SES theory promotes a transdisciplinary approach to studying such systems, necessarily integrating the distinct theories and methodologies of the social and natural sciences. In the study of landscapes, much of the literature on SES is based around the concepts of "sustainability" and "resilience", as part of an emerging body of literature on "sustainability science" (Balvanera et al., 2017a, Childers, 2015, Wu, 2013). Based around the principles of self-organization and adaptation to change, resilience research has increasingly come to address not only ecological systems but social systems as well, now representing a major paradigm in SES studies (Wu, 2013). While the integration of sociocultural factors into the study of ecological systems is not without challenges, it is likely imperative to addressing climate and environmental problems through the lens of equity and justice. As renowned systems theorist Donella Meadows expresses, researchers must "pay attention to what is important, not just what is quantifiable...No one can precisely define or measure justice, democracy, security, freedom, truth, or love...But if no one speaks up for them, if systems aren't designed to produce them... they will cease to exist" (Meadows, n.d.)

"Place-based" modes of inquiry have emerged across disciplines out of a recognition of the critical importance of understanding unique contextual factors in both knowledge acquisition and application. These approaches are typically grounded in a cognitive/phenomenological definition of *place* as an emergent concept which includes location, context, and subjective human meaning. This integrated understanding of physical conditions, contextual variation, and human experience have made place-based approaches an appealing mode of inquiry for sustainability science (Wu, 2013) and social ecological systems researchers (Balvanera et.

al, 2017b). As Wu (2013) states: "Landscape sustainability science is a *place-based* [emphasis added], use-inspired science of understanding and improving the dynamic relationship between ecosystem services and human well-being in changing landscapes under uncertainties arising from internal feedbacks and external disturbances" (p. 999).

This dissertation uses Portland's Green Streets to demonstrate how social and ecological processes co-create urban ecosystems and explores how policy and design shape these emergent social-ecological systems. Portland is a recognized international leader in green infrastructure development, and multiple past studies have explored Portland's green infrastructure through a variety of spatial, biological, cultural, and economic lenses (Baker et. al, 2019, Church, 2015, Shandas, 2015, Everett et al., 2018, Looper, 2019, Netusil et. al, 2014). The current study builds upon this literature by applying place-based methods to the investigation of urban green infrastructure. This research is grounded in the view of place-based inquiry articulated by Balvanera et al. (2017b):

> Place-based research addresses the particularities of specific landscapes, seascapes or transitional zones as dynamic social–ecological systems. A place (e.g. Mexico City) or a region (e.g. Sub-Saharan Africa) is not only a territorially bounded spatial unit with features that make it unique or distinguishable from other areas, but it is also where social, economic and political influences converge, as well as where multiple biophysical and societal flows and networks meet. Place-based social-ecological research, aimed at understanding how social–ecological systems evolve over time and respond to policy interventions through the exchange of knowledge across disciplinary boundaries and among different stakeholders to address sustainability challenges at a particular place is uniquely positioned to explore the interplay between the local and the global scales, by recognizing the distinctiveness of local entities, while addressing the impacts of global dynamics from them (p. 2).

In this dissertation, I focus on three Portland neighborhood communities in both ecological and social examinations, using the concept of place to inform both social and ecological study design. In employing a place-based approach to the study of urban green infrastructure landscapes, this dissertation both advocates for the critical role of place-based methods in landscape architecture research and asserts their particular utility for exploring the complexity of human-environment relationships in interdisciplinary landscape studies.

Research Framework

In my work, I propose an interdisciplinary research approach to the study of human-environment relationships in urban landscapes. To do so, I utilize place as a unifying concept for integrating social and ecological considerations in landscape scholarship. My research framework integrates two distinct bodies of knowledge: 1) literature on the nature of place from geography and psychology, and 2) interdisciplinary literature on the conceptualization and study of social-ecological systems. This integrated research framework is visually represented by the Place-Based Human-Environment Relationship Framework (Fig. 1.1). This model is an integrated adaptation of John Agnew's (1987) tripartite model of place as comprised of location, locale, and sense of place, and Pickett et al.'s (1997) Human Ecosystem Model which articulates the relationship between a *social-ecological resource system* (comprised of ecosystem patterns and processes, socioeconomic resources, and cultural resources) and a *human social system* (which includes numerous social factors such as commerce, knowledge, and identity). The integration of these models demonstrates the ability for place to serve as a bridging concept between social and ecological considerations. Furthermore, because not all human-environment relationship studies will utilize all of these components, the model also provides a tool for comparing studies and language for articulating place-based human-environment relationship research with greater specificity.

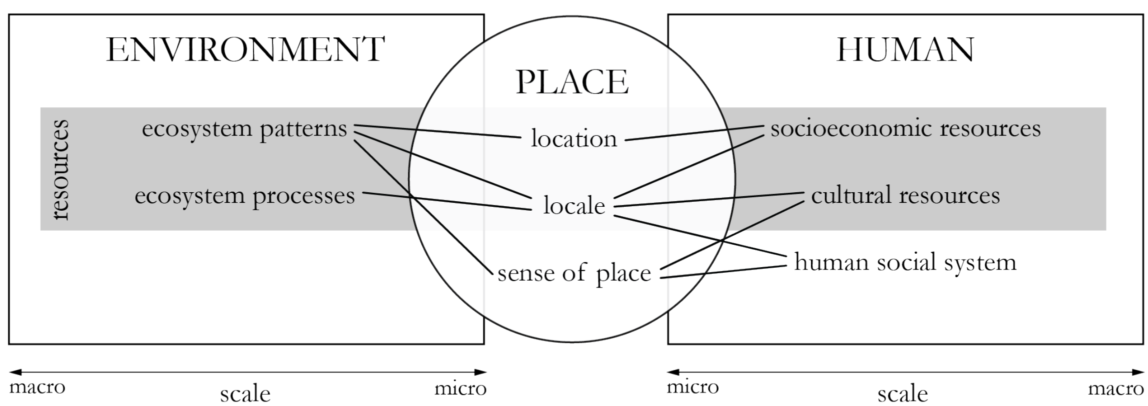

Figure 1.1. The Place-Based Human-Environment Relationship Framework, a conceptual model for place-based research on human-environment relationships. Lines connecting aspects of place to social and ecological components indicate a relationship between these factors; the nature and direction of these relationships varies. The dimension of scale is also included for both human and environmental components, indicating that these components may be considered across a range of spatial scales.

In addition to the organizing framework, this study employs three unifying themes in both empirical studies of green infrastructure: plants, maintenance, and community involvement. These themes were chosen because of their shared relevance to both environmental and social considerations; in other words, like the concept of place, these themes function as bridging concepts between ecosystem patterns and processes and the human resource and social systems. While the themes are utilized differently across studies, they provide a shared foundation for the development of research questions and the interpretation of results.

Document Organization

This document is divided into 5 chapters, inclusive of this introduction. Chapters 1, 2, and 5 provide theoretical framing, context, and interpretation for the empirical findings presented in Chapters 3 and 4. While Chapters 2, 3, and 4 are each legible as independent studies, they should simultaneously be interpreted as a single integrated place-based social-ecological study of Portland's Green Streets.

Chapter 2 explores the application of place-based research methods to the study of complex social-ecological landscape systems. It traces the concept of *place* from its origin in environmental psychology and humanistic geography through its implementation in landscape architectural research. It explores the relevance of place to interdisciplinary concepts of human-environment relationships from urban ecology, environmental justice, and urban political ecology, and advocates for the potential contributions of place-based methods to the study of intertwined sociocultural and bioecological processes within landscapes. This chapter provides the conceptual foundation for the following empirical studies which draw on place-based approaches and interpretation in the study of green infrastructure landscapes.

Chapter 3 presents the findings of bioecological sampling in Green Street planters across multiple neighborhoods in Portland, Oregon, revealing spatial and contextual variation in soil microbial communities. While most characteristics of these spaces—growth medium, plant community composition, and maintenance regime, among others—are tightly mediated by human action, soil communities provide demonstrable examples of human-mediated ecological processes with relevance to how designers and land managers curate these spaces. Microbial ecology offers a unique window into undesigned aspects of otherwise highly engineered urban stormwater ecosystems, highlighting the inextricable link between sociocultural and ecological processes in these designed spaces. The study described in this chapter was conducted with support from several collaborators and will be submitted for publication with co-authors Krista McGuire, Kaye Shek, Bart Johnson, and Chris Enright.

Chapter 4 presents the results of a randomized mailed survey conducted in the same neighborhoods where bioecological sampling took place. This survey gathered residents' reported knowledge, opinions, and interactions with the Green Streets, with a particular emphasis on qualities with direct relevance to designers, planners, and land managers. I compare results across neighborhoods and demographic variables and explore the implications of these findings to planting and ecological design, maintenance, and community involvement in urban green infrastructure planning.

Finally, Chapter 5 offers concluding thoughts regarding the integration of human and environmental considerations in place-based research. I revisit the research framework developed in this introduction and explore its application within each chapter. I reflect upon challenges and limitations in the current study and use the framework to discuss next steps in the development of interdisciplinary place-based research approaches. I close by reflecting upon the relevance of my work to the broad topics of urban ecological resilience and environmental justice.

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CHAPTER II

PLACE-BASED APPROACHES TO THE STUDY OF HUMAN-ENVIRONMENT RELATIONSHIPS: FOUNDATIONS AND FUTURE DIRECTIONS IN LANDSCAPE ARCHITECTURE

Place and Place-Based Discourse

In contemporary landscape theory, *place* generally refers not simply to a physical location but rather to an emergent concept rooted in human experience. This definitional significance of *place* is traceable to phenomenological theories of place articulated largely in humanistic geography and, to a lesser extent, cognitive theories arising from environmental psychology. From a humanistic geography perspective, Yi-Fu Tuan asserts that "place is created by human beings for human purposes...Place, at all scales from the armchair to the nation, is a construct of experience" (Tuan, 1975). Similarly, geographer Edward Relph presents a dialectical relationship between space and place in which aspects of space are differentiated as "place" through the concentration of human experience (Relph, 1976). In his essay *Against Space*, anthropologist Tim Ingold articulates a similar distinction between "the most abstract, the most empty, the most detached" term of *space* (p. 145), and the "groundedness" of *place* (p. 146), extending this argument to suggest that the phenomenon of place is delineated by the embodied experience of movement (what Ingold refers to as "wayfaring") (Ingold, 2011, p. 148). More recently in this same academic lineage, phenomenologist David Seamon has defined *place* as "not the material environment distinct from people related to it but, rather, the indivisible, normally unnoticed phenomenon of person-or-people-experiencing-place" (Seamon, 2013, p. 150).

The phenomenological emphasis on the mediating role of human experience in the construction of place is shared by cognitive theories of place. Early discussions of place in environmental psychology distinguish between the environment (i.e. space) and *place* as "a psychological or 'perceived' unit of the geographical environment" (Russell & Ward, 1982, p. 654). Emphasizing the interconnection between place and human perception, psychologist David Canter defines place as the fundamental unit of analysis, or "'atoms' of environmental experience," while also noting that "unlike an atom of a particular element, what we refer to as a 'place' will change with the perspective we bring to bear" (Canter, 1977, p. 35-36). Sociologist Per Gustafson highlights the parallel thinking on the constituent elements of place across disciplines, as demonstrated by comparing Relph's model of place as comprised of physical setting, activities, and meanings with Canter's proposed components of physical attributes, actions, and conceptions (Gustafson, 2001). Political geographer John Agnew also defines a tripartite model for place as location (position), locale (setting and context), and sense of place (aspects of subjective meaning) (Agnew 1987, Creswell, 2014). While the terminology used within these models differs, all essentially distinguish place as constituted of 1) a physical setting, 2) the various processes and elements that occur there, and 3) the human meanings and ideas that are attached to it (Figure 2.1).

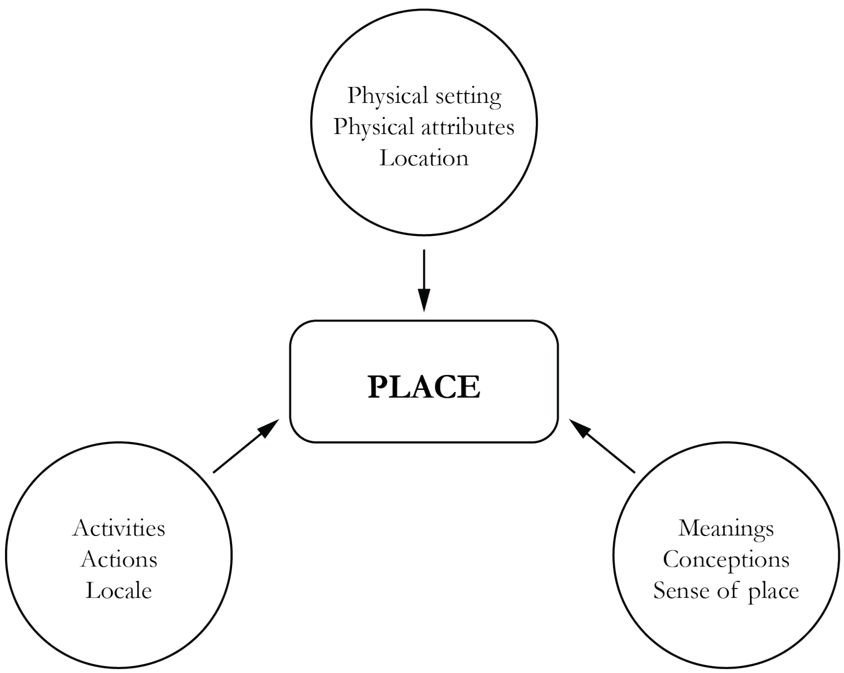

Figure 2.1. The tripartite model of place articulated by scholars across disciplines includes 1) a physical setting, 2) processes and elements that occur in that setting, and 3) associated meanings and ideas.

The broad idea that places may have particular and varied significance to people arises naturally from this tripartite model and is discussed through the concept of *place meaning*. Gustafson's analytical framework for the study of place meaning provides a particularly accessible articulation of the widely varied factors which may make places meaningful to individuals (Gustafson, 2001). Using a three-part model of "self", "other", and “environment”, Gustafson classifies place meaning attributions based on their association with one or more of these categories. In this model, one place might become meaningful to someone because of its association with a beloved relative (the interplay between “self” and “other”) while another place might be significant for its natural beauty (“environment”). Underlying these categorizations, Gustafson notes four dimensions—distinction, valuation, continuity, and change—which facilitate the attribution of place meanings regardless of category. “Distinction” implies that places must be identifiable and categorizable in order to acquire meanings, while “valuation” suggests a normative component to the development of meaning. “Continuity” and “change” both reference the temporal dimension of place meaning, referencing both the importance of ongoing place relationships and the potential for shifting meanings through time. The results of Lynne Manzo’s (2005) interview-based investigation in New York City support the relevance of these four dimensions while also illuminating other potential dimensions of place meaning, most notably the importance of socially constructed identities (including gender, sexuality, race, and ethnicity) in shaping relationships to place.

Place and its ability to carry meaning are often discussed alongside several closely-related concepts including *place identity* (Proshansky et al., 1983, Twigger-Ross & Uzzell, 1996), *sense of place* (Hay, 1998), and perhaps most prominently, *place attachment* (Altman & Low, 1992, Lewicka, 2011, Manzo & Devine-Wright, 2014). The study of place attachment in particular has proliferated since the early 1990’s (Lewicka, 2011). Although place attachment studies offer a range of competing definitions for this term, at its core the phrase simply refers to the “bonding of people to places” (Low & Altman, 1992, p. 2). While place attachment may be studied through empirical means, the term *sense of place* generally refers to broader, more subjective qualities. “‘Sense of place’ differs from place attachment by considering the social and geographical context of place bonds and the sensing of places, such as aesthetics and the feeling of dwelling” (Hay, 1998, p. 5). This definition is consistent with Agnew’s tripartite model, where *sense of place* is used to represent the subjective meanings attached to a place (Agnew, 1987). In contrast to *place attachment* and *sense of place* which focus on the significance and meaning of places themselves, the concept of *place identity* shifts this focus to human self-image, considering how personal identity may be shaped by particular places and place relationships

(Proshansky et al., 1983, Twigger-Ross & Uzzell, 1996). While a lack of definitional clarity and consistency in place-related research is an ongoing challenge (Hernández et al. 2014), the proliferation of place-related concepts is also indicative of an active and evolving area of ongoing investigations.

In recent decades, *place-based* approaches to inquiry and practice have emerged across a wide range of disciplines and the prevailing transdisciplinary view of place as experientially-defined and socially-constructed is foundational to this discourse. As their name implies, place-based approaches acknowledge the relevance of unique contextual factors by centering the concept of place. While the specifics of what this term signifies vary by field, place-based discourse is clearly unified across disciplines by its emphasis on the critical importance of context for interpreting information, structuring research, and directing interventions. For example, place-based education is an approach to pedagogy which draws connections to the local context, including cultural, environmental, economic, and political factors (Smith, 2007). In public health, place-based approaches feature "community and stakeholder agencies collaborat[ing] to address health and contextual factors influencing social well-being of a population within a defined geographic area" (Dankwa-Mullan & Pérez-Stable, 2016, p. 637). In public policy, place-based policy refers to interventions which are targeted based on geographic boundaries rather than individual or household qualities (Kline and Moretti, 2014) and which often approach economic development with the perspective that "the context of each and every city, region and rural district offers opportunities for advancing well-being" (Beers et al., 2020, p. 5). Across fields, this place-based discourse both implicitly and explicitly draws upon the shared cognitive/phenomenological definition of place. The rationale for geographically targeted policies or the ability for contextual factors to influence social well-being, for example, rest on an implicit model of place as not only a location but as a container for processes.

Place-based approaches have been explicitly adopted in the study of environmental and ecological systems, drawing on a similar, context-focused, definition of place seen across other fields. In the introduction to their edited volume on place-based ecological research, ecologists Mary Price and Ian Billick echo this definition, stating: "In our usage, 'place' does not equal 'point in space,' nor does it mean 'field site.' . . . We reserve 'place' to represent all of those idiosyncratic ecological features. . .that define the ecological context of a field study; and 'ecology of place' or 'place-based research' for research that assigns the idiosyncrasies of place, time and taxon a central and creative role in its design and interpretation" (Price and Billick, 2010, pp. 4-5). These authors note that ecology, much like the social sciences, is confronted with the challenge of studying "complex entities whose current state is the product of individual properties, history, and setting," qualities which can benefit from a place-based approach to research (p. 5). It is understandable therefore that place-based approaches have been particularly relevant to the study of environmental processes as explicitly connected to human behaviors and needs. In this capacity, place-based approaches have been employed within numerous subfields at the intersection of the social and environmental sciences such as natural resource management (Kruger & Williams, 2007; Cheng et al. 2003), sustainability science (Cockburn et al. 2018), and the study of ecosystem services (Potschin & Haines-Young 2013).

The Study of Place in Landscape Architecture

As a discipline rooted in the specificity of site, landscape architecture scholars have embraced the literature and theory on place originating in geography and environmental psychology. The writings of architecture professor and phenomenological geographer David Seamon have done much to bring foundational phenomenological concepts of place to a design audience (Seamon, 2013). In a similar capacity, the work of landscape architecture professor and environmental psychologist Lynne Manzo has advanced empirical research on place meaning and attachment (Manzo, 2005, Manzo, 2014) with a particular emphasis on the environmental design and planning fields (Manzo & Perkins, 2006). Emphasizing the complementarity of these approaches, Seamon contributed the first chapter to Manzo and Devine-Wright's defining interdisciplinary text on place attachment (Manzo & Devine-Wright, 2014 and 2021), underscoring the connection between environmental psychology and phenomenology which Seamon had been exploring for over four decades (Seamon, 1982). While by no means the only scholars connecting place-related scholarship from adjacent disciplines to contemporary design scholarship, Seamon and Manzo are illustrative of the breadth of place-related topics and approaches of interest to landscape architects, spanning from the philosophical to the empirical. Both of these scholars also underscore landscape architecture's continued dependence on theory and methods of place studies originating outside of the design disciplines.

The translation of place-related environmental psychology research and theory into a landscape architectural context is perhaps most prominent in restorative landscape design which draws heavily on the work of Stephen and Rachel Kaplan. The Kaplans' early work, which focused on the restorative properties of natural environments articulated through Attention Restoration Theory (Kaplan, 1995), has been foundational to the evidence-based approach to therapeutic garden design led in particular by Clare Cooper Marcus and Naomi Sachs (Cooper Marcus and Sachs, 2014). While not explicitly grounded in the terminology of 'place,' the Kaplans' research nevertheless makes clear the critical importance of people-place relationships and the relevance of understanding the psychology underlying these place experiences in creating sites and cities which support human well-being. This is particularly visible in the Kaplan's design-focused text *With People in Mind* (Kaplan et al., 1998) as well as their more recent work on the Reasonable Person Model, which suggests that "an effective approach to bringing out the best in people often requires addressing problematic aspects of the environment" (Kaplan & Kaplan, 2009, p. 338). Or, put another way, external qualities and environmental conditions drive place meanings and attachments which may be deeply influential on human behavior. While few other sub-fields of landscape architecture draw as explicitly on empirical environmental psychology research as does the study of restorative landscapes, this illustrative example highlights the relevance of place-based qualities to human experience and their applicability within the design disciplines.

While landscape scholarship engages most directly with place-related concepts through the lens of environmental psychology, a limited number of landscape scholars have attempted to integrate the concept of place directly into the process of landscape architectural analysis and practice. Christophe Girot outlines four "operating concepts" ('landing,' 'grounding,' 'finding,' and 'founding') for site investigation, which are intended to guide designers in "acquir[ing] the understanding of place" (Girot, 1999, p. 60). While Girot's brief essay stops short of fully operationalizing these concepts, their sequenced progression offers a general framework for the process of uncovering place and a guide for reconciling "our senses with our science"

(Girot, 1999, p. 66). Girot's concepts highlight the relevance of place-related concepts to the experience of the designer, particularly in relation to site analysis and professional practice.

Kevin Thwaites' discussion of experiential landscape place offers another attempt to operationalize place meaning in landscape architectural investigation (Thwaites, 2001). By integrating environmental psychological theories of place experience with architect Christian Norberg-Schulz's constituent elements of existential space (center, direction, transition, and area), Thwaites considers how place experiences may be interpreted spatially. Thwaites' ideas form the foundation of his book *Experiential Landscape: An Approach to People. Space, and Place,* co-authored with Ian Simkin, which provides a thorough philosophical contextualization of human-environment relationships and the concepts of space and place (2007). Based around the premise that "place perception is intrinsically a phenomenon of continuity," (p. xv) Thwaites and Simkin use the elements of existential space (here referred to as CDTA for center, direction, transition, and area) as "a conceptual means to read the changing rhythms of place experience during our journeying about" (p. xv). A particular contribution of the text is the application of the experiential landscape concept to four case studies, which employ "experiential landscape methods" in site analysis, public participation, design solution development, and site history investigation.

A final instructive example of the role of place in landscape research is Sarah Dooling et al.'s (2006) place-based exploration of Seattle's urban ecology through the lens of park planning. Drawing on the field of urban ecology's increasing appreciation for interdisciplinarity in the study of urban ecosystems (Alberti et al., 2003), the authors employ a "place-based, historically grounded approach" to scholarship which focuses on "drivers, processes and patterns of urban change" (p. 301) and explores the specific sociopolitical, economic, and ideological factors which have influenced the structure of Seattle's parks through time. In contrast with studies *of* place, Dooling et al.'s work (and to a lesser extent the work of Girot, Thwaites, and Simkin) may be seen as an example of studies *through* place, in which the ultimate aim is not merely to gain understanding of the phenomenon of place itself, but rather to structure a methodology reliant upon the concept of place in order to better understand a site, a neighborhood, or a city. The terminology of place-based research, which is used across a range of disciplines to refer to this type of study *through* place, is less common in landscape architecture, perhaps because of a tacit and unarticulated assumption that landscape research always occurs "in a place." As demonstrated by Dooling et al. however, a place-based approach to research in landscape architecture is more than research "in a place," but rather, research through methodologies which center the specificity of place-related knowledge. Or, to echo the words of ecologists Price and Billick, "research that assigns the idiosyncrasies of place, time and taxon a central and creative role in its design and interpretation" (Price and Billick, 2010).

While the concept of place clearly occupies a prominent role in contemporary landscape architectural research, a more nuanced, discipline-specific articulation of place and its role in landscape research remains an opportunity for future scholarship. Foundational place-related theory is primarily grounded in geography, planning, and particularly environmental psychology and while landscape scholarship should be applauded for its breadth of interdisciplinary connections, there continues to be space for more discipline-specific scholarship on place in the lineage of Lynne Manzo's extensive and thoughtful development of place-related concepts (Manzo, 2005, Manzo & Perkins, 2006, Manzo & Devine-Wright, 2014). In particular, studies which consider the role of place within their approach and methods, as in Dooling et al. (2006), would contribute to the advancement of place-based research in landscape architecture. The study of place, broadly construed, is foundational to the theory and practice of landscape architecture; the ability to articulate and define a research approach around this fact will enable landscape architectural scholars to contribute to the interdisciplinary literature on place-based practice and research.

Equity, Urban Ecology, and Place-Based Research

Landscape architecture in the 21st century has a tall order. Not only is the field responsible for creating meaningful, evocative, functional, and aesthetically pleasing spaces as it has since its inception but there is an increasingly urgent imperative for both practitioners and researchers to address issues of social equity and environmental resilience in the built and designed environment. The American Society of Landscape Architecture's Code of Environmental Ethics outlines numerous ethical obligations of the field, including to: "promote the creative planning, design and management of communities that respect ecological and cultural systems, promote economic development, strive for social equity, and provide places for positive social interaction" (American Society of Landscape Architects, 2017). This broad mandate requires landscape architectural practitioners and scholars to consider the aesthetic and functional qualities of landscapes (the traditional purview of the design disciplines) alongside and in relation to their biophysical dynamics and their socioeconomic and cultural qualities. In responding to this call, landscape scholars have the opportunity to explore new methods for considering human-environment relations. Place-based approaches present one potential strategy for investigating sustainability and justice in complex social-ecological landscape systems that draw on the strengths of design training and praxis. Because of their intrinsic emphasis on context and human experience, place-based methods present an opportunity to embed issues of social, spatial, and environmental justice into landscape research. Similarly, since addressing environmental resilience is dependent upon understanding the human role within environmental systems, the explicit attention to human-environment relationships inherent in place-based research makes these methods particularly appropriate to sustainability research.

Place-based approaches are especially suitable for addressing issues of justice and equity in the designed landscape because they acknowledge the importance and uniqueness of human experience and identity in influencing individual and community values and perceptions of their surrounding environment. By incorporating not only "location" (to borrow terminology from Agnew's tripartite model of place), but aspects of "locale" and "sense of place" into studies of landscape, place-based research approaches can produce investigations which foreground human experience and elevate community voices. Writing from a natural resources management perspective, Cheng et al. assert that "a key goal of place-based inquiry is to foster more equitable, democratic participation in natural resource politics by including a broader range of voices and values centering around places rather than policy positions" (Cheng et al., 2003, p. 89).

Environmental justice scholarship has heavily relied on spatial analysis since the 1980's when the United Church of Christ (UCC) Commission on Racial Justice published *Toxic Wastes and Race in the United States*. This report used maps to display the alarming spatial correlations between hazardous waste sites and people of color (UCC Commission on Racial Justice, 1987). Since this time, a large number of studies have used geographic information systems (GIS) methods to consider spatial correlations between population demographics, typically race and household income, and the distribution of numerous other environmental burdens or amenities (e.g. Huang et al., 2011, McConnachie & Shackleton, 2010, among numerous examples). While such studies have done much to advance understanding on the spatial dimensions of inequity, they have also implicitly perpetuated views of justice as predominantly concerned with the distribution of resources. Furthermore, while racial identity and income have indisputable relationships with personal and community privilege in contemporary America which can hardly be overstated, the near-exclusive use of aggregated demographic variables as a default heuristic for community privilege in practice results in a somewhat narrow definition of (in)justice in this work. Conceptual limitations to this correlational methodology have been noted, such as the inadequacy of distance measures for accurately reflecting on-the-ground exposure, risk, or hazard; simultaneously, these studies must contend with analytical limitations such as inconsistency in results across geographic scales of data aggregation (Maantay, 2002). With these limitations in mind, scholars have increasingly worked to include more complex considerations of temporal processes and causes of inequity (e.g. Boone et al., 2009, Hoffman et al., 2020). I argue that place-based approaches can represent a further step in this advancement of methods in the study of environmental justice, both in landscape architecture and beyond.

Through advancing place-based research, I advocate for an expanded set of methods for interrogating inequity which views injustice in the built environment as process-based, multi-scalar, and systemic. This approach is inspired in part by the four pillars of David Pellow's Critical Environmental Justice Framework: 1) the exploration of varied and intersecting forms of social inequity, 2) the use of multiscalar research approaches and theories, 3) the recognition that injustice as systemically produced and sanctioned, and 4) a focus on the "indispensability" (rather than expendability) of both human and non-human. In discussing unevenness and injustice within the built landscape, I draw upon perspectives from several relevant bodies of literature adjacent to landscape architecture. These include: scholarship surrounding the environmental justice movement (Schlosberg, 2013, Bullard, 2000, Taylor, 2000, Pulido, 2000) in addition to the framing of Critical Environmental Justice (CEJ) by sociologist David Pellow mentioned above (Pellow, 2018); the writings of Urban Political Ecology (UPE) scholars (Heynan, 2014, Zimmer, 2010, Swyngedouw & Heynan, 2003) which arise from Marxist geographic traditions and draw heavily on the works of David Harvey and Neil Smith (Harvey, 1996 Smith, 1984,); and the concept of spatial justice and the socio-spatial dialectic as framed by geographer Edward Soja (Soja, 2010, Soja, 1980). Though arising as distinct academic lineages, these constructivist approaches share many complementary concerns regarding the systemic production of unevenness in urban space. Importantly, these approaches move past reductive notions of distributive justice, emphasizing instead (with substantial variation in nuance) the co-creation of social, environmental, and spatial outcomes through human systems of power. "The urban built environment is a 'socionature'" writes Pellow (2018), "because it is impossible to delineate where its human imprint ends and its nonhuman imprint begins, or vice versa, and that environment shapes how humans think and behave" (p. 20).

The frame of "socionature" articulated by Pellow is representative not only of environmental justice and urban political ecology scholarship but is notably echoed by place-based researchers. "Each place, then, embodies and gives rise to its own set of social and political processes and, as a result, social and cultural meanings...emerge as result of the interaction between biophysical attributes and social and political processes," write place-based researchers Cheng et al. (2003, p. 99). By centering the concept of "places" as emergent social-ecological systems (or "socionatures,"), place-based approaches to research may give greater voice to the contextual specificity of these human-environment relationships. Place-based methods, then, may be appropriate when pursuing a research agenda which centers a more nuanced view of justice since they similarly acknowledge the specificity and uniqueness of place and context and center community voices by de-prioritizing dominant narratives. Specific contributions of place-based research to equity and justice in landscape scholarship include the transcending of reductive demographic descriptions of communities, the elevation of community voices through self-description, and the reshaping of dominant narratives.

Place-based approaches to research in landscape architecture can help scholars move beyond simplified models of communities based on demographics to identity-driven, context-dependent views of communities which consider the integration of social and environmental processes. The first pillar of David

Pellow's Critical Environmental Justice Framework calls for the consideration of more diverse social categories of identity as well as the intersections of their resulting inequities (Pellow, 2018). By offering strategies for empirically exploring community identity in greater detail, place-based research methods can help illuminate intersectional identities and nuances to privilege which might be obscured by simple demographics. Rather than responding to questions of "Where?" and "Who?", place-based methods have the potential to provide insights into "Why?" and "How?" While demographics will (and, indeed, should) continue to play a formative role in problem identification, a more process-oriented approach to equity and justice research offered by place-based approaches may be better situated to provide insights into possible solutions.

By facilitating self-description, place-based approaches not only advance scholarship but can also directly empower communities and individuals who may feel alienated by dominant narratives. The previously discussed move beyond primary reliance on demographics to describe community identity can be one step in this direction. Furthermore, by employing methods such as interviews, surveys, discourse analysis, document analysis, and various ethnographic approaches, place-based research can center the notion of identity by elevating self-description. Writing from a natural resource management perspective but equally true in regard to other environmental design and planning professions, Cheng et al. (2003) eloquently state:

> ...the dominant groups. . .have developed a fairly narrow set of place meanings considered in natural resource decision making, whereas the meanings people assign to places and the connections people form with places can be extremely diverse, nuanced, and multilayered. This relatively narrow set of place meanings serves to legitimize the existing power of the dominant groups. . .Missing are the rich, layered place meanings that are expressed and valued by people not strongly affiliated with organized interest groups or industries, or trained in a natural science discipline or resource management. (p. 101).

Elevating community voices not only allows disenfranchised groups and underrepresented identities to feel more included in the research and design process, it can also provide alternative narratives which question dominant assumptions (e.g. Doucet, 2020). For researchers who are willing to have their own assumptions and values about the designed landscape challenged, place-based research can provide a powerful opportunity for new insights.

Beyond the specific focus on equity and environmental justice, place-based methods offer a valuable approach for studying urban ecological systems more broadly and considering sustainability and resilience, through their implicit emphasis on human-environment relationships. There is growing consensus in the fields of urban ecology and sustainability science that methods of investigation that allow sociocultural qualities to be investigated as intertwined with ecological characteristics will be necessary for holistic ecological investigations (Redman et al., 2004, Mussachio, 2009). As Alberti et al. (2003) explain, "In their separate domains, neither the natural nor the social sciences can explain how integrated human and ecological systems emerge and evolve, because human and ecological factors work simultaneously at various levels" (p. 1174). Pickett et al.'s (1997, 2001) elaboration of the Human Ecosystem Framework for urban ecological studies is a particularly influential precedent, incorporating both discipline-specific ecological and sociological theory with the specific concerns of planning and landscape architecture. Interdisciplinary ecological research initiatives such as the network of Long-Term Ecological Research sites in the U.S. (Grimm et al., 2008) or the International Programme on Ecosystem Change and Society (Balvanera et al., 2017a) demonstrate the feasibility of applying social-ecological theories in field research contexts. Balvanera et al. (2017b) highlight the potential contributions to global sustainability of place-based social-ecological research including: 1) a better understanding of cross-scale interactions and relationships, 2) attention to influential human values which occur at the individual level/local scale, 3) the co-construction of solutions with a variety of stakeholders, and 4) greater attention to the value of local and indigenous knowledge.

In urban landscapes, human social, cultural, political, and economic systems both influence and are influenced by environmental conditions. The emphasis on context makes place-based methods particularly useful strategies for considering the impact of such human contextual factors on environmental systems and processes. Intangible human considerations—values, experiences, and perception—are a critical part of many environmental contexts, particularly in urban areas, and may have enormous impact on environmental systems, both at an individual level (as through environmental stewardship) and at a societal level (as through environmental policies). Community psychology and development researchers Mihaylov and Perkins (2014) describe the relationship between environmental conditions and community response using a disruptionresponse conceptual framework which centers the concept of place. In this model, environmental disruptions trigger a community interpretive process based on cognitive and affective aspects of *place* including *place definition, place identity, place bonding,* and *place dependence*. The outcome of this interpretive process (the dependent side of the model) is the resulting human response. Importantly, the interpretive process itself, as well as the dependent community response, is informed by social dimensions of the community including factors such as sense of community, collective efficacy, neighboring, and citizen participation. This model therefore asserts that a community's responses to the physical environment are defined by the integration of that community's social qualities and the significance of place that those qualities contribute to.

In this light, place meaning and community identity provide insight into the foundational motivations which shape behavior and value in relation to environmental resources; whether a place inspires stewardship, enjoyment, neglect, protection, or avoidance is connected to the meaning(s) and significance(s) that a place holds to individuals and communities. These place meanings, therefore, are highly relevant for understanding environmental system dynamics and outcomes in complex urban social-ecological systems. Or, as Manzo and Perkins (2006) articulate, "Our thoughts, feelings, and beliefs about our local community places—what psychologists call "intra-psychic" phenomena—impact our behaviors toward such places, thus influencing whether and how we might participate in local planning efforts" (p. 336). Place-based approaches may be useful strategies for incorporating these human contextual qualities into environmental and ecological studies. As natural resource management scholars Williams and Patterson note, "the concept of place embeds. . .resource attributes back into the system of which they are a part, reminding managers that resources exist in a meaning-filled spatial (and temporal) context" (Williams & Patterson, 1996, pp. 508-509). By emphasizing identity and reshaping narratives, place-based approaches offer an opportunity for landscape scholars to explore the intricacies of human-environment relationships in urban ecosystems more holistically.

Towards a Place-Based Research Agenda in Landscape Architecture

As a field, landscape architecture is increasingly asked to consider not only a wide range of landscape dimensions (from biophysical and ecological to socioeconomic and cultural, to aesthetic and technological, and so on) but also the interactions and feedbacks between these elements and processes to understand the emergent "landscape" as a comprehensive whole. As the methods and topics that fall within the realm of responsibility of the discipline expand, the field must contend with the implications of this disciplinary breadth and consider how new research methods can work to address these seemingly disparate but interconnected aspects of landscape. I assert that place-based methods offer a promising direction for landscape architectural researchers interested in exploring this disciplinary breadth. Specifically, I suggest that by embedding interdisciplinary investigations within a shared spatial and contextual *place*, landscape scholars may integrate methods from across disciplines, co-interpreting findings within the frame of this shared concept. While there are many avenues to interdisciplinary scholarship, place-based methods may be particularly suitable to landscape architecture because of the discipline's existing attention to place-related concepts and the profession's emphasis on *site*.

Fields related to landscape architecture such as cultural geography, urban ecology, environmental sociology, and environmental economics, to name but a few, have established methods for evaluating truth claims around the interactions of human and environmental systems. As landscape architecture expands to include topics and methods more traditionally assigned to these adjacent fields, what might a landscape architecture research agenda offer that these disciplines do not? I assert that landscape architecture's intimate connection to the concept of *landscape* – and with it the intertwined concept of *place* – is one critical characteristic that can distinguish landscape architectural research from that which occurs within these other disciplines, even when similar methods may otherwise be employed.

There has been much debate over what, exactly, the word *landscape* signifies (c.f. Daniels & Cosgrove, 1988, Ingold, 1993, and Jackson, 1997). I begin here from Tim Ingold's definition because of its articulation in relation to place and experience: "the landscape is the world as it is known to those who dwell therein, who inhabit its places and journey along the paths connecting them" (Ingold, 1993). In this concise definition, Ingold articulates the landscape as a collection of experientially mediated and interconnected places. Ingold further explores the relationship of place and landscape to one another stating:

> ...a place in the landscape is not 'cut out' from the whole, either on the plane of ideas or on that of material substance. . . It is from this relational context of people's engagement with the world, in the

> business of dwelling, that each place draws its unique significance. Thus, whereas with space, meanings are *attached to* the world, with the landscape they are *gathered from* it (p. 62).

Thus for the purposes of design research, I operationalize Ingold's definition as the collection of *places*, including their constituent locations, locales, and subjective meanings, within a researcher or designer's spatially and delineated area of focus, or 'site.' While at first pass, the process of 'delineation' may appear to contradict the very premise of Ingold's explication, I suggest that this process of spatial delineation can instead be seen as affirming of Ingold's experientially mediated definition of place. As Ingold goes on to write: "no feature of the landscape is, of itself, a boundary. It can only become a boundary, or the indicator of a boundary, in relation to the activities of the people (or animals) for whom it is recognized or experienced as such" (p. 62). Therefore, I suggest that the thoughtful delineation of *site* and *landscape* which must typically occur within the design and research process, can be interpreted as emblematic of the human experience of dwelling within landscape.

Landscape architectural researchers and practitioners are constantly confronted with problems which are delineated, not by the theoretical constraints of a disciplinary approach, but by the spatial and conceptual extent of real-world sites (*places* and *landscapes*) that they construct and interpret. As a field, therefore, landscape architecture foregrounds the understanding of a breadth of considerations in context with one another, the "world as it is known to those who dwell therein." Instead of *deep dives,* landscape researchers often benefit from considering *wide slices* or cross-sectional cuttings of the various subsystems that make up the landscape. Researchers across disciplines are increasingly considering landscapes as complex social-ecological systems, underscoring the importance of this kind of broad, interdisciplinary thinking (Folke et al., 2016, Childers et al., 2015, among numerous others). As landscape architecture, a field with a comparatively new research agenda, works to refine and define its epistemological stance, place-based approaches offer one possibility for defining a design-specific approach to social-ecological research.

I suggest that place-based research offers an exciting possibility to *ground* and *bound* increasingly broad interdisciplinary research in landscape architecture as the field works to define a research agenda which is both science-driven and socially conscious. By this I mean that place-based approaches physically *ground* research in a specific site or location and conceptually *bound* the study to the salient processes and meanings (the *locale* and *sense of place* to again borrow Agnew's terms) that the site carries. Place-based research provides locally sensitive understanding of landscapes by *grounding* the study within them physically. While this use of the term *ground* bears a superficial similarity to Girot's four trace concepts, it is here intended to indicate a structural quality of place-based investigations, in contrast to Girot's individual process of place discovery. Nevertheless, the concept of *grounding* in this structural/methodological sense is in many ways analogous to Girot's individual/personal *grounding,* articulated as "orientation and rootednesss" (p. 62). These qualities of orientation and rootedness can be seen in the site-specificity of the professional design process; a place-based research agenda in the academy will have obvious benefits for practice as these methods are used to educate future practitioners and may ultimately lead to increased opportunities for academic/practitioner partnerships.

Beyond site specificity, place-based approaches also offer the possibility for generalizable knowledge, thanks to the utility of *boundedness* for focusing and distilling the complexity of emergent landscape systems. As ecosystem service researchers Potschin and Haines-Young (2013) succinctly articulate, "The importance of place is that it provides the context in which the problems can be recognised and articulated" (p. 1054). Price and Billick (2010) note a similar conceptual importance to place-based ecological studies in their potential to suggest new problems for future research (p. 279). By focusing research spatially and contextually rather than purely disciplinarily, place-based methods offer a means of scoping and structuring interdisciplinary investigations, allowing salient processes and connections within social-ecological landscape systems to become more apparent.

Bridge

The framing and motivation of place-based research in landscape architecture presented in this chapter is integral to the structure of the following empirical inquiries. In conducting investigations into both bioecological and sociocultural elements of urban green infrastructure in Portland, I use three Portland, Oregon neighborhoods and three place-specific case studies and draw on the concept of place-based research to inform my study design. In the following chapter, I use microbial ecological methods to explore the role of "place" – location, context specific factors, and human behavior – in shaping green infrastructure bioecology in urban neighborhoods.

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CHAPTER III

MICROBIAL COMMUNITIES IN DESIGNED GREEN INFRASTRUCTURE LANDSCAPES: RELATIONSHIP OF ABOVE-GROUND VARIABLES TO SOIL FUNGAL COMMUNITY STRUCTURE

Multiple individuals contributed to the field sampling, laboratory analysis, and data processing described in the chapter. Dr. Krista McGuire, Dr. Bart Johnson, and Dr. Chris Enright contributed to high-level study design and facilitation. Kaye Shek developed the PCR specifications used in this study and was responsible for bioinformatics processing of sequence data. Shek was also the original author of multiple data analysis scripts which were modified for use on this project. Numerous members of the McGuire Lab at the University of Oregon provided non-technical assistance with field sampling and sample processing efforts. I was responsible for the majority of study design details, was the primary contributor to laboratory processing of samples including DNA extraction and PCR amplification, conducted all data analysis and visualization, and did all the writing except the details on bioinformatics methods (provided by Shek from past studies).

Introduction

With the anticipated escalation in extreme weather events due to climate change, urban areas are turning to green infrastructure solutions like bioswales, green roofs, and rain gardens for managing runoff from impervious surfaces. Accompanying their primary hydrologic functions, green infrastructure is increasingly recognized for its multifunctionality in providing additional benefits including carbon sequestration (Kavehei et. al., 2019), pollutant degradation (Blecken et al., 2015, Lucke & Nichols, 2015), and biodiversity-fostering habitat within cities (Kazemi et al. 2011). In contrast to the more well-studied hydrological functions of green infrastructure, the study of these bioecological functions is relatively underdeveloped (Zhang & Chui, 2019). While the plant communities of these urban habitat patches are structured through human design and maintenance, microbes are performing many of the functions green infrastructure is valued for but remain largely unconsidered in the design and planning process.

Soil microbes contribute to a wide array of biogeochemical and ecological processes of relevance to urban green infrastructure including nutrient cycling, pollutant degradation, and the formation of mutualistic relationships with plants. Fungi and bacteria are instrumental in multiple phases of the nitrogen cycle including nitrogen fixation, nitrification, and denitrification (Pajares & Bohannen, 2016), as well as in soil respiration and carbon cycling (Gougoulias et al., 2014). Microbial decomposers are critical for breaking down recalcitrant chemical structures such as cellulose and lignin into more bioavailable forms; this function means that they can degrade many common pollutants found in urban environments such as polycyclic aromatic hydrocarbons (PAHs) (Leahy & Colwell, 1990, Pilon-Smits, 2005). Microbial mutualists also confer direct benefits to aboveground plant communities through the formation of symbiotic associations with host plants. Examples of these relationships include nitrogen-fixing bacteria which receive carbon from their hosts in exchange for their conversion of atmospheric nitrogen (N_2) into biologically available forms, and arbuscular mycorrhizal fungi (AMF) which confer pathogen resistance and heavy metal tolerance to hosts, as well as increasing soil water and nutrient access (Augé et al., 2015).

The soil microbiome is an important yet poorly documented source of biodiversity across the globe (Fierer & Jackson, 2006), including in urban areas where soil physical and biological properties have been substantially altered by human activity (Scharenbroch et al. 2005). Past studies have shown that green infrastructure soils may house a diverse microbiome which may rival or exceed the phylogenetic diversity of other urban soils (Gill et al. 2017) and which may be compositionally distinct from other nearby green space (McGuire et al., 2013). The importance of overall biological diversity for ecosystem function is a well-established ecological principle (Hooper et al., 2005, Loreau et al., 2001, Tilman, 1999). While the nuanced relationship between species richness, functional diversity, and ecosystem processes remains an active research area in microbial ecology, there is evidence that microbial community composition does impact ecosystem processes (Maron et al., 2018, Philippot, 2013, Allison & Martiny, 2008). Furthermore, important microbe-driven ecosystem processes such as denitrification have been documented in engineered green infrastructure soil mixes through the quantification of functional gene abundance (Chen et al, 2013). Together, these findings suggest that green infrastructure installations have the potential to function as more than just hydrological features but as biodiverse and multifunctional habitat patches in the urban environment.

The growing field of urban ecology emphasizes the important role that human systems and processes can play in structuring ecological communities in developed areas (Kaye et al., 2006, Pickett et al., 2011). This is exemplified in the siting, design, and maintenance of public green infrastructure which, in addition to hydrological considerations, is strongly influenced by economic, aesthetic, technical, and cultural considerations. Numerous studies on agriculture systems have demonstrated that human management practices can have a substantial impact on microbial diversity (Souza et al., 2013, Lupwayi et al., 1998), however this has not been explicitly studied in the context of green infrastructure systems. In contrast to natural systems, green infrastructure installations typically involve the careful curation of specified plants from approved lists of species, with potential ramifications for the associated microbiome. Studies on natural soils demonstrate an association between above-ground plant communities and below-ground soil microbial communities (Kowalchuk et al. 2002) with potential consequences for ecosystem functions (Zak et al., 2003). Hoch et al. (2019) documented a correlation between plant communities and soil fungal assemblages in green roofs, however to date no studies have extended this work to individual plant species or to ground-level green infrastructure installations.

In Portland, Oregon, on-site stormwater management with vegetated facilities is mandated wherever feasible for all new public and private developments and redevelopments over 500 square feet in area (City of Portland, 2016). When either public or private developments impact the public right of way, stormwater must be managed within the right of way through public green infrastructure installations known as "Green Streets". The city's Stormwater Management Manual specifies design standards for these installations which includes growth medium requirements and a short list of approved plant species for Green Streets (City of Portland, 2016). After an initial 2-year establishment period (City of Portland, 2016), maintenance is conducted by city contractors along with a cadre of community volunteers known as Green Street Stewards who adopt individual planters to care for (City of Portland, n.d.). Green Street performance monitoring is focused on infiltration and flow testing at a subset of installations, with limited soil testing for contaminants also conducted at an even more limited set of sites (City of Portland, 2013). Nitrogen cycling and soil bio-physiochemical properties of Green Streets have been examined by researchers (Looper, 2019), but no studies have considered the bioecological communities of Green Street soils.

No known studies have explicitly considered the relationship between design and planning variables and microbial community structure in green infrastructure installations, and it is currently not known how the limited plant palette, variability in maintenance practices, and siting decisions may or may not influence the microbial communities within these engineered sites. We extend the emerging body of literature on green infrastructure microbial ecology to test the hypothesis that siting, plant choice, and maintenance variables may impact microbial community structure. This study is structured around four research questions:

1. Do soil fungal communities differentiate between individual Green Street planters? Are patterns in microbial biogeography visible at larger scales (i.e. street or neighborhood)?
2. Does microbial community composition vary between soils associated with different plant genera in either rhizosphere or bulk soils?
3. Does microbial community composition vary between sites located on high and low traffic streets?
4. Does microbial community composition vary between soils associated with different maintenance treatments?

To answer these questions, we characterize soil microbial community compositions in 42 streetside stormwater planters across four neighborhoods in Portland, Oregon and assess differences across a range of urban conditions. We evaluate the importance of siting across scales, considering differences between sites, individual streets, and neighborhood clusters. We compare fungal community structure in soils associated with seven dominant plant genera and evaluate the local impact of street traffic and roadway pollutants by comparing fungal communities on high and low traffic streets. Finally, we consider the impact of maintenance practices by comparing community structure between planters which receive only city maintenance and those which receive additional maintenance from community stewards.

Methods

Study site selection and description

Soil samples were collected from 42 Green Street facilities across downtown and east Portland, Oregon between 45°28' N and 45°33 N and 122°31' W and 122°42' W (Fig. 3.1). Planter size was variable, ranging from as small as 6 square meters to over 60 square meters with a mean area of 27.6 square meters. Portland's climate is characterized by seasonal precipitation patterns and moderate temperatures. The mean annual temperature for Portland is 12.4 C with approximately 1102 mm mean annual precipitation (Western Regional Climate Center n.d.).

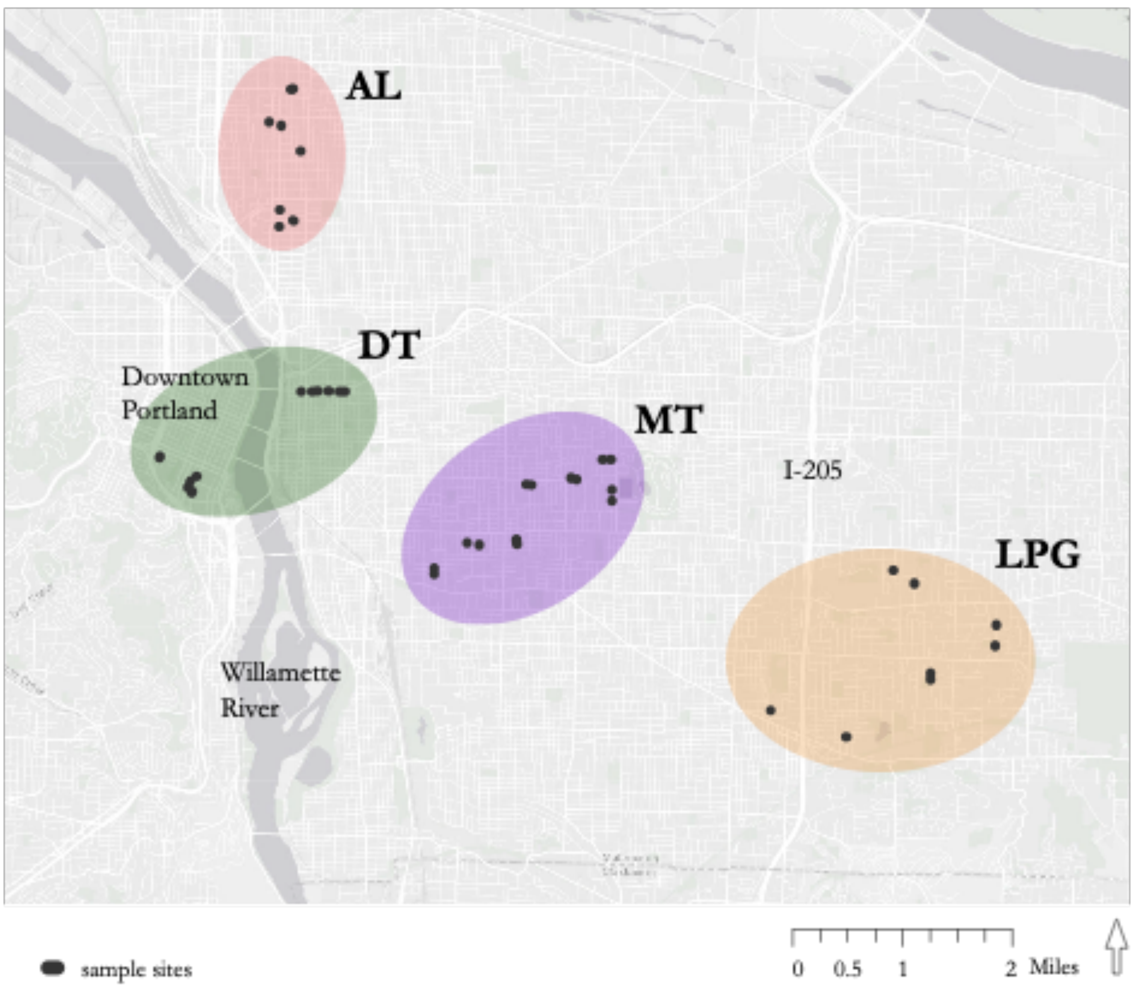

Figure 3.1. Map of study site locations across four Portland neighborhoods, Albina (AL), Downtown (DT), Mount Tabor/Richmond (MT), and Lents/Powellhurst-Gilbert (LPG).

Green Street facilities are roadside stormwater planters which receive runoff from city streets and sidewalks either from sheet flow or at designated inlets; while design specifications vary, they typically run parallel to the road and are between 1 and 3 feet wide with concrete curbs and designated overflows back to the street or directly to the sewer system. At the time of sampling there were 2784 Green Street facilities in the city's database; facilities were distributed unevenly across the city due to city policy and development conditions. Four focal areas with a high number of installations in close proximity were selected for sampling, including three neighborhoods in east Portland as well as the downtown core. These areas were selected to represent a range of urban environmental conditions and the breadth of the spatial distribution of planters across east Portland.

We conducted an initial inventory of the more than 600 planters in these focal areas, noting the dominant plant species and overall condition of each planter. We also used a city database which tracks community maintenance of Green Street facilities to note which sites had been adopted by community members; in addition to the seasonal maintenance performed by city contractors on all facilities, these sites received a variable amount of additional maintenance from community "stewards."

To account for potential community instability during the establishment phase of these novel ecosystems as posited by McGuire et al. (2013), planters installed less than 4 years prior were excluded from the study. Sites in poor overall condition with failing or immature plant communities were also excluded. A final set of planters across three neighborhoods was selected to represent all major dominant plant species noted during surveys. Where possible, planters were selected in co-located pairs on the same street with differing management regimes (city managed versus community stewarded).

Field sampling

All field sampling was conducted throughout March and April of 2020, based on Gill et al.'s (2017) findings that bacterial diversity in bioswales appears robust to short-term temporal and climatological variation. For each site, soil samples were taken adjacent to dominant plant species, from the rhizosphere of dominant plant roots, from randomized points throughout the planter, and adjacent to the inlet and overflow.

With the exception of rhizosphere soils, all samples were taken at 10 cm depth using a 2.5 cm diameter soil corer; rhizosphere soil samples were removed directly from the roots of collected plants.

Based on the documented relationship between plant and soil microbial communities (Zak et al. 2003, Kowalchuk et al. 2002, Hoch et al. 2019), soil samples were collected adjacent to dominant plant species. Dominant species were defined as intentionally-planted species with multiple individuals present within a site; weedy invasives were outside the scope of this project. Because of the highly curated nature of these sites, dominant species were straightforward to discern. For each dominant plant species, five random individuals were selected for sampling of bulk soils. For species with appropriate rooting structure to retain soils when uprooted from the ground, rhizosphere soils were manually removed from roots. Bulk soil samples were also collected from five randomized points throughout each planter. Finally, one bulk sample each was taken at the inlet and overflow/low point of each planter to represent the path of water travel across the site. Soil samples were stored on ice in the field and immediately placed in -20°C freezers upon return to the lab storage.

Illumina sequencing

We employed barcoded high-throughput Illumina sequencing to identify fungal community structure in collected soil samples. Briefly, DNA was extracted using a Qiagen DNeasy PowerSoil extraction kit, following the manufacturer's protocol. We used a an in-house two stage PCR process to amplify and index target gene regions for fungi. In the first stage, the target gene region was amplified using gene-specific primers with Truseq stubs as well as heterogeneity spacer sequences as unique molecular identifiers. In the second stage, universal PCR primers were used to attach TruSeq adapters and dual-index barcodes to the amplicons. This method allows the same primers to be used for the second round of PCR regardless of target gene region.

For fungal ASVs, the internal transcribed spacer region 1 (ITS1) was amplified using the ITS1F and ITS2 primer pair. Amplification was carried out on a BioRad T100 thermal cycler with the following conditions: initial denaturation at 94°C for 3 minutes; 30 amplification cycles of 45 sec at 94°C, 1 min at

54°C, and 90 sec at 72°C; followed by a 10 minutes final elongation phase at 72°C. Unique TruSeq adapters and indexed barcodes were added in a second round of amplification with the conditions: denaturation at 94°C for 3 mins; 12 amplification cycles of 45 sec at 94°C, 1 min at 52°C and 90 sec at 72°C; and a final extension at 72°C for 10 minutes.

First stage PCR reactions were carried out using 10 uL GoTaq DNA polymerase, 7.9 ul water, 0.1 uL bovine serum albumin, and 0.5 uL each of 10 uM forward and reverse primer pools for a total reaction volume of 20 uL. Second stage PCR reactions were carried out using 2 uL of the first round of PCR products, 10 uL GoTaq DNA polymerase, 10.9 uL water, 0.1 uL bovine serum albumin, and 2 uL iTag primers, unique to each sample, for a total reaction volume of 25 uL.

After each round of amplification, PCR products were imaged on an agarose gel to confirm amplification. Amplicon concentrations in final PCR products were quantified with PicoGreen dsDNA assay and pooled in equimolar concentrations. Pooled products were purified using Qiagen QIAquick PCR purification kit; sample purity was confirmed using a NanoDrop spectrophotometer. Final pools were sequenced using the NovaSeq Illumina sequencer at the Genomics and Cell Characterization Core Facility at the University of Oregon (Eugene, Oregon).

All sequence data were demultiplexed and deduplicated using an in-house bioinformatics pipeline to handle the two stage PCR protocol. Briefly, reads are re-oriented by querying each individual sequence for the biological primers before demultiplexing sequences into their respective samples with generous tolerance and quality thresholds, since downstream processing performs sequence quality filtering. Orienting and demultiplexing scripts are in-house python scripts. Once sequence reads are assigned sample IDs, the pipeline utilizes the heterogeneity spacers in first stage PCR primers as unique molecular identifiers (UMIs) that can parse apart duplicated sequences due to PCR bias as opposed to true biological multiplicity. The deduplication step aligns reads to the taxonomic reference database (UNITE) using bowtie2 and assigns UMI tags to each sequence using samtools. UMItools is then used to filter out duplicate reads from PCR duplication (those with the same UMI), and retains reads with the highest alignment score to the reference database. Deduplicated sequences were used as input to the DADA2 pipeline for quality filtering and assembling into amplicon sequence variants (ASVs) with standard parameters, which does not cluster sequences at a similarity threshold like traditional OTU approaches, maintaining strain-level diversity in DNA sequences in our target region. Taxonomy was assigned using the UNITE database with the 'assignTaxonomy' function in DADA2. To normalize differences in ASV counts across samples, we performed variance stabilization in the Deseq2 R package. This method utilizes a Bayesian mixture model that scales ASV counts within and across samples, avoiding taxon abundance biases introduced by traditional rarefying methods.

Statistical analyses and visualization

We analyzed fungal sequence data across several spatial and site characteristic variables. All analyses were conducted in R and utilized the 'phyloseq' package which is designed to store and handle microbiome sequencing data as an object. To explore biogeographical patterns, we compared Green Street fungal community structure at multiple scales. We examined fungal communities by individual planter and by neighborhood using the random soil samples taken at each site. In many cases, planters were sampled in pairs (i.e. two planters co-located on the same street); we used these pairs of sites to compare fungal communities at the scale of the street, an intermediate spatial scale. We used inlet and outlet/overflow samples to compare soil fungal community variation along the path of travel for stormwater entering a facility.

We explored plant-fungal associations by comparing fungal community structure in both bulk and rhizosphere soil samples taken adjacent to dominant plant species. We also evaluated fungal community variation based on two anthropogenic site characteristics, maintenance treatment and traffic load. For maintenance, we compared fungal community structure in random samples between two maintenance treatments, sites which received only minimal city maintenance and those which reportedly also received maintenance from community stewards. Similarly, for traffic load, we compared fungal community structure in random samples between low traffic streets (<3000 daily trips recorded) and high traffic streets (>5000 daily trips recorded).

We used PERMANOVA in R to test for significance of clustering for all variables. For variables such as plant species with more than two factor levels, we conducted multiple pairwise comparisons to test for significance between each pair of factors. All comparisons utilized the Bray-Curtis dissimilarity index and were implemented using the 'vegan' package in R (Oksanen et al., 2022).

Where appropriate, we employed non-metric multidimensional scaling (NMDS) plots to visualize fungal community clustering by relevant variables. We used the FUNGuild package in R to categorize and visualize fungal communities by functional group. Additional relative abundance visualizations of taxa within key functional groups were generated in R using 'ggplot2.'

Results

Location and biogeography

Green Streets fungal communities displayed significant clustering at the scale of the planter (R^2=0.30, $p<0.001$), the street (R^2=0.10, $p<0.001$) and the neighborhood (R^2=0.04, $p<0.001$) (Fig. 3.2). Pairwise comparisons demonstrate significant differentiation between all neighborhoods (Table 3.1), as well as between all streets. Within each neighborhood, fungal communities in individual Green Street sites were also distinct from one another (Fig. 3.3). Pairwise comparisons were conducted between sites within each of the four neighborhoods; of these 216 pairwise comparisons, 209 (or 97%) were significant (100% in DT, 96% in MT, 89% in AL, and 100% in LPG). In other words, differences in Green Street soil fungal communities persisted across a range of spatial scales in the built environment. No significant difference was found between soil fungal communities in soils sampled at inlets and at overflow/low points of planters.

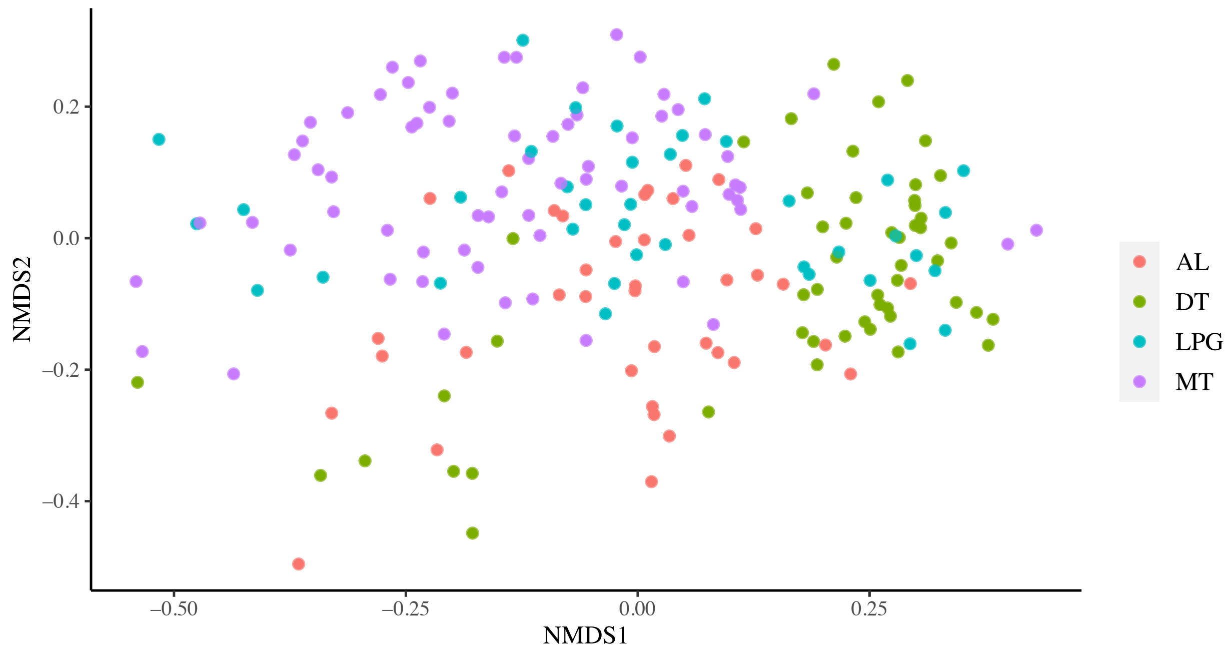

Figure 3.2. Non-metric multidimensional scaling plot of fungal communities in Portland Green Streets with significant clustering by neighborhood.

Table 3.1. Pairwise PERMANOVA results by neighborhood.

Combination	SumOfSqs	MeanSqs	F.Model	R^2	p-value	p (corrected)
AL <> DT	1.096	1.096	2.653	0.030	0.001	0.001
AL <> LPG	0.861	0.861	2.073	0.027	0.001	0.001
AL <> MT	0.877	0.877	2.079	0.017	0.001	0.001
DT <> LPG	1.176	1.176	2.854	0.031	0.001	0.001
DT <> MT	1.757	1.757	4.198	0.034	0.001	0.001
LPG <> MT	0.993	0.993	2.360	0.021	0.001	0.001

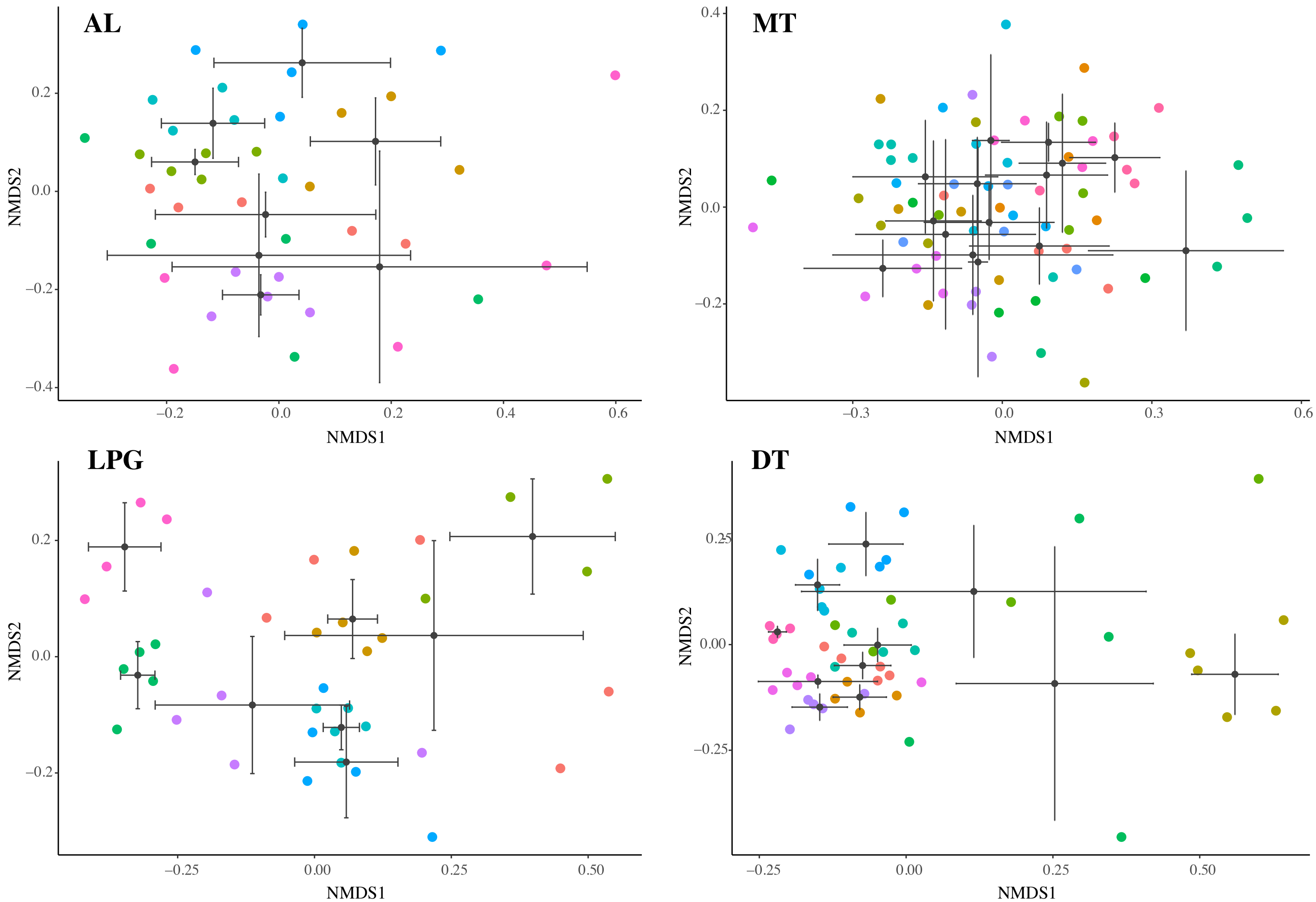

Figure 3.3. Non-metric multidimensional scaling plots of fungal communities by site in each of four Portland neighborhoods; within each neighborhood, fungal communities were significantly differentiated by site.

In addition to overall fungal community structure, we compared relative abundance among specific functional groups across sites and neighborhoods. We found significant variation in both plant pathogens (R^2=0.03, p<0.001) and saprotrophs (R^2=0.04, p<0.001) by neighborhood. Despite these differences, functional group relative abundance displayed similar high-level patterns across neighborhoods (Fig. 3.4); these patterns persisted in all soil subsets (rhizosphere samples, plant-associated bulk samples, and random samples). Although present in relatively low numbers in all neighborhoods, relative abundance of arbuscular mycorrhizal fungi was highest in the DT neighborhood in all soil subsets sampled.

Plant-microbe associations

We observed a significant effect of plant species on soil fungal community structure in both rhizosphere (R^2=0.06, p<0.001) and bulk soils (R^2=0.07, p<0.001) at the city scale. When plants were grouped at the genus level, a significant but weaker difference persisted in both rhizosphere (R^2=0.03, p<0.001) and bulk soils (R^2=0.04, p<0.001). Genera-level differences were significant (p<0.05) for all pairwise plant comparisons in bulk and rhizosphere soils.

As seen across sites, functional group relative abundance showed similar patterns across plant species though significant differences were present within specific functional groups (Fig. 3.5). Relative abundance of plant pathogens was significantly different in bulk soils across dominant plant genera (R^2=0.03, p<0.001). Relative abundance of saprotrophic genera was also significantly different across plant genera in bulk soils (R^2=0.03, p<0.001). Arbuscular mycorrhizal fungi were found in low numbers in bulk soils associated with all dominant plant genera with woody genera (*Cornus, Mahonia, Nandina, Spiraea*) exhibiting the greatest relative abundance of AMF.

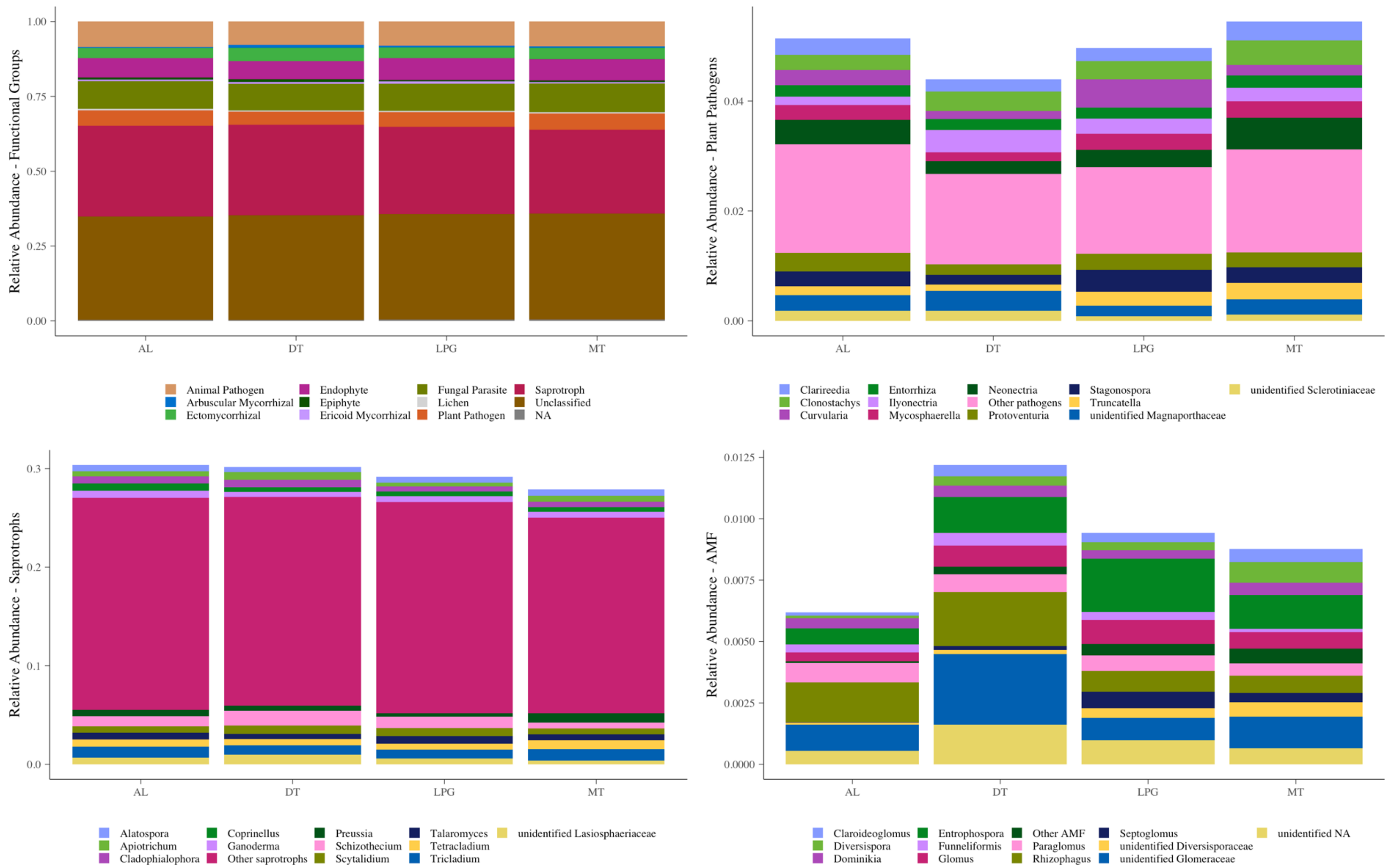

Figure 3.4. Relative abundance of fungal functional groups detected in Green Street soils across four neighborhoods.

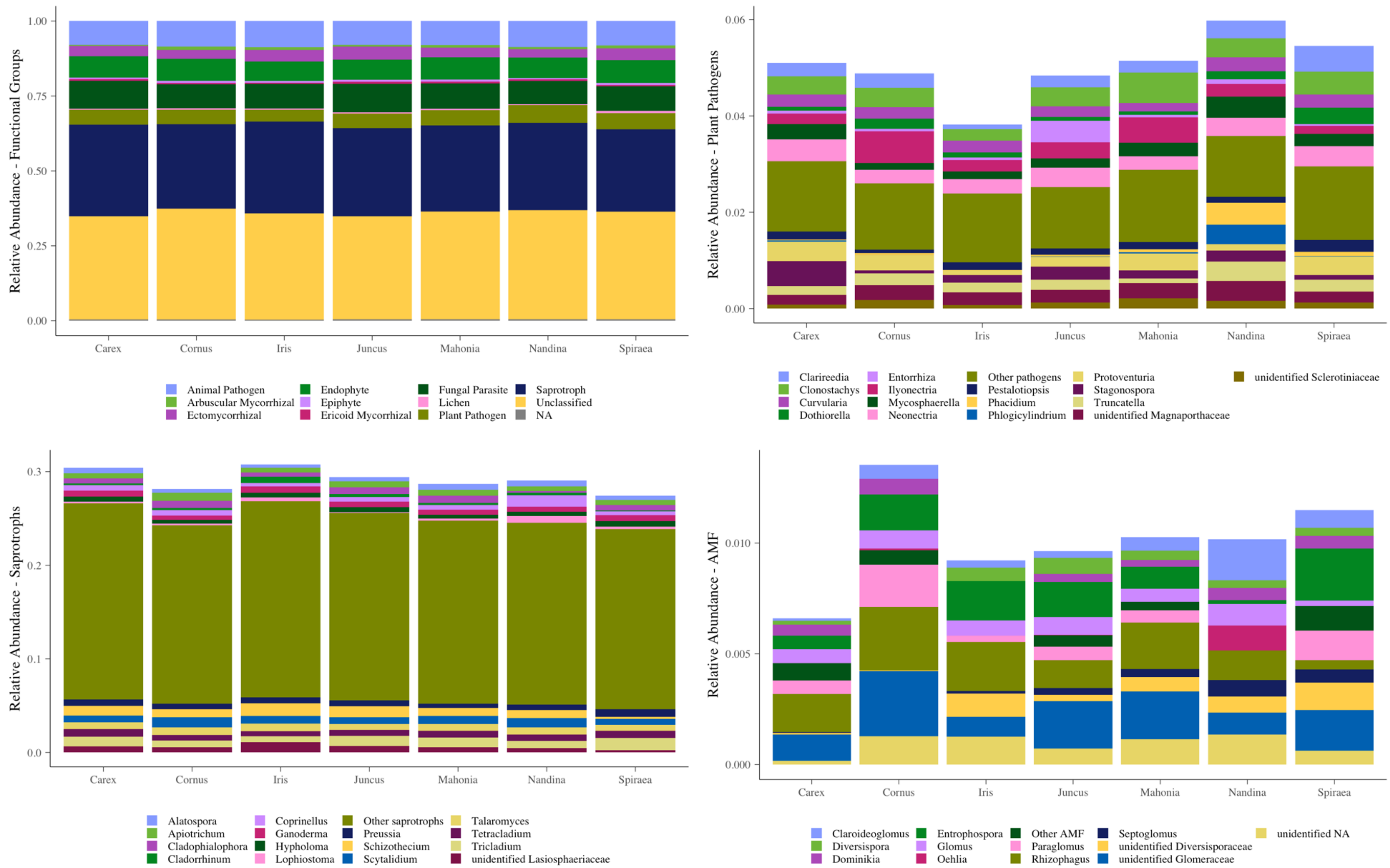

Figure 3.5: Relative abundance of fungal functional groups detected in Green Street soils across seven dominant plant genera

Anthropogenic factors

We found that fungal community structure varied significantly between planters located on streets with high and low traffic loads (R^2=0.02, p<0.001) (Fig. 3.6a). When comparing only samples taken at planter inlets, this effect was more pronounced (R^2=0.04, p<0.001) (Fig. 3.6b). Notably, relative abundance of AMF was greater in planters on high traffic streets (Fig. 3.7). A significant effect on fungal community structure was also visible between community-maintained and city-maintained sites (R^2=0.02, p<0.001).

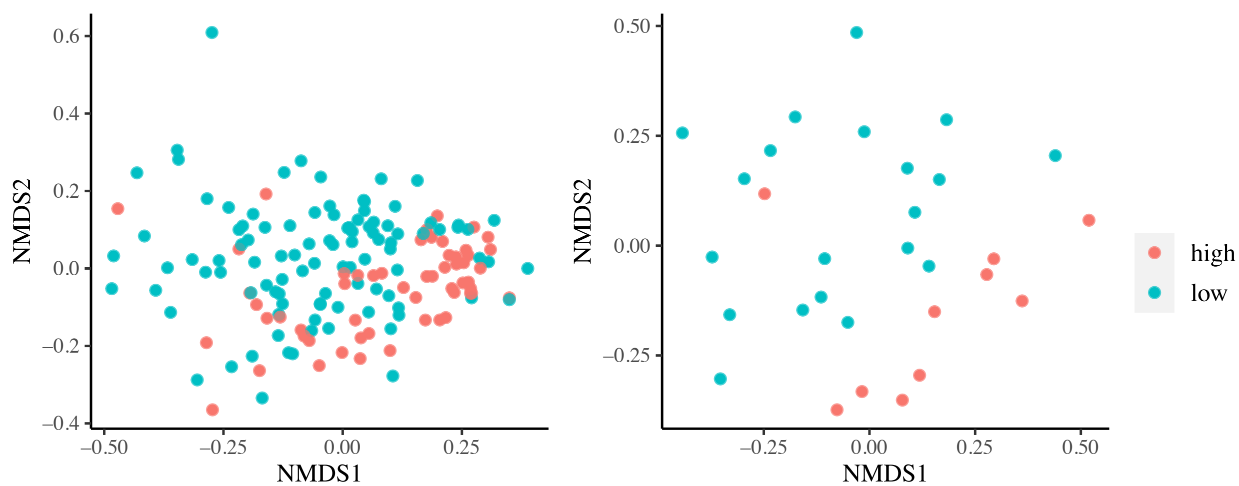

Figure 3.6. Non-metric multidimensional scaling plots of fungal communities in Green Street soils adjacent to low and high traffic roads, sampled from **A)** multiple sites throughout planters (left) and **B)** at planter inlets only (right).

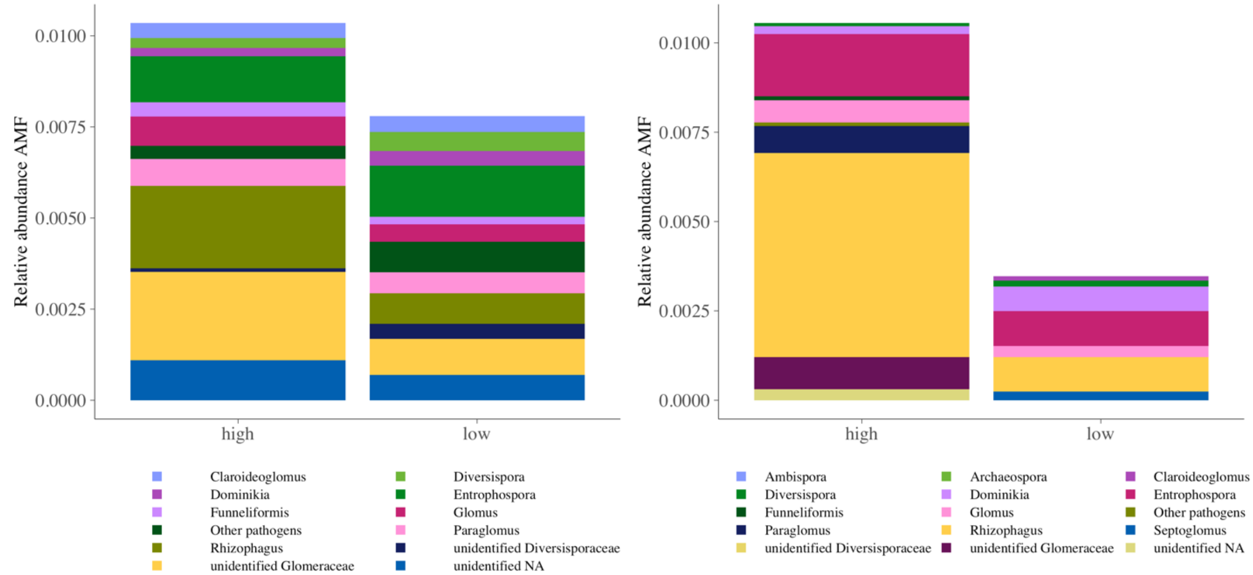

Figure 3.7. Relative abundance of AMF fungal taxa detected in Green Street soils adjacent to high and low traffic roads, from soils samples collected **A)** throughout planters and **B)** from near planter inlets only.

<u>Discussion</u>

Green Street microbial communities are spatially varied

Our examination of soil fungal communities in Green Street planters across four neighborhoods in Portland, Oregon revealed substantial differentiation in community structure at multiple spatial scales, suggesting that fungal community assembly processes are impacted by place-specific factors. In addition to a strong locational effect for individual planters and streets, we observed that Green Street fungal communities differentiated across broader neighborhood clusters. Spatial clustering echoes similar findings in green roof fungal communities which demonstrate biogeographical differentiation by roof location (McGuire et al. 2013). Because Green Streets across the city share a similar plant palette, engineered soil medium, and general climatic conditions, spatial variation in fungal community structure is likely due in part to the influence of site-specific conditions such as microclimate, nutrient loading, and the presence of nearby fungal communities which facilitate dispersion and colonization.

Fungal biogeography is shaped by a range of spatial, climatic, edaphic, and floristic variables, however at a global scale, spatial variables appear to be less predictive of fungal community composition than other factors (Tedersoo et al., 2014). However, our findings suggest that spatial factors may play a greater role in fungal community structure at smaller scales. There is evidence that dispersal limitation plays an important role in fungal community assembly at small scales, particularly in the context of fragmented landscapes (Li et al., 2020, Norros et al., 2012). Thus, site-specific factors such as wind patterns, stormwater source conditions, and proximity to other fungal communities may be of particular importance in the fungal biogeography of urban green infrastructure. Since the engineered soil mix used in Green Streets is dictated by the city's standard construction specifications, soils across sites should be relatively consistent. Thus, the similarity of overall functional group relative abundance across neighborhoods may indicate the strong impact of edaphic characteristics on fungal community structure seen in other ecosystems (Lauber et al., 2008).

In addition to spatial variation in overall fungal community structure, we specifically observed a greater relative abundance of arbuscular mycorrhizal fungi in all soil subsets in the DT neighborhood, the most urbanized location, suggesting that Green Street plants could be more likely to form mycorrhizal associations in higher-stress environments. Spatially, these planters were located in Portland's downtown core and receive the highest food traffic, urban heat island effect, human trash, and associated stressors. Mycorrhizal associations are well-documented to confer various forms of stress resistance to host plants including drought tolerance, nutrient uptake, and pathogen resistance (Augé et al., 2015, Borowicz, 2001, Smith et al. 2009). Our findings echo those of Winfrey et al. (2017) which provided the first documentation of AMF associations in streetside stormwater planters and which shows colonization in several species including both *Carex* and *Juncus* species previously classified as non-mycorrhizal. More work is needed to begin to articulate the relationship between urban environmental conditions, AMF associations, and stress tolerance in engineered soils.

Plant-microbe relationships are visible in engineered ecosystems

We observed plant species-specific fungal community assembly patterns at both the species and genus level in Green Street planters, suggesting that planting palettes may be important in determining the planter microbiome and may ultimately influence functions mediated by microbes in these systems. This finding corroborates past work in engineered green roof soils in New York City which also found a plant species effect on soil fungal community structure (Hoch et al., 2019). While there is substantial evidence of a tree species effect on soil microbial communities in various ecosystems (Prescott & Grayston, 2013, Urbanová, Šnajdr, & Baldrian, 2015), Green Street planters are dominated by graminoids, woody shrubs, and forbs, which lack the long lifespan and substantial litter deposition typical of trees. Furthermore, Green Street "soils" are typically engineered blends which are designed primarily to facilitate drainage. It is notable to see a species effect persist even among these short-lived plant species in highly disturbed urban ecosystems. While we anticipated a greater species effect to be visible in rhizosphere soils, we found that the species effect on soil fungal community tended to be more pronounced in bulk samples. This may be indicative of a greater role of litter in this process than anticipated.

Anthropogenic factors influence microbial communities

In addition to spatial and species effects on fungal community structure, our findings point to the influence of anthropogenic factors such as maintenance and street traffic on structuring microbial community composition in urban green infrastructure soils. Green Street planters receive stormwater directly off adjacent streets which may accumulate a variety of heavy metals and organic pollutants (Benfenati et al., 1992). The differentiation of soil fungal communities between high and low traffic streets suggests that stormwater pollutants such as PAHs which are associated with roadways may be influencing the fungal community composition. The dominant presence of the AM fungal genus *Rhizophagus* in high traffic street and inlet samples further supports this, as fungi of this genus have documented pollutant tolerance (Aranda et al., 2013, Driai et al., 2015). Indeed, our findings provide additional context to previous studies which have demonstrated the high diversity of functional genes related to pollutant degradation in bioswale soils (Gill et al., 2017).

The effect of maintenance treatment deserves further exploration as reported maintenance status is substantially less reliable than a formal experimental maintenance treatment. Nevertheless, the finding of even a weak effect of maintenance treatment on soil fungal community assemblage suggests that direct human influence on Green Street fungal communities is occurring. The important role of disturbance in structuring ecological communities is well-established in the literature (Roxburgh et al., 2004) and the impact of stewardship actions on fungal community structure underscore the degree to which human maintenance actions operate as disturbance regimes in urban green infrastructure systems. If our previous hypothesis regarding the contribution of litter to the structuring of plant-specific fungal communities is correct, maintenance regimes which include litter removal could be impacting microbial communities by this same mechanism. More work needs to be done here to explore how different maintenance treatments might impact microbial communities and nutrient cycling processes, which could inform specific maintenance policies for achieving desired ecosystem functions.

Conclusions

Our findings show that soil fungal communities in engineered soils respond to a range of site-scale design and management factors, demonstrating the relevance of human design, planning, and policy decisions in the structuring of urban ecological communities. We have demonstrated heterogeneity in the fungal communities of urban green infrastructure soils across several spatial, siting, and design variables, with implications for the planning and management of these spaces. The probable role of green infrastructure design variables in microbial community structure has been previously noted due to the shared characteristics of microbial communities across a range of green infrastructure types (Gill et al., 2020) and our findings further underscore the specificity of green infrastructure fungal biogeography.

The shared importance of site-specificity and green infrastructure design factors highlight the value of longitudinal studies and place-based ecological research (Price and Billick, 2010) in the ongoing examination of microbial communities in urban green infrastructure. More controlled experimentation and modeling is needed to fully develop a more complete understanding of the factors influencing fungal biogeography in engineered urban soils. While this study was conducted *in situ*, the design of more closely regulated treatment and control in engineered systems could answer important questions with direct relevance to designers and managers of green infrastructure facilities such as: "how does engineered growth medium impact fungal community composition?" and "How do various maintenance treatments support or impede microbial abundance and diversity?" While more work is clearly needed to develop green infrastructure planning and design guidelines to support fungal diversity, the documented impacts of various design and planning factors in the structuring of fungal communities in urban green infrastructure indicate the importance of designing with microbial communities in mind.

Bridge

In this chapter, I demonstrated the importance of anthropogenic and locational variables in shaping green infrastructure bioecology in urban neighborhoods through the use of microbial ecology methods. While the current chapter has explored the bioecological elements of the Green Street social ecological system, in the following chapter I use a community survey to illuminate the sociocultural factors in this system. I explore Green Streets in the same Portland neighborhoods, considering many of the same factors including plant communities and maintenance, but with a new focus on human community response to green infrastructure.

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CHAPTER IV

RESIDENT VIEWS ON PORTLAND'S GREEN STREETS: IMPLICATIONS FOR DESIGN, PLANNING, AND MANAGEMENT OF PUBLIC GREEN INFRASTRUCTURE IN URBAN NEIGHBORHOODS

Introduction

While urban green stormwater infrastructures, such as bioswales and rain gardens, are typically installed to address hydrological conditions, these features assume sociocultural relevance due to their prominence within the public landscape of communities. With the widespread adoption of these strategies in the face of global climate and urbanization pressures, the salience of these engineered systems to community members as aesthetic and cultural elements of the built environment has become increasingly clear. By altering the aesthetics, movement patterns, and ongoing maintenance requirements of a neighborhood or street, green infrastructure elements physically influence the communities in which they are installed in potentially positive and negative ways. These physical alterations are accompanied by experiential and perceptual impacts on community members which are influenced not only by the physical changes themselves but by existing personal and community values and identities. The salience of green infrastructure characteristics to community members is of practical importance to designers, planners, and policymakers, particularly in regard to improving community support for current and future projects. This study examines differences in human understanding, perception, and engagement with public green infrastructure installations across three neighborhoods in east Portland, Oregon, to better understand the variation in human experience of green infrastructure and the role of individual and community factors in shaping these experiences.

The relevance of urban green stormwater infrastructure to surrounding human communities is well-acknowledged in the literature. The concept of Artful Rainwater Design (ARD), developed by Echols and Pennypacker, for example, explores stormwater management designs as site amenities which "enhance a project's attractiveness or value" through various means such as education, recreation, and aesthetic richness (Echols & Pennypacker, 2008, p. 268). However, only a limited number of studies have explored human perception, health and safety outcomes, and community participation in relation to green stormwater infrastructure. A systematic literature review conducted in 2019 found only 18 studies which directly analyzed green stormwater infrastructure from the perspective of human health or social well-being, with even fewer relying on primary social data and none allowing for causal inference (Venkataramanan et al., 2019). This small number of relevant studies is particularly notable given the relatively broad definition of green stormwater infrastructure which encompassed not only constructed features like bioswales and green roofs but elements like riparian corridors and street trees. The majority of identified studies employed econometric approaches to evaluate green infrastructure's impact on adjacent property values using the hedonic price method, with mixed results (c.f. Netusil et al., 2014, Irwin et al., 2017, Polyakov et al., 2017). While studies on public health are limited, Kondo et al. (2015) employ a difference-in-differences approach to evaluate the relationship between green infrastructure installation and various health and safety outcomes, finding a significant post-treatment reduction in certain crime rates though no effect on health variables. Finally, while a variety of studies in communities across the globe have considered resident knowledge and engagement with green stormwater infrastructure in a broad sense (e.g. Ward & Winter, 2016, Herringshaw et al., 2010), only a handful of studies, all conducted in Portland, Oregon, have considered resident perceptions in regards to urban bioswales (Church, 2015, Everett et al. 2018, Shandas, 2015).

Portland, Oregon is recognized internationally for its extensive and well-developed green stormwater infrastructure network, a cornerstone of which are the city's public Green Streets. Green Streets are streetside stormwater planters located within the public right of way and managed by the City of Portland's Bureau of Environmental Services (BES). Portland city policy requires onsite stormwater management for development projects throughout the city; the construction of Green Streets is usually initiated when either a public or private development project triggers this requirement in the public right of way. While private developers may be required to construct Green Streets and maintain them during their establishment, Portland's Green Streets are publicly-owned and managed urban amenities. In addition to contracted maintenance organized by BES's Watershed Revegetation Program (WRP), the city has a robust volunteer program, the Green Streets Stewards (GSS) program, which allows community members to "adopt" facilities and participate in the care of Green Street planters. In addition to the GSS, the city has worked to engage communities with green infrastructure, most notably through the the "Tabor to the River" (T2R) program in East Portland which combined community engagement initiatives and academic research with the development of public and private green infrastructure, including Green Streets, in a defined area within central southeast Portland.

There is an established awareness in Portland that green infrastructure has the capacity to serve social as well as ecological functions. A 2010 BES report entitled *Portland's green infrastructure: Quantifying health, energy, and community livability benefits* outlines multiple community livability benefits provided by green infrastructure including aesthetics, community cohesion, environmental equity, and access to nature (Entrix, 2010). Portland's green infrastructure has been the focus of several socially-focused studies following this report, which range from economic to behavioral and perceptual (Baker et al. 2019, Church 2015, Everett et al. 2018, Netusil et al. 2014, Shandas, 2015). Multiple studies gather perceptual data directly from Portland residents through survey and interview methods. The largest of these employed a pre-post mailed survey approach, soliciting input on neighborhood perceptions from 2634 households before and after the construction of nearby green infrastructure (including but not limited to Green Streets) in the T2R program area (Shandas, 2015). Another study in the T2R area used semi-structured interviews to explore resident perceptions of Green Streets, revealing general support for the facilities but concern over specific qualities such as aesthetics and function (Church, 2015). In particular this study suggested that people may not easily connect Green Streets to ideas of "nature" or "habitat," but that observation of these facilities might contribute to environmental learning, particularly if supplemental information is provided. Outside the T2R program area, another semi-structured interview study evaluated resident perceptions of Green Streets along a time series since installation, finding common perceptual themes regardless of Green Street age (Everett et al., 2018). Similar to Church's results, this study found widespread acceptance of Green Streets despite only a moderate understanding of their function, as well as recurring complaints about maintenance, litter, and potential safety hazards.

Another set of studies employs spatial and statistical methods to consider the socioeconomic impacts and context of Green Streets at a citywide scale. Netusil et al. (2014) use the hedonic pricing method to estimate the effect of Green Street characteristics, proximity, and abundance on surrounding home prices. Their study found that Green Street characteristics such as tree canopy cover and number of plant taxa present are positively correlated with residential sale prices. Furthermore, they find that while proximity to individual Green Streets slightly but significantly reduces home prices, overall Green Street abundance within a census tract has a positive effect on sale prices beyond a threshold value. Baker et al. (2019) conducted spatial regression analysis and hierarchical modeling to consider equity in the distribution of aboveground green infrastructure facilities (including green roofs, detention ponds, infiltration facilities, porous pavement, filters, swales, and vegetative strips) throughout Portland. They demonstrate a significant negative relationship between both percent white and median income and green infrastructure density, potentially reflecting a proactive awareness by the city to issues of environmental equity (Entrix, 2010).

Taken together, the existing literature on Portland's green stormwater infrastructure portrays a well-established network of facilities which provides a range of benefits but also potential burdens (both real and perceived) to surrounding communities. Importantly, the spatial distributions of these facilities and their associated impacts are demonstrably spatially heterogeneous (Baker et al., 2019, Netusil et al., 2014). In addition to purely spatial variation, findings from Shandas' 2015 survey suggests that pre-existing conditions at both the individual and societal level may have a significant impact on the degree to which residents accept and care for stormwater facilities, implying that the construction of "burden" and "benefit" across communities may vary in ways not exclusively linked to the physical characteristic of facilities.

Place-based research methods center around the idea that places have meanings to people beyond geographic locale and therefore that contextual factors related to a study's location may be relevant to the interpretation of results (Cheng et al., 2003, Kruger & Williams, 2007, Potschin & Haines-Young, 2013). Furthermore, the particular place attachments and place meanings that both individuals and communities have to their local environment can influence their engagement and experience of planning actions (Manzo and Perkins, 2006, Mihaylov & Perkins, 2014). With this frame in mind, this study attempts to expand the scope of Green Streets studies in Portland to include neighborhoods which have been under-explored in past green infrastructure research. Specifically, it includes two neighborhoods notable for their racial diversity, 1) northeast Portland's Albina district, the historic epicenter of Portland's black community and 2) the Lents and Powellhurst-Gilbert neighborhoods of outer southeast Portland, which include the "Jade District" and the city's highest concentration of east Asian immigrants, in addition to the Mount Tabor and Richmond neighborhoods which are located in the T2R program area. While acknowledging the substantial contributions of Shandas (2015) to understanding resident perceptions around green infrastructure in the T2R area, this study explores the degree to which perceptions and engagement may vary across Portland neighborhoods by examining the T2R program area alongside two other neighborhoods.

Past studies have suggested common topics of interest for residents regarding Green Streets, including maintenance, plant preference, community voice, and environmental learning, among others (Everett et al., 2018). However, since both studies that considered such factors in Portland employed interview-based methods with relatively small numbers of participants, the ability to draw more generalizable conclusions is limited (Church, 2015, Everett et al., 2018). Furthermore, differences in place meaning and identity across neighborhoods may lead to spatial variations in the relative importance of these various factors.

This study uses a place-based approach to build upon the existing literature on Portland's Green Streets by 1) expanding the geographic scope of past perception surveys and 2) providing a more comprehensive examination of resident perceptions on specific design and planning aspects of Green Streets. With these aims in mind, the study is structured around the exploration of two broad research questions:

1. How do Portland residents perceive specific planning and design aspects of green infrastructure including community inclusion, plants and ecology, and maintenance?
2. How do resident understanding and perception of, and engagement with, public green infrastructure facilities vary between three neighborhoods in East Portland, Oregon with different development histories and cultural contexts?

Additionally, the study provides an embedded opportunity to consider the degree to which different demographic groups and communities engage (or do not) with green infrastructure by critically evaluating participation in the study itself. This leads to an additional supporting question regarding outreach and engagement methodologies:

3. How are various demographic groups represented within randomly solicited survey responses on green infrastructure and do intentional efforts to provide equitable access lead to a demographically representative sample?

Methods

Neighborhood selection

Study neighborhoods were selected to represent a broader range of spatial and sociocultural conditions than has been sampled in past studies (Fig. 4.1). Out of acknowledgment of the local context, neighborhoods were named and spatially delineated based on existing neighborhood association boundaries (each study neighborhood consists of two or more neighborhood associations and is referred to by their combined acronyms, given below). I initially filtered potential focal neighborhoods in East Portland, Oregon based on 1) inclusion of substantial green infrastructure development, 2) a predominantly residential character, 3) relative demographic consistency across census block groups contained within the neighborhood boundary. Three focal neighborhoods were ultimately selected to represent a range of spatial and demographic conditions indicative of East Portland (Table 4.1). Furthermore, these neighborhoods were selected to represent a variety of city planning and development conditions.

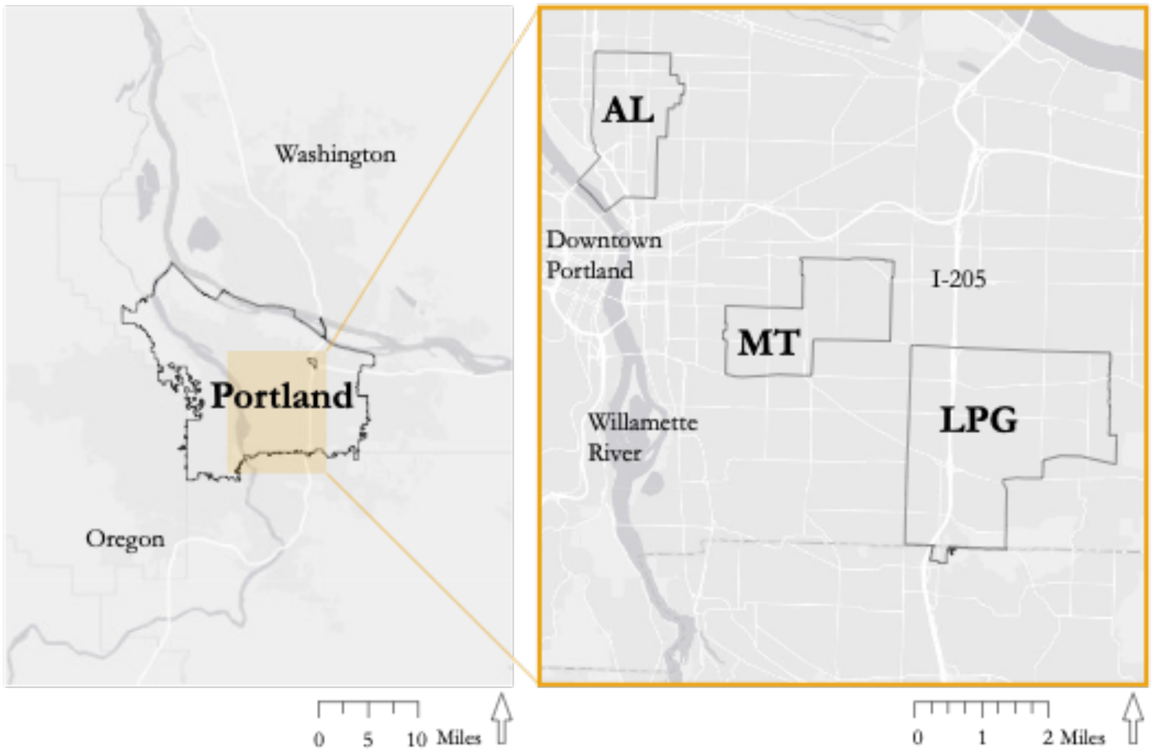

Figure 4.1. Context map of Portland study areas, Albina (AL), Mount Tabor/Richmond (MT), and Lents/Powellhurst-Gilbert (LPG).

Table 4.1. Study neighborhood demographics for Mount Tabor (MT), Albina (AL), and Lents/Powellhurst-Gilbert (LPG).

	MT	**AL**	**LPG**
Total population	21,602	17,569	45,544
Total housing units	9,977	8,728	16,439
Percent homeowners	59.91%	40.07%	50.50%
Percent nonwhite	12.68%	37.30%	36.38%
Median household income (block group median)*	$82,470	$58,056	$43,500
Median household income IQR	$22,569	$30,156	$16,561

*median household income for each neighborhood is reported as the median value of all reported block group median household income values, for block groups at least 50% contained within the study neighborhoods.

The Mount Tabor/Richmond (MT) neighborhoods in central southeast Portland were selected because of the area's significance in the city's past green infrastructure development and outreach through the Tabor to the River program (T2R). The T2R program has meant that the MT neighborhood and surrounding areas have been the focus of multiple past research studies on green infrastructure (Church, 2015, Shandas, 2015). An established residential community, this neighborhood has been a relatively economically stable area for most of its history. Located adjacent to the city's renowned Mount Tabor Park, the area is largely higher income with a relatively low proportion of nonwhite residents. As of 2019, this area is home to 161 Green Streets, nearly half of which were constructed in 2010, including 42 which have been adopted by GSS participants (26% of all planters in the neighborhood).

The Albina area (AL) in northeast Portland was selected due to its racial diversity and rapidly changing character. The historic epicenter of Portland's black community, Albina has a history of racialized community displacement for "urban renewal" projects, redlining, and more recent gentrification (Parks, 2012, Gibson, 2007). "Albina" is not an official Portland neighborhood and is generally considered to encompass the neighborhoods of Eliot, Irvington, Lloyd, Boise, Humboldt, King, Sabin, and Woodlawn (Gibson, 2007); for this study, the neighborhoods of Eliot, Irvington, King, Boise, and Humboldt were included in the study neighborhood. As of 2019, this neighborhood was home to 78 Green Streets constructed since 2006, with a peak in construction between 2008 and 2010. Forty-nine of these facilities (63%) have been adopted through the GSS program, by far the highest rate of any study neighborhood.

The Lents/Powellhurst-Gilbert (LPG) neighborhoods, sometimes referred to as "the Numbers" in outer east Portland was selected for its position on the urban periphery, infrastructural inadequacies including discontinuous sidewalks and unimproved roads, and racial diversity (Bussel, 2018, Goodling et al., 2015, Griffin-Valade et al., 2014). This area includes Portland's "Jade District," the heart of Portland's Chinese and Vietnamese immigrant communities, as well as a large Hispanic population. In this auto-oriented part of the city, development is less dense and neighborhoods cover larger areas. Green Street construction in this area began earlier than other neighborhoods, in 2004, and peaked between 2006 and 2008. This neighborhood is home to a total of 382 Green Streets including several large, clustered developments; 62 of these facilities are cared for by GSS participants (16%, the lowest rate of the study neighborhoods).

Survey design and analysis

I conducted randomized mailed surveys across the three study neighborhoods in East Portland Oregon. Surveys were designed to gather data on green infrastructure knowledge, opinions, and engagement from neighborhood residents (Appendix A). Although Green Streets are a potentially esoteric topic, surveys were written to be accessible to individuals without prior knowledge of green stormwater infrastructure and without any special training or education.

The survey design was intended to reach residents who may or may not have any existing understanding or knowledge of Green Streets but who are likely to have encountered them in their neighborhood. I therefore limited my sampling frame to residents within 200 feet (a standard Portland block size) of a Green Street facility to avoid sampling residents who have no exposure to these facilities. I used publicly available master address and taxlot GIS shapefiles accessed from Portland Metro's Regional Land Information System as the source for potential mailing addresses. Within my three focal neighborhood boundaries, I filtered for only residential taxlots using ArcMap. Using a shapefile of all Green Street facilities provided by Portland BES in 2019, I implemented a 200-foot buffer around public Green Streets facilities to further refine this address list to a final set of 7,181 addresses. I cleaned this initial list for null address values and had the list run through address validation by a third-party contractor to assure postal service deliverability for a final list of 6,017 addresses. From this list I randomly selected 1,830 final addresses evenly divided across the three neighborhoods using the Mersenne Twister algorithm implemented in ArcMap. A total of 15 surveys were either unmailable or returned for a total of 1,815 final mailed surveys.

Survey distribution and recruitment methods were designed based on the recommendations of Dillman et al. (2014) as well as the precedent survey by Shandas (2015). Surveys were mailed to all selected households on October 28, 2021. Surveys were assigned unique IDs which could be linked to addresses while maintaining respondent confidentiality. Each survey contained a postage paid return envelope which included the unique ID number. While compensation was not provided, participants could elect to be entered into a raffle for one of 5, $10 gift cards to a local grocery store to incentivize participation. Reminder postcards were sent on November 23, 2021 to households who had not yet responded with instructions for completing the survey or requesting an additional copy.

Because of the high concentration of non-English speakers in the LPG neighborhood, I had the survey translated to both Mandarin and Spanish to ensure equitable access. I used publicly available American Community Survey (ACS) 5-year estimate data (2010-2014) hosted by the City of Portland to evaluate Limited English Proficiency by Census tract. Any address in a tract with greater than 5% Chinese or Spanish speakers received a translated version of the survey in addition to the English version. (The dissemination of non-English versions was limited to specific tracts due to the significant cost resulting from overweight postage.) A total of 91 Chinese versions and 52 Spanish versions were disseminated.

The survey was carefully written to be answerable by anyone with exposure to Green Streets, even if they had no knowledge of their name or purpose. The introduction to the survey provided the following description of Green Streets:

> Green Streets are small planted areas built along roads. They are public spaces like sidewalks or parks that are managed by the city. Green Streets provide many benefits to both humans and the natural environment. The City of Portland installs them to help manage stormwater (water from rain storms) and provide green space in the city.

This description was constructed to provide an accessible and factual description of Green Streets to those who are not familiar with the facilities, while avoiding biasing or guiding survey responses. As such, this description avoided discussing specific Green Street functions and benefits directly and instead described BES's rationale for installing them as well as noting their location and public status.

Survey questions focused on three main themes: knowledge of Green Streets, opinions about Green Streets, and interactions with Green Streets (Table 4.2). "Knowledge" questions were intended to evaluate residents' awareness of external aspects of Green Streets. Knowledge was evaluated in two questions which addressed: 1) overall awareness of Green Streets and 2) awareness and perception of potential Green Street functions. Opinion questions evaluated residents' personal, subjective views of Green Streets. Opinions were explored through four questions which addressed: 1) overall opinion, 2) opinions related to plants, 3) opinions of impacts on the neighborhood, and 4) factors which would change opinions. Finally, questions about interactions addressed both passive behaviors and active stewardship actions. Interactions were evaluated through three questions which addressed: 1) frequency of various interactions, 2) participation in stewardship actions, and 3) reasons for not engaging in stewardship. An additional seven questions at the end of the survey evaluated demographic variables.

Table 4.2. Survey Questions.

Question	Sub-question	Type
Knowledge		
Were you familiar with Portland's Green Streets before receiving this survey?		3-point Likert
Green Streets can provide many important functions in cities. Based on your current understanding, rate how helpful you think Green Streets are for:	i) Preventing urban flooding, ii) keeping our waterways clean, iii) making neighborhoods more pleasant, iv) providing habitat for wildlife, v) combating climate change, vi) improving property values, vii) teaching people about the environment	3-point Likert (with opt out)
Opinions		
How would you describe your opinion of Green Streets overall?		5-point Likert
Please rate how much you agree with each of the following statements about Green Streets:	i) Green Streets are beautiful, ii) Green Streets are a safety hazard, iii) Green Streets look messy, iv) Green Streets aren't worth the cost of maintenance and installation, v) Green Streets in my neighborhood improve my quality of life, vi) Green Streets in my neighborhood improve my quality of life, vii) I don't like how Green Streets have changed my neighborhood, viii) My community has a voice in whether Green Streets are installed, ix) I'm glad there are Green Streets in my neighborhood	5-point Likert
"The one thing that would most improve my opinion of Green Streets is…"		Multiple choice

Table 4.2 continued

Question	Sub-question	Type
Plants are an important part of Green Streets. Please rate how much you agree with each of the following statements about plants:	i) It's important to me that Green Streets plants look neat and tidy, ii) I like when there are many different types of plants in Green Streets, iii) I care more about how Green Streets function than about how the plants look, iv) I don't really notice the plants in Green Streets	5-point Likert
Interactions		
People interact with Green Streets in different ways. Please rate how often you participate in the following activities:	i) walk/bike past a Green Street, ii) remove litter or weeds from a Green Street, iii) talk about Green Streets with a friend/neighbor, iv) volunteer time to help maintain a Green Street, v) stop to look at plants or animals in a Green Street, vi) read about, attend a meeting on, or learn more about Green Streets, vii) think about how Green Streets impact my neighborhood	5 point Likert
Do you help maintain a Green Street?		Multiple choice
If you responded 'No, I do not maintain a Green Street,' which of the following best describes your feelings?'		Multiple choice

Survey responses were manually digitized and responses for all questions were analyzed using RStudio. Categorical data were visualized and compared qualitatively using contingency tables. For Likert scale questions, difference between neighborhoods was evaluated using a Kruskal-Wallis test and a Dunn's post-hoc test with Holm adjustment to account for multiple pairwise comparisons; non-parametric tests were selected due to the ordinal nature of the survey data.

<u>Results</u>

Survey response quality was overall very high and no surveys had to be discarded in their entirety due to poor data quality. A total of 219 surveys were returned for an overall response rate of 12%. This response rate was highly uneven across the three neighborhoods with a 19% response rate in MT and an 8% and 9% response rate in LPG and AL, respectively.

As anticipated for a mailed survey, the pool of survey respondents over-represents homeowners and white participants in all neighborhoods when compared to demographics derived from the Census (Table 4.3); the survey also overrepresents high-income households. Across neighborhoods, 82.6% of survey respondents owned their home, and 51% of respondents reported household income over $100,000 a year. While no single non-white racial or ethnic group made up greater than 5% of respondents on its own, nearly 16% of total respondents identified as non-white, multiracial, or ethnically Hispanic. The majority of respondents in all neighborhoods had been to college. Survey respondent age was relatively evenly distributed across age groups 35 and up, with between 19% and 26% of respondents from each 10-year age bracket; only 8% of respondents were under age 35. Housing tenure displayed a bi-modal distribution with 30% reporting a very long tenure (>20 years) and 22% reporting short-duration residency (1-5 years).

Table 4.3. Survey respondent demographics compared with neighborhood Census demographics.

	MT survey	MT census	AL survey	AL census	LPG survey	LPG census
% non-white	11%	13%	22%	37%	21%	36%
% homeowners	90%	60%	62%	40%	89%	51%

Reported knowledge, opinions, and interactions across neighborhoods

Green Streets knowledge

The majority of survey respondents (52%) reported being somewhat familiar with Green Streets before receiving the survey. Approximately a third of respondents (32%) expressed that they were "very familiar" with Green Streets. The remaining 16% of survey respondents had no prior familiarity with these facilities.

A large majority of residents were confident of the hydrologic benefits of Green Streets (Table 4.4). Ninety-one percent of respondents agreed that Green Streets were either "very helpful" or "somewhat helpful" at preventing urban flooding, while 88% thought Green Streets were "very helpful" or "somewhat helpful" at keeping waterways clean (Fig. 4.2). For both of these functions, over half of respondents (53% and 54% respectively) felt that Green Streets were "very helpful." For both hydrological functions, no more than 8% of respondents expressed "no opinion" in contrast to between 13 and 22% for all other functions except "making neighborhoods more pleasant," suggesting that the majority of respondents had some understanding of the primary hydrological functions of Green Streets.

Table 4.4. Potential Green Streets functions and functional categories.

Stated Green Street Function	Category
"Preventing urban flooding"	Hydrological
"Keeping our waterways clean"	Hydrological
"Providing habitat for wildlife"	Bioecological
"Combating climate change"	Bioecological
"Improving property values"	Sociocultural
"Teaching people about nature"	Sociocultural
"Making neighborhoods more pleasant"	Sociocultural

Respondents were substantially less confident of the sociocultural and the bioecological functions of Green Streets than in the hydrological functions though a majority still agreed that Green Streets were at least "somewhat helpful" for all functions listed. "Making neighborhoods more pleasant" was the most highly rated non-hydrologic function, with over 85% of respondents expressing that Green Streets were either very or somewhat helpful at this. Respondents were less certain about the economic and educational impacts of Green Streets with less than a quarter of respondents rating Green Streets as "very helpful" at improving property values and teaching people about the environment. Similarly, only 30% and 25% of respondents, respectively, viewed Green Streets as "very helpful" for the two bioecological functions of habitat provision and climate change mitigation. A plurality of 46% of respondents felt that Green Streets were "somewhat helpful" for these two bioecological functions.

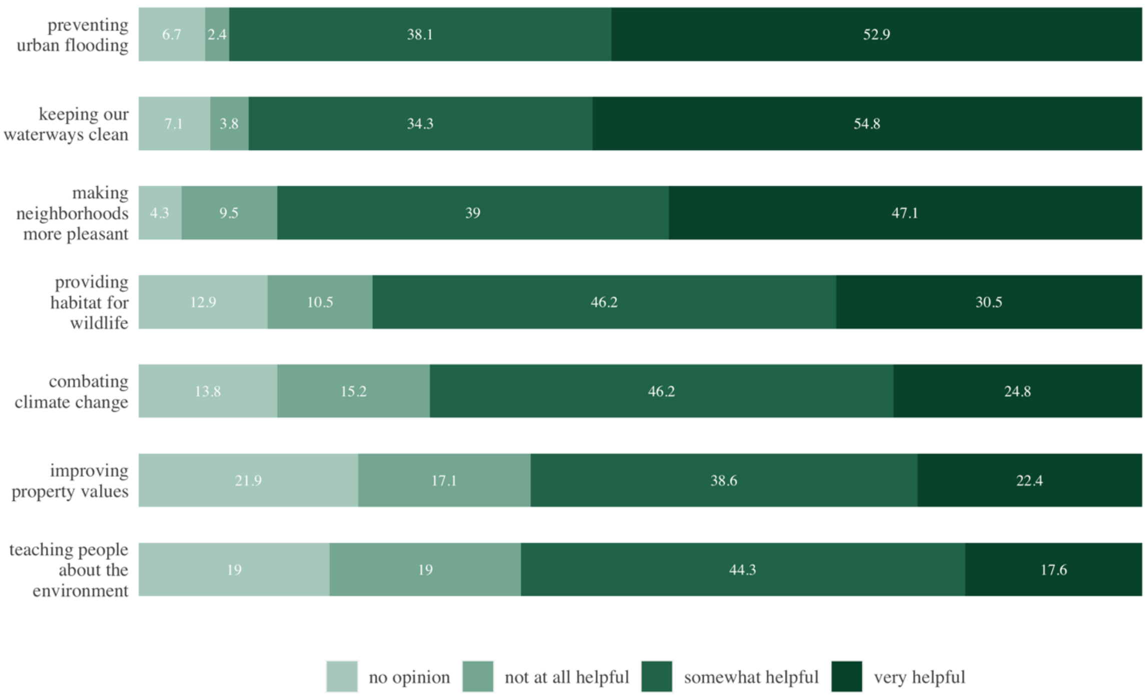

Figure 4.2. Proportional breakdown of survey respondents' ratings of how helpful they understood Green Streets to be for various functions.

Green Streets opinions

Overall, 78.6% of survey respondents reported either a "very positive" or "somewhat positive" opinion of Green Streets. When asked about specific aspects of Green Streets, the majority of respondents continued to respond in agreement to positive statements about Green Streets (Fig. 4.3). The statement "Green Streets are beautiful" garnered the greatest agreement from respondents with over 80% either strongly or somewhat in agreement. The statement "I'm glad there are Green Streets in my neighborhood" elicited a similar combined proportion of "strongly agree" and "somewhat agree" responses (79%) but garnered a much higher proportion of "strongly agree" responses (48.3%), 12 percentage points greater than "Green Streets are beautiful" and over 19 percentage points greater than "Green Streets in my neighborhood improve my quality of life." This discrepancy implies that a substantial number of respondents are glad to have Green Streets in their neighborhood for reasons other than their own quality of life or aesthetic appreciation.

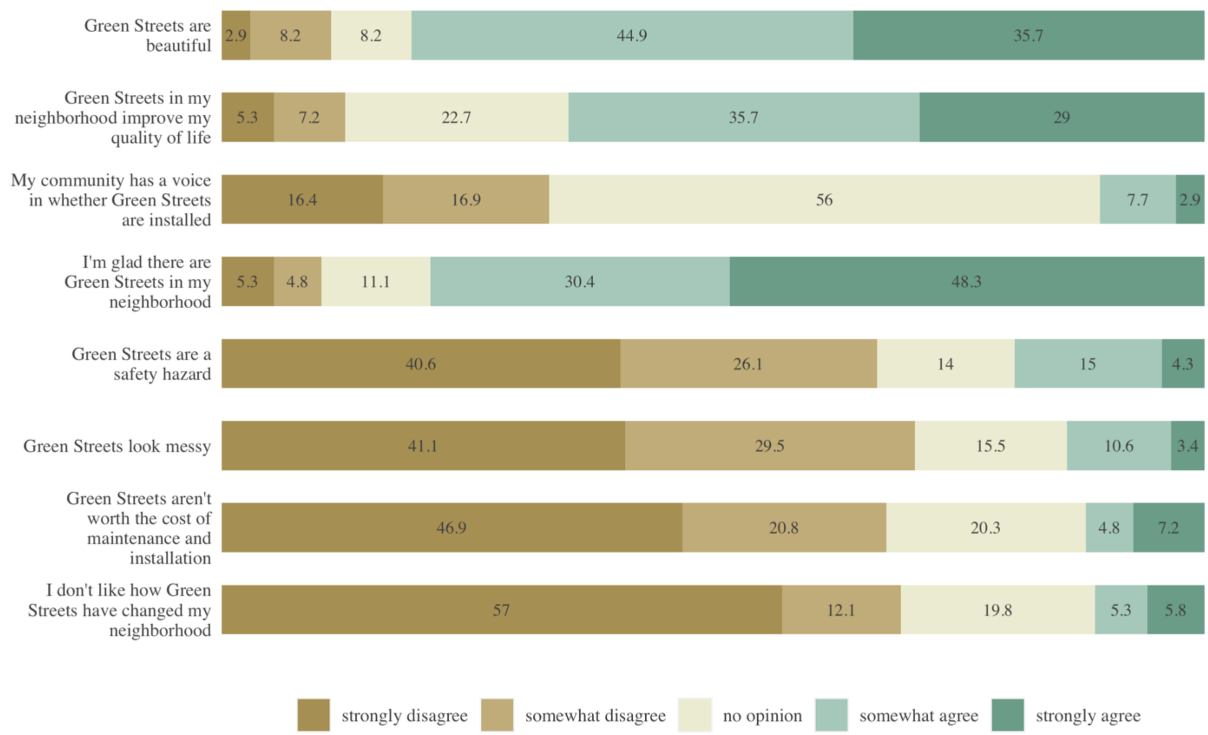

Figure 4.3. Proportional breakdown of survey respondents' level of agreement with various opinions about Green Streets

In contrast to strong agreement with all other positive statements, a majority (56%) of respondents expressed no opinion in response to the statement "my community has a voice in whether Green Streets are installed." This was the only statement for which more than a quarter of respondents expressed no opinion and the only positive statement for which disagreement exceeded agreement. Only 2.9% of respondents expressed strong agreement, the smallest proportion for any statement, either positive or negative. Overall, just 10.6% of responses were in agreement that communities had a voice in Green Street installation while 33.3% were in disagreement.

All negative statements about Green Streets were met with similarly high levels of disagreement, ranging from 66 to 71% of total respondents. The statement "I don't like how Green Streets have changed my neighborhood" garnered the strongest disagreement with 57% of respondents expressing strong disagreement. For all negative statements except "Green Streets are a safety hazard," a greater number of respondents expressed no opinion than expressed agreement, suggesting indifference rather than actively negative sentiment.

When asked for opinions on plants specifically, most respondents expressed an awareness of Green Streets plants and a majority expressed support for plant diversity and a tidy aesthetic (Fig. 4.4). A majority of respondents (72%) disagreed with the statement “I don’t really notice the plants in Green Streets.” Similarly, respondents expressed a preference to diverse planting with over 87% of respondents in agreement and nearly half of total respondents expressing strong agreement with the statement “I like when there are many different types of plants in Green Streets.” While a majority of respondents (59%) agreed that Green Street function was more important than plant aesthetics, an even greater number of respondents (68%) agreed that it was important for Green Street plants to look tidy, highlighting a potential tension between aesthetic and functional priorities.

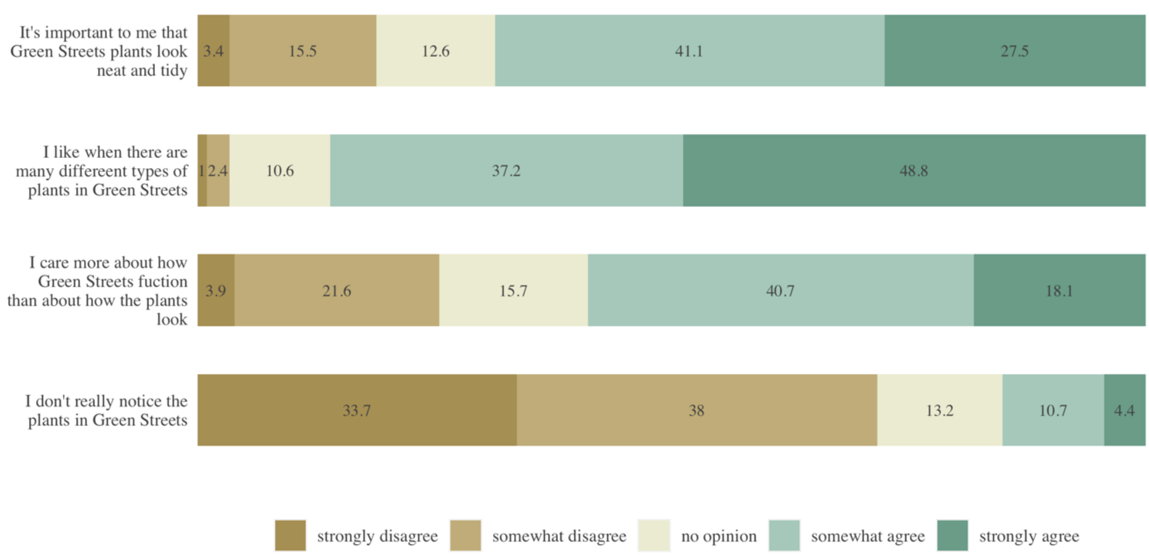

Figure 4.4. Proportional breakdown of survey respondents' level of agreement with various opinions about Green Street plants

Respondents were divided on what potential changes would most improve their opinions of Green Streets (Fig. 4.5a). Better information (24%) and better maintenance (21%) ranked similarly as the two most popular proposals. A notably small number of respondents (n=1) indicated that private funding (and an implicit reduction in taxpayer burden) would alter their opinion. In contrast to the full pool of respondents, individuals who expressed an overall negative or neutral view of Green Streets were more likely to select maintenance and community involvement as changes that would improve their opinions and less likely to select different planting and better information (Fig. 4.5b). Overall, 23% of respondents expressed entrenched views ("none of these [modifications] would change my opinion"). This rate was higher (33%) for those with negative to neutral views of Green Streets.

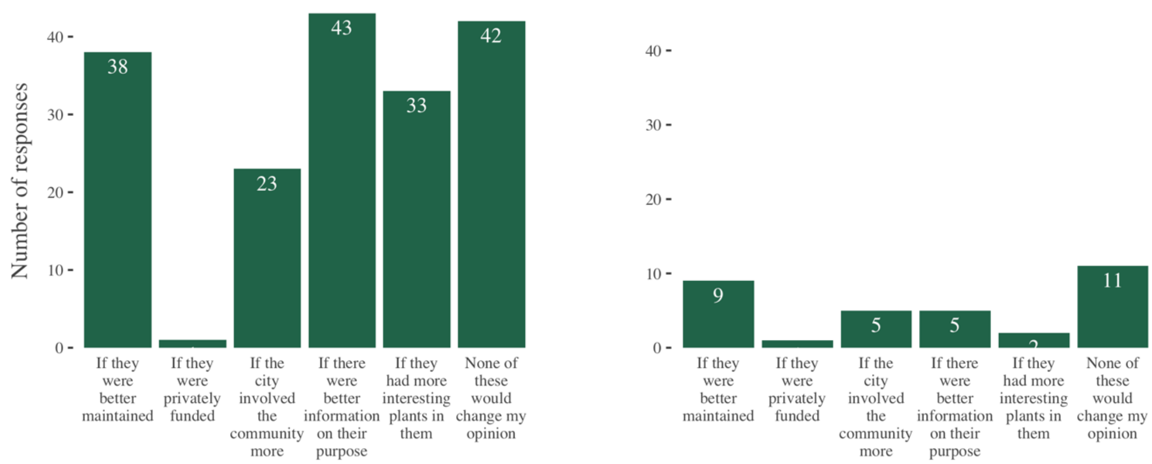

Figure 4.5. Breakdown of responses to the question "The one thing that would most improve my opinion of Green Streets is…" from **A)** all survey respondents (left) and **B)** only survey respondents who expressed overall negative or neutral views of Green Streets (right).

Green Streets interactions

Respondents reported generally moderate to low levels of engagement and interaction with the Green Streets in their neighborhoods (Fig. 4.6). The only activity that a majority of respondents engaged in once a month or more was walking or biking past a Green Street. A majority of respondents (75%) reported stopping to look at plants or animals in a Green Street at least several times a year; just over half of respondents (53%) also expressed thinking about the impact of Green Streets on their neighborhood at least several times a year. Notably, these three most reported behaviors were all passive in nature, including actions like passing by on a walk or bike ride, stopping to look at Green Streets, or reflecting on their role in the neighborhood.

Unsurprisingly, more active forms of engagement were substantially less common among survey respondents. A majority of respondents reported never reading or learning about Green Streets (71%) and never talking about Green Streets with their neighbors (54%). The least commonly reported behavior was volunteering time to maintain a Green Street. While nearly 87% of respondents reported never having volunteered, 55% expressed having at some point removed litter or weeds, a discrepancy which is perhaps reflective of a more ad-hoc form of community stewardship. In further support of this informal stewardship, over 20% of respondents reported engaging in litter or weed removal more than once a month.

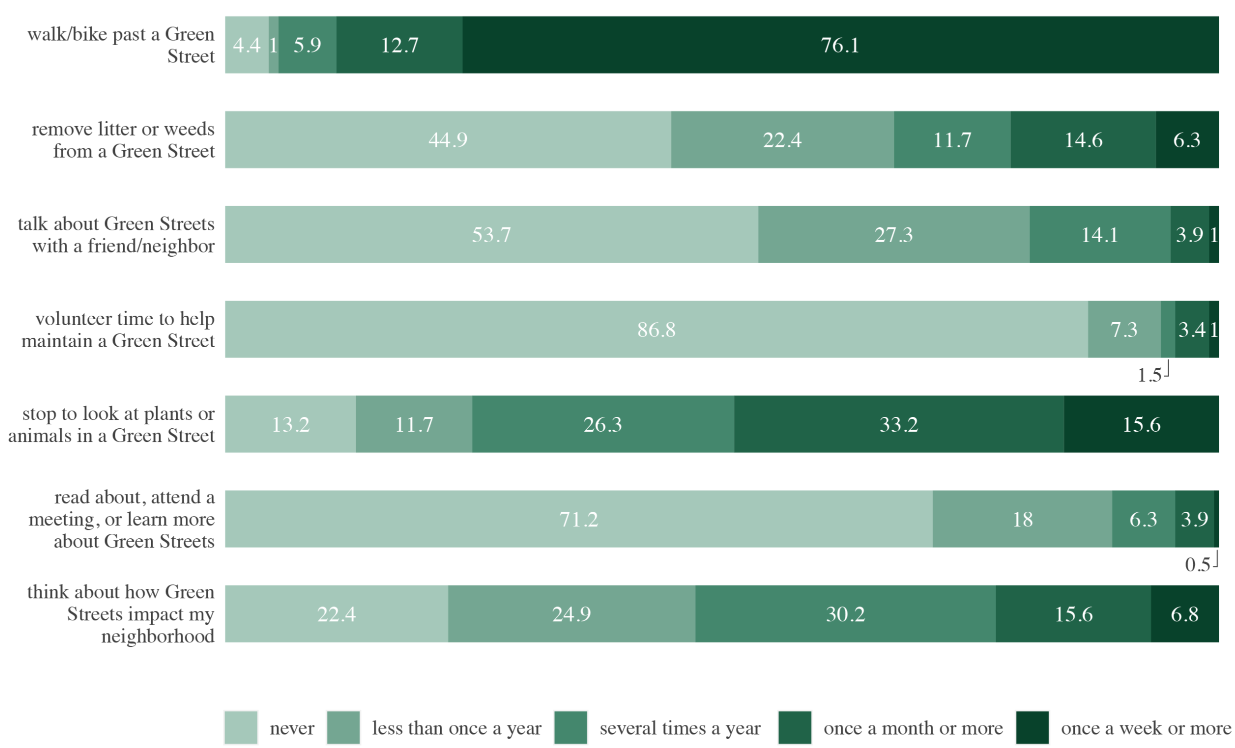

Figure 4.6. Proportional breakdown of survey respondents' ratings of how frequently they participate in a variety of activities related to Green Streets

In keeping with these results, formal participation in Green Streets stewardship activities was very low among survey respondents. Only 3 respondents were members of the Green Street Stewards program with another 9 reporting that they volunteer to help maintain a Green Street through other (unspecified) means. Low stewardship numbers among survey respondents were expected given the overall stewardship participation within study neighborhoods as recorded in datasets provided by Portland BES; only 52 individuals, businesses, or organizations were responsible for all formal GSS stewardship in the three study neighborhoods (15 each in LPG and AL and 22 in MT). When asked to share their feelings about volunteering, just over half (51%) of non-volunteers expressed that they were not aware of the Green Streets Stewards program and would consider participating now that they have learned about it. Other common responses were "too busy" (20%) and "just not that interested" (18%).

Neighborhood variation in survey responses

Variation in respondent demographics

Taken together, demographic variables demonstrate distinct trends for each neighborhood's respondents which align with demographic differences between neighborhoods seen in Census data. MT respondents as a group were the most educated (90% held at least a bachelor's degree) and oldest (76% were over the age of 45), and overwhelmingly identified as white (89%). They had high household incomes (55% over $100,000 a year), were typically homeowners (89%) and a notably high proportion (37%) had been in their homes for more than 20 years. Like MT respondents, AL respondents were also highly educated (80% held at least a bachelor's degree) with similarly high incomes (also 55% over $100,000 a year). However, AL respondents tended to be younger (a plurality of 38% between 35 and 44) and more racially/ethnically diverse than respondents overall (22% identifying as non-white). In comparison to other neighborhoods, AL respondents had shorter housing tenure (43% had been in their homes less than 5 years) and were more likely to be renting than respondents from other neighborhoods (61%, compared to 89% in MT and LPG). Like AL respondents, LPG respondents were similarly younger (also a plurality of 38% between 35 and 44) and more racially/ethnically diverse (20% non-white). As a pool, LPG respondents were lower income (27%

under $35,000) and less educated (42% had not completed a bachelor's degree); while a large majority of LPG respondents were homeowners (89%), their tenure in these homes was shorter than MT respondents.

Variation in Green Streets knowledge, opinions, and interactions

Green Streets familiarity was significantly different across neighborhoods ($H(2) = 27.278$, $p<0.001$) (Fig. 4.7). A pairwise post-hoc Dunn test with Holm adjustment indicates a significantly greater familiarity in MT when compared to both other neighborhoods ($p<0.001$), as anticipated based on the prevalence of past outreach in this area. Only 8% of MT respondents reported never having heard of Green Streets before receiving the survey, in contrast to 23% in AL and 29% in LPG. Similarly, while 46% of MT residents expressed being "very familiar" with Green Streets, only 15% of AL residents and 16% of LPG residents reported being "very familiar."

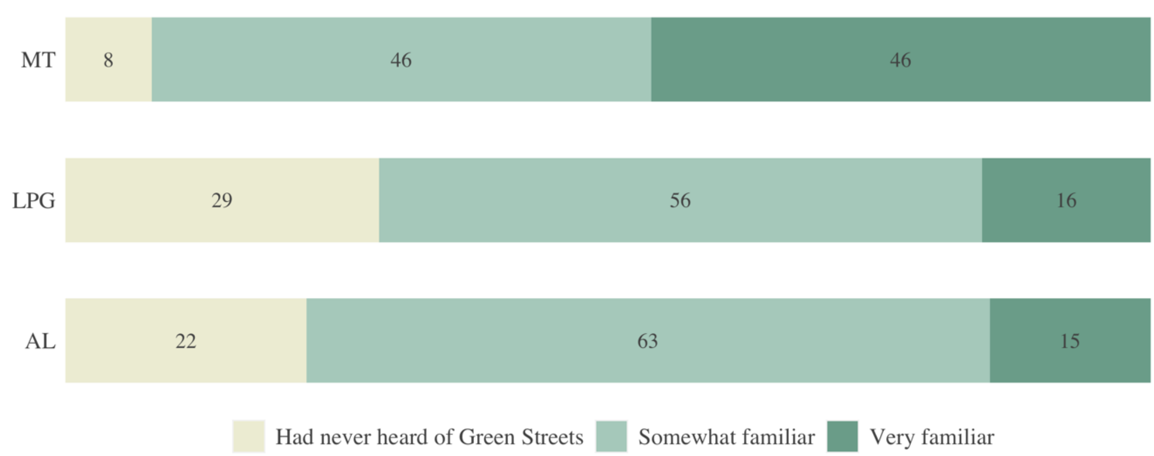

Figure 4.7. Proportional breakdown of survey respondents' reported level of familiarity with Green Streets prior to receiving the survey.

While respondents rated Green Streets' hydrological functionality at similarly high levels regardless of neighborhood, differences emerged in regard to understanding of bioecological and sociocultural functions. There was a significant difference across neighborhoods in the degree to which residents saw Green Streets as helpful for making neighborhoods more pleasant ($H(2)=10.744$, $p=0.005$), providing habitat for wildlife ($H(2)=10.187$, $p=0.006$) and improving property values ($H(2)=10.018$, $p=0.007$). In all cases, AL respondents considered Green Streets significantly more helpful at these functions than did MT respondents (p=0.003, p=0.005, and p=0.006, respectively). No other pairwise comparisons were significant.

Overall opinions of Green Streets were not significantly different by neighborhood, with a majority of respondents in all neighborhoods viewing Green Streets at least somewhat positively and 5% or fewer of respondents expressing strongly negative views (Fig. 4.8). When asked which of several improvements would most improve their opinions, however, each neighborhood's pool of respondents had a different modal response. In AL, 36% of respondents expressed that better information on Green Streets would most improve their opinion (in contrast to 20% in MT and 19% in LPG). Better maintenance was a priority in LPG where 30% of respondents indicated that this would most improve their opinions (in comparison to 20% in MT and 17% in AL). MT respondents appeared to have the most entrenched views on Green Streets when compared to other neighborhoods with 29% of respondents reporting that nothing would change their opinions of Green Streets (in comparison with only 17% in LPG and 16% in AL).

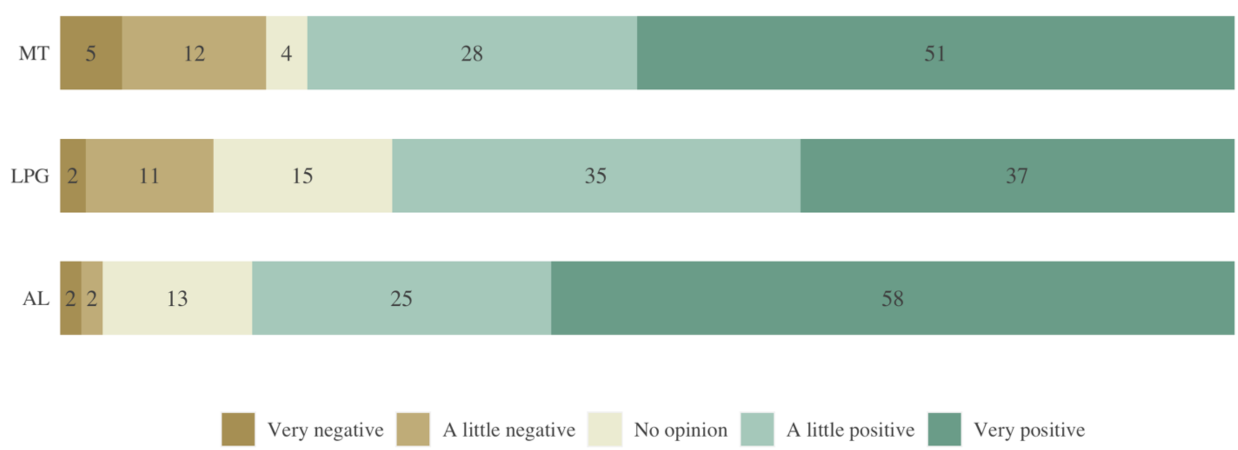

Figure 4.8. Proportional breakdown of survey respondents' expressed overall opinion of Green Streets, reported by neighborhood.

Respondents across neighborhoods were in agreement on many of their opinions about Green Streets, including their perception of Green Streets as beautiful, their opinion of how Green Streets have changed their neighborhood, and the degree to which Green Streets improve their quality of life. Opinions of plants were also not significantly different by neighborhood. However, there was a significant difference across neighborhoods in the degree to which respondents saw Green Streets as messy ($H(2)=8.000$, $p=0.02$) and whether or not Green Streets are worth the cost ($H(2)=9.074$, $p=0.01$). A post-hoc Dunn test confirmed that AL respondents were in significantly greater disagreement than either LPG ($p=0.033$) or MT ($p=0.031$) respondents with the assertion that Green Streets are messy. Similarly, AL residents significantly were more likely to disagree that Green Streets aren't worth the cost when compared to LPG ($p=0.023$) and MT ($p=0.017$) respondents.

Only 12 respondents (5%) across all neighborhoods reported participating in either formal or informal stewardship of Green Streets, three from AL, four from LPG, and five from MT. Only three total respondents reported enrollment in the GSS program; two of these were from LPG and one from MT. Non-stewards were asked to provide more information on their reasons for not engaging in Green Street stewardship. For all three neighborhoods, a plurality of non-stewarding respondents expressed that they did not know about the GSS and would consider participating now that they did know (Fig. 4.9). This sentiment was most prevalent among AL respondents, 59% of whom selected this option, 9 percentage points higher than in MT and 17 greater than in LPG. For all three neighborhoods, "I am too busy" and "I'm just not very interested" were the next most common reasons, with a higher proportion of LPG respondents indicating busyness (24%, compared to 20% and 19% for AL and MT respectively) and a higher proportion of MT respondents indicating disinterest (21% in comparison to 16% and 11% for LPG and AL respectively). Notably, 13% of respondents in LPG indicated feeling unsafe or physically unable to help, an option which was only selected by 4% of respondents from each of the other neighborhoods.

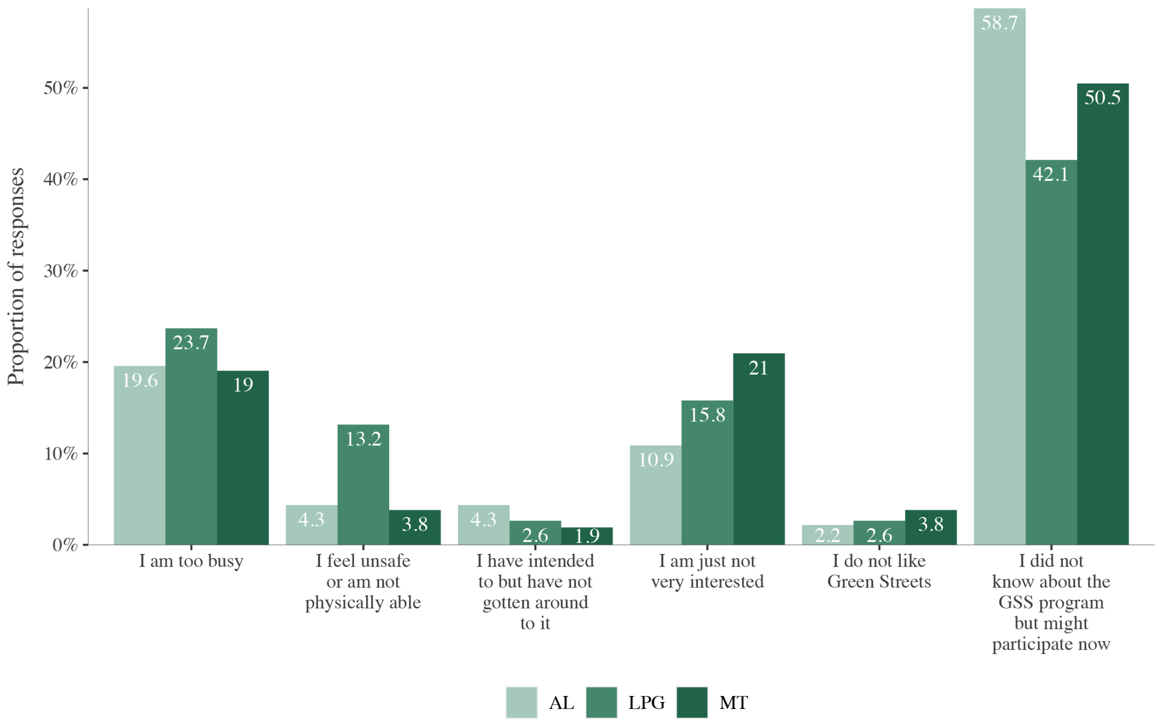

Figure 4.9. Reasons for lack of participation in Green Streets maintenance, reported by neighborhood.

Demographic variation in survey responses

Overall approval of Green Streets was generally high among respondents, with little observed difference across demographic groups. High income, educated, younger respondents were more likely to express approval, however these differences were not statistically significant. Housing tenure was the only ordinal demographic variable for which there was an observed significant effect ($H(5)=24.836$, $p<0.001$). A post-hoc test of pairwise comparisons revealed significant differences between very long-term residents (20+ years) and medium-term residents of both 6-10 years ($p=0.002$) and 11-15 years ($p=0.004$), with significantly lower approval among long-term residents. Notably, respondent age was not a significant predictor of Green Street approval suggesting that this is due to long duration residency per se and not its potential correlation with older age. When specifically asked to respond to the statement "I don't like how Green Streets have changed my neighborhood," 23% of respondents who had lived in their homes for 20+ years agreed, as did

19% of respondents who had been in their homes for 16-20 years; no more than 8% of any other group agreed with this statement.

While long term residents were significantly less likely to approve of Green Streets, these respondents were relatively evenly split on the specific factors that could improve their opinions, with no factor receiving more than a quarter of responses. Indeed, the most frequent response to this question for long-term residents was that nothing would change their opinions (25%). This differed notably from short term residents and renters, both of whom expressed less entrenched views and a desire for more information on Green Streets. Thirty-five percent of short-term residents (<5 years) and 41% of renters said that greater information on the purpose of Green Streets would most improve their opinion; only 14% of renters and 18% of short-term residents expressed that nothing would change their view.

While overall approval was generally similar across demographic groups, differences across both race and income were apparent in regards to which factors would most improve respondent opinions of Green Streets. High income respondents (income >$100,000) were most likely to express wanting better information (30%) and least likely to cite wanting greater community involvement (11%); low-income respondents were more evenly divided in recommendations, with maintenance ranking highest (25%). A majority (65%) of nonwhite residents expressed that either greater community involvement (24%) or better information on Green Street purpose (41%) would most improve their opinion. In contrast, these reasons only accounted for a combined 31% of responses from white respondents, for whom the most preferred change was better maintenance (24%). White respondents were also more likely to express that no changes would improve their opinion of Green Streets (25%, the modal response) when compared to non-white respondents (14%).

Discussion

The purpose of this study was to build upon the scope of existing green infrastructure research in Portland through an expanded geographic scope and an explicit focus on factors relevant to the design, planning, and management of public green infrastructure landscapes. In responding to the study's three research questions, results across three neighborhoods offer several insights about the relationship between place, demographic identity, and perception of green infrastructure.

First, results demonstrate that neighborhoods across Portland tend to share many perspectives on Green Streets. Despite significant differences in their initial awareness of Green Streets, respondents from all three Portland neighborhoods had similarly high levels of approval for these landscapes. Respondents also shared a common understanding of the hydrological function of Green Streets and a common appreciation for plant diversity, function, and aesthetics. In terms of the transferability of past studies (e.g. Shandas, 2015, Church, 2015, Everett et al., 2018), this finding of relative geographic consistency is optimistic, suggesting that conclusions regarding social acceptance and perceptions of green infrastructure may have relevance outside of their initial contexts. However, these findings have more complicated implications for evaluating the efficacy of community engagement efforts. While the concerted efforts of the T2R program are demonstrable in the significantly greater awareness of Green Streets in the MT neighborhood, approval of Green Streets by MT residents was no higher than in LPG and AL, indicating that a change in awareness was not necessarily accompanied by a change in acceptance.

Second, place attachment appears to be a factor in Green Street acceptance but is apparent along temporal rather than spatial dimensions. Duration of residency was found to have an inverse relationship with Green Street approval, with long-term residents expressing significantly more negative views of Green Streets. Long-term residents were also most likely to express not liking how Green Streets had changed their neighborhoods. One explanation for this finding is that over time, residents develop affective connections to their neighborhoods, or "place attachments" (Manzo & Devine-Wright, 2014). Longer-term residents who have spent more time developing these place attachments may find changes to their neighborhood which don't align with their sense of place to be particularly jarring or unwelcome. As place attachment scholars Manzo and Perkins note, "those who feel their relationships to their community places are threatened by redevelopment may consequently resist a proposal regardless of its potential value" (2006). These findings support the work of place attachment researchers which suggest that place attachment plays an important role in perspective on, and engagement with, planning and development initiatives at both the individual and community levels (Mihaylov & Perkins, 2014, Manzo & Perkins, 2006).

As a corollary, this same phenomenon of place attachment may also offer a potential insight into the notably positive perception of Green Streets within the AL neighborhood. AL respondents tended to express slightly (and in some cases significantly) more positive opinions about Green Streets than did respondents from other neighborhoods and also had the lowest proportion of long-duration residents of any neighborhood. Sixty-four percent of AL survey respondents reported having lived in the neighborhood for 10 or fewer years. Given that over half of the neighborhood's Green Streets were constructed more than a decade ago, they are unlikely to disrupt an established sense of place for the majority of residents; indeed, new residents may even have selected the neighborhood due to a new and evolving sense of place which includes Green Streets and which differs from that which most long term residents hold.

The flipside to the prevalence of short-duration resident perspectives among AL respondents is the near-total absence of long-term residents of color among survey respondents. Historically home to a substantial portion of Portland's black community, the AL neighborhood has been a hotspot of recent economic development resulting in the displacement of a large number of the area's long-term black residents. The well-documented move back to Portland's inner-city areas by whiter, more affluent, and educated populations is driven in part by values of walkability and environmental sustainability which have clear relevance to Green Streets (Goodling et al., 2015). The neighborhood's black community has been severely mistreated by past planning and development actions (Legacy Emanuel Medical Center, n.d.) and have demonstrated an understandable skepticism to other sustainability-minded planning initiatives (Lubitow & Miller, 2013). While any interpretation of non-response is necessarily speculative, the potential implications of systemic racism on community interest in, and engagement with, urban design and planning initiatives like Green Streets are hard to discount.

Finally, in regard to the study's final research question, survey participation itself suggests that interest in Green Streets may have a demographic component. Substantial efforts were made in study design to assure the survey was accessible to participants regardless of background. The inclusion of more racially, ethnically, and economically diverse study neighborhoods did appear to improve participation by non-white and low-income community members as well as non-homeowners. Nevertheless, participation by these groups did not achieve levels that are fully representative of neighborhood demographic composition. Furthermore, no surveys were returned in either Spanish or Chinese. These results indicate that while some improvement to participation of traditionally underrepresented groups can be achieved simply through a more inclusive sampling strategy, this is likely insufficient on its own. Particularly for communities who may view public agencies and researchers with skepticism, equity in access may be insufficient to result in equitable representation. Targeted outreach, reliance on trusted community partners, and an emphasis on relationship-building may be helpful for boosting participation in traditionally underrepresented communities (though clearly at the expense of a random sample). Future research could supplement the randomized sampling efforts of the existing study with more targeted, personalized, and educational outreach efforts in specific communities to better represent these perspectives.

While survey responses provide substantial insight into Green Streets opinions, knowledge, and interactions across Portland neighborhoods, there are limitations to the interpretation of these results. A major challenge of survey efforts is achieving a robust and representative sample. Mailed surveys were selected for this project to maximize equity in access and assure geographically targeted recruitment of participants. However, these methods resulted in substantially higher distribution costs than web-based materials, limiting the breadth of survey distribution and reducing the overall pool of potential respondents. Despite this limitation, the survey achieved just above a 12% response rate, resulting in a 6.6% margin of error at a 95% confidence interval. While greater statistical power could be achieved through a larger sample size, these results provide a strong indication of valid neighborhood comparisons and substantial qualitative data with relevance to various planning and design variables.

Given this moderate response rate, however, along with the underrepresentation of certain demographic groups, the potential impact of non-response bias on survey results is worth considering. A particular challenge with technical and esoteric topics like Green Streets is getting individuals with little awareness or understanding of these systems to participate; failing to do so may result in oversampling individuals with more existing knowledge or stronger opinions. While this study attempted to minimize this bias through the use of approachable language and an emphasis on personal experience, the overrepresentation of highly educated respondents and residents who were likely exposed to past outreach efforts suggests that individuals without pre-existing knowledge of green infrastructure may have been less likely to participate. While the qualitative and comparative interpretation of results still offers numerous insights into Green Street perspectives across neighborhoods, it is important to acknowledge that certain views may be underrepresented, including most notably the views of those who lack interest or awareness of Green Streets at all. Anticipating this particular challenge of non-response bias, the current study was designed to critically consider the demographics of respondents as potentially illuminating data itself on Green Streets interest and engagement.

Implications for planting and ecological design

Across neighborhoods, respondents shared a common set of opinions about the plants in Green Streets and a high level of awareness of Green Streets plants, underscoring the relevance of Green Street planting design in residential neighborhoods and providing specific guidance for landscape architects and designers. Respondents were in near-universal agreement about their preference for diverse plantings. While the approved plant list for Portland's Green Streets includes 13 non-tree species, in practice a large proportion of planters throughout east Portland rely on just two dominant species *Carex obnupta* and *Juncus patens*. These "workhorse plants" are known to be effective and hardy in harsh conditions but are often planted in monocultures or outcompete adjacent plants to form large massings which are seemingly in aesthetic conflict with resident preferences. While not abandoning tried and true species, designers and planners might consider prioritizing mixed-species planters in areas of high visibility or residential character.

This tradeoff between plant diversity and established best practice speaks in part to a tension which emerged within survey respondents. While a majority of respondents agreed that plant function was more important than aesthetics, about a quarter of respondents actively disagreed with this statement. Notably, a much higher proportion of respondents expressed positive views about Green Streets than expressed a preference for function over aesthetics. This suggests that while a large majority of respondents support Green Streets, some portion of this support may be predicated on their aesthetic appeal. This underscores the potential benefit to municipalities of investing in creating spaces which meet the aesthetic preferences of residents. With some exceptions, the majority of survey respondents in Portland neighborhoods expressed that they found Green Streets to be beautiful, demonstrating that current BES practices are indeed meeting the aesthetic standards of many residents.

Finally, while respondents expressed strong awareness and interest in Green Streets planting, it is interesting to note that not all respondents appeared to recognize the potential bioecological value of these spaces. When compared to high levels of reported understanding of Green Streets hydrological function, respondents were less confident about the degree to which Green Streets provide habitat or impact climate. This is consistent with Church's findings that views on whether or not Green Streets are examples of "nature" are mixed and that the idea of Green Streets serving as habitat is "for the most part overlooked" (2015, p. 233). Based on unfavorable comparisons offered by interview participants to rain gardens, Church suggests that this perception may be due in large part to the small scale, use of concrete, and limited plant diversity seen in many Green Streets (Church, 2015), further affirming the potential importance of diverse plantings.

Implications for management and maintenance

Past studies have suggested that maintenance is a primary concern regarding urban green infrastructure for community members (Everett et al., 2018). In keeping with this, respondents from all neighborhoods generally expressed a preference for a tidy aesthetic and numerous respondents wrote in comments to this effect. The majority of respondents in all neighborhoods did not express viewing Green Streets as messy, suggesting that the overall level of maintenance that Portland is achieving currently is largely satisfactory to many community members.

Sentiments about maintenance appeared to vary between neighborhoods and may well represent real variation in on-the-ground conditions. Better maintenance was a particular priority in LPG where nearly a third of respondents noted this as the most important change to improve their view of Green Streets. Write-in responses from this neighborhood expressed that Green Streets are not well maintained, and that there are "horrendous trash problems" associated with them in this area. Located on the urban fringe of Portland's east side, the LPG neighborhood is more auto-oriented with multiple large arterials and less well-developed pedestrian infrastructure than other study neighborhoods. A lower-income area with a different development history, this area is frequently cited for its lack of amenities and services when compared to the rest of the city (Griffin-Valade et al., 2014, Portland Bureau of Transportation, 2019). This inequity is likely not directly pertinent to Green Streets maintenance; indeed the city of Portland has put intention into funding green infrastructure in underserved communities (Baker et al. 2019, Entrix, 2016). More likely, the compounding impacts of auto-oriented development and less informal stewardship of interstitial public spaces in this area has resulted in greater negative impacts on Green Streets than those seen in other neighborhoods, which likely increase the amount of maintenance required on facilities in these areas. This highlights the importance of considering place-specific factors when allocating resources to the management of urban green infrastructure.

While only a handful of survey respondents reported engaging in formal or informal Green Streets maintenance actions, a surprisingly large number, around half of all respondents, expressed willingness to do so now that they are aware of the GSS program. While it's unlikely that most respondents will follow through on this claim in practice, widespread receptivity to the idea is itself promising. This strongly suggests that outreach and recruitment efforts could effectively increase participation in community maintenance programs like the GSS since lack of information, rather than active disinterest, appears to be the dominant factor in disengagement. It is worth noting that LPG respondents reported feeling unsafe or physically unable to help with maintenance at a notably higher rate than residents of other neighborhoods. While it's not possible to know the specific barriers these individuals are referencing, the pedestrian infrastructure in this area is clearly less developed and the road network is known to have especially high accident rates in this area (City of Portland, n.d.). As with city contracted maintenance, it may also be important to consider place-specific contextual barriers to community engagement.

Very few residents in any neighborhood expressed concerns about maintenance costs and the use of public funds for Green Streets installation and maintenance. However, several respondents (all residents of MT) expressed disapproval of recruiting community volunteers to help with maintenance since these same community members were paying taxes to fund contracted maintenance. For example, one respondent shared that "city maintenance was a commitment of the city from the beginning of this Tabor to River." While these sentiments were not commonly expressed, they do highlight the importance of messaging and the long memory that communities may have regarding the public planning process. The implication of these comments is that MT residents felt the city had sold them on a program by promising a high-quality amenity and after the fact came back to ask them for maintenance help. Whether founded in reality or not, these perceptions are clearly damaging to resident buy-in and highlight the importance of clear messaging in early engagement efforts.

Implications for community outreach and engagement

Portland's Tabor to the River program, initiated in 2008, has demonstrated a thoughtful approach to green infrastructure development which combines public project implementation with a robust community education and outreach campaign and associated academic studies. The scope and impact of the T2R program is readily apparent in the experience and knowledge of MT survey respondents. Ninety-two percent of respondents in the MT neighborhood were aware of Green Streets before receiving the survey and 90% reported walking or biking by a public Green Street on a weekly basis, significantly more than in other neighborhoods. Furthermore, while demographic variables are likely partially responsible for varied survey response rates between neighborhoods, the magnitude of this difference suggests that previous engagement around green infrastructure may have better prepared MT residents to be interested in and confident about responding to the survey.

Given these notable differences in awareness and engagement, it is surprising to see that overall approval of Green Streets in MT is consistent with other neighborhoods. Despite extensive outreach, MT respondents did not perceive Green Streets as more valuable or beneficial for a variety of functions and were not more likely to volunteer to maintain or interact with Green Streets (apart from walking by them). While their opinions on plants, aesthetics, community inclusion, and maintenance were generally positive and supportive of the program they were no more so than residents of other neighborhoods. This finding raises questions about the efficacy and impact of community involvement in green infrastructure planning and design initiatives.

One interpretation of this finding is that individuals and communities are predisposed to either approve or disapprove of green infrastructure based on pre-existing values such as environmental sustainability. This echoes Shandas' (2015) findings on predictors of stormwater stewardship, specifically that pre-existing personal and community characteristics "interact with biophysical changes either to attract or obstruct public participation in stewardship efforts (p. 16). From this perspective, while programs like T2R can work to increase the total pool of individuals who are aware of green infrastructure, many individuals may be predisposed to have either a positive or negative opinion regardless of the information presented to them. An alternative interpretation of this finding which is more optimistic for the potential impacts of community engagement efforts is that the educational and values-transforming effects of the T2R program actually transcended the spatial delineation of the defined program area by raising awareness of green infrastructure with Portland residents more broadly. Both interpretations hold instructive lessons for involving communities in engagement.

The International Association for Public Participation (IAP2) spectrum of public participation expresses how public participation can range from simply keeping communities informed of plans to giving communities full autonomy of decision-making processes (Fig. 4.10). It is clear that the T2R program has been highly effective at informing the community of urban green infrastructure development yet seems to have had less impact on overall approval rates. The IAP2 spectrum's focus on community member impact on decision-making offers a potential interpretation for this finding and a reflection on how to structure future green infrastructure engagement programs. Targeting engagement efforts not merely at "informing" the public, but at other categories on the spectrum which give community members greater say in the decision-making process may build greater buy-in from residents who would otherwise feel disenfranchised. This sentiment is expressed by one MT resident who wrote:

> When they put in all the new rain gardens on 30th Avenue between Hawthorne and Division, it felt like an insult!. . . I get the intention, but the real life experience of having weird planning decisions imposed on us makes me feel irritable about how ideas get translated in our city.

While it is clear that past outreach efforts in Portland have worked hard to make residents feel included, it is also apparent that for at least some residents, this engagement work has missed the mark in large part because they felt these decisions were "imposed". The overwhelming number of survey respondents who expressed "no opinion" about whether their community had a voice in the installation of Green Streets further suggests that even residents who have no problem with Green Streets are not clear of the role they are able to play in shaping the public landscape of their neighborhoods.

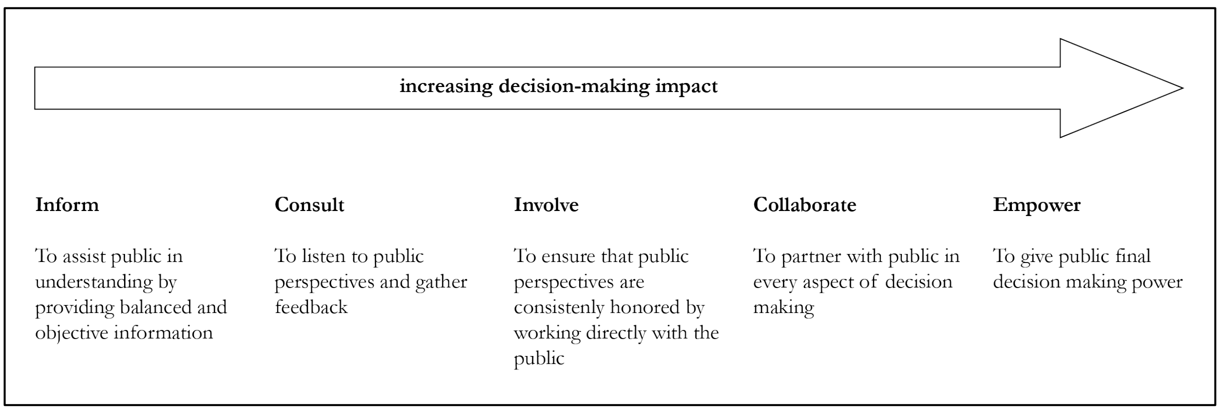

Figure 4.10. IAP2 public participation spectrum. Graphic is adapted from the International Association for Public Participation materials retrieved from: https://www.iap2.org/page/pillars

Finally, although sample sizes were not adequate for robust analyses on the role of race in Green Streets engagement, it is qualitatively apparent that this factor deserves further attention. Most notably, nearly two thirds of non-white respondents expressed that the biggest improvement to their perception of Green Streets would come through either better information or better community involvement. This is a strong indication that communication may be particularly important to residents of color or that existing channels of public communication are not as effective at reaching these residents, particularly since these changes were only preferred by less than one-third of white respondents. Furthermore, the relatively low survey participation by individuals with non-white racial identities suggests that different engagement methods may be needed to reach these communities, both for gathering their opinions and for including them in green infrastructure planning initiatives.

Conclusions

This study attempts to present a more holistic view of sociocultural perspectives on green infrastructure in Portland, Oregon by exploring the views of residents from neighborhoods which have not been represented in past studies. While awareness of Green Streets varied significantly by neighborhood and residents expressed some diverging opinions and behaviors in relation to these spaces, overall approval and opinions were quite similar across neighborhoods. However, lower levels of support for Green Streets among long-term neighborhood residents suggests that established place meanings may impact how residents view the addition of Green Streets to their neighborhoods.

By including more racially and economically diverse neighborhoods which have received less focus in past work and structuring the study to facilitate accessibility, this study attempts to demonstrate an equity-focused approach to research on the built environment. While more diverse neighborhoods did produce more diverse respondent pools, it is clear that equity in access did not itself fully produce equity in participation. This strongly confirms that access is not the only barrier to engaging traditionally underserved communities in urban planning and design research and that community-specific factors which lead to disengagement or distrust of public planning initiatives must be addressed as well.

While past studies have addressed community opinions on green infrastructure in terms of neighborhood change, aesthetics, and educational functions, this study focuses on issues which are of direct management relevance to landscape architects, landscape managers, and city planners. Respondents shared an appreciation for plant diversity and a tidy aesthetic which should be considered in planting design and maintenance practices. A surprising number of respondents expressed willingness to help steward these spaces, indicating that additional recruitment efforts could prove fruitful. Past engagement efforts appear to have been highly effective at improving awareness of Green Streets, though impacts on approval are less clear; future engagement efforts might consider the importance of community agency and personal values when designing outreach aimed at increasing support for green infrastructure.

As cities prepare to meet the climate challenges of the 21st century, green infrastructure is likely to become an increasingly ubiquitous feature in communities across the country and world. Understanding the sociocultural role of these landscapes in residential communities is critical to the development of equitable, place-specific, and community-informed public green infrastructure initiatives. By emphasizing features of these landscapes with direct relevance to designers, planners, and landscape managers, this study contributes tangible insights into the creation of inclusive, aesthetically pleasing, and functional public green infrastructure landscapes in urban neighborhoods.

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CHAPTER V

CONCLUSIONS: REFLECTIONS ON THE INTERDISCIPLINARY STUDY OF HUMAN-ENVIRONMENT RELATIONSHIPS

The Place-Based Study of Human-Environment Relationships

The preceding chapters present an exploration of urban green infrastructure which combines methods from across the natural sciences, social sciences, and humanities to study human-environment relationships through the lens of place. The twofold purpose of this inquiry is 1) to present original research with practical planning and management implications for urban green infrastructure which centers urban ecology and environmental justice alongside more traditional design considerations, and 2) to demonstrate a place-based approach to the study of human-environment relationships in a design context. Chapter 2 provides a theoretical foundation for an interdisciplinary place-based research approach which informed the empirical studies on urban green infrastructure detailed in Chapters 3 and 4.

Chapter 2 provides a theoretical grounding in both discipline-specific and interdisciplinary place-based research practices and probes their potential for illuminating interconnections between social and ecological aspects of landscape systems. In this chapter, I integrate diverse bodies of literature to propose the application of place-based approaches to research in landscape architecture and articulate connections between place-based approaches and theories of human-environment relations (Fig. 5.1)

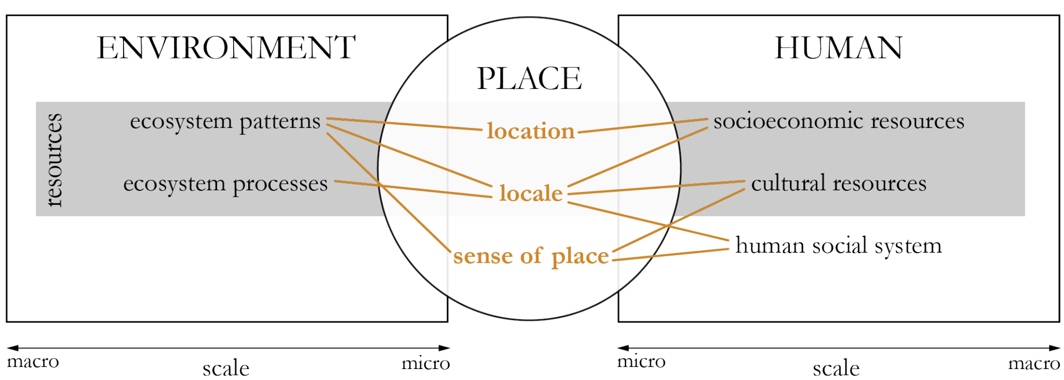

Figure 5.1. Chapter 2 conceptual framework.

Chapter 3 provides an ecological examination of human-environment relationships in Portland's Green Streets through the lens of microbial ecology. I explore variation in Green Street fungal community structure, revealing significant differences across a range of spatial scales and in response to various anthropogenic factors such as street traffic and maintenance regime. This study, which is primarily ecological in nature, examines ecosystem patterns (microbial biogeography) and ecosystem processes (microbial community assembly) in relation to human socioeconomic resources (maintenance and infrastructure); this study emphasizes the locational and locale aspects of place (Fig. 5.2).

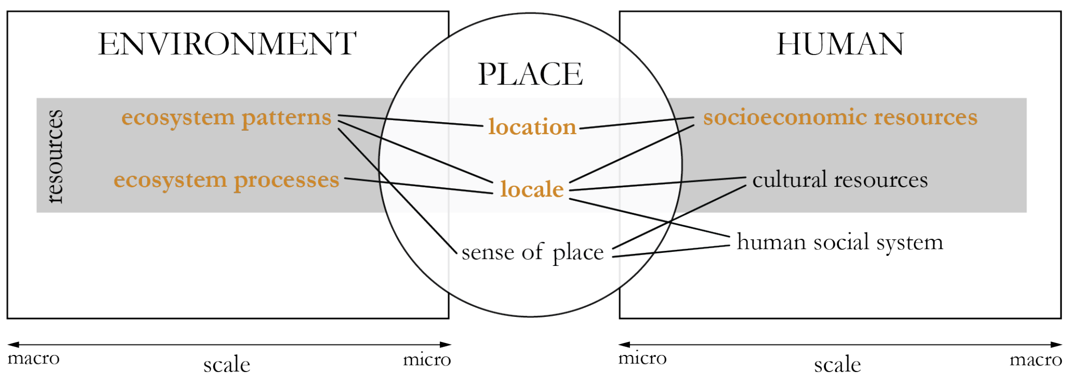

Figure 5.2. Chapter 3 conceptual framework.

Chapter 4 presents a study of the human community response to Green Streets facilities, exploring how community members view and interact with these landscapes with a particular emphasis on the same design and planning variables such as plants and maintenance considered in Chapter 3. I find that while individuals across Portland neighborhoods share positive views of Green Streets both socioculturally and bioecologically, engagement with these spaces is minimal and aspects of place meaning and attachment may influence perceptions of these facilities. This study emphasizes human components of these systems including cultural resources (beliefs and values), socioeconomic resources (maintenance and infrastructure), and various aspects of the human social system (identity, knowledge, and government), and explores the relationship of these components to ecosystem patterns (Green Street location and plant community composition) (Fig. 5.3). This study therefore emphasizes the locale and sense of place aspects of place with a particular emphasis on human values, opinions, and experiences inherent in these human-environment relationships.

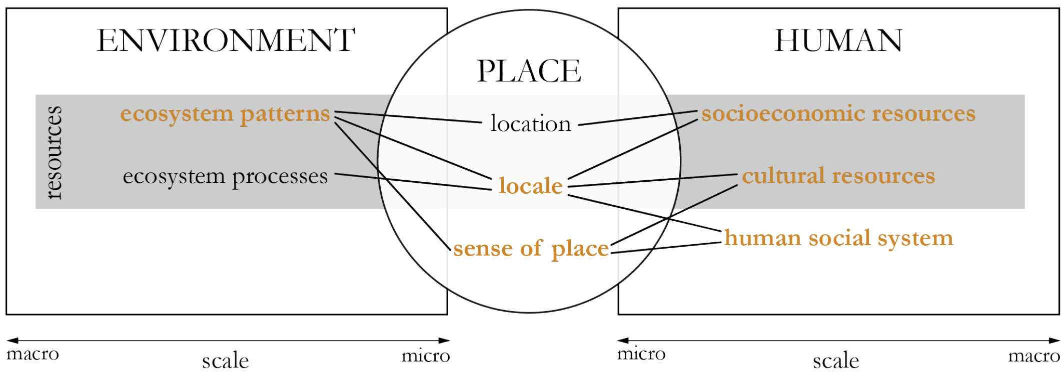

Figure 5.3. Chapter 4 conceptual framework.

Challenges and Future Directions in Place-Based Human-Environment Research

As articulated above, this research was intended to serve two purposes 1) to generate design-relevant knowledge regarding human-environment relationships in Green Streets and 2) to advance an integrated place-based approach to social-ecological research. With regards to the first purpose, each of these examinations has clear relevance to green infrastructure design and management in urban areas, offering insights into the specific ecological (Chapter 3) and social (Chapter 4) variables that contribute to green infrastructure outcomes. The study's contribution to the second, broader purpose, is more complex. The two empirical studies described above each independently demonstrate the relevance and applicability of place-based approaches to the study of human-environment relationships. However, while the results of these studies have relevance within a shared context and place, their methods were insufficiently integrated to facilitate the detailed co-interpretation of bioecological and sociocultural results. This challenge is indicative of several specific opportunities for further refinement and development of the proposed place-based interdisciplinary research approach.

In Chapters 1 and 2, I proposed place-based methods for unifying social and ecological studies and providing shared understanding of complex human-environment relationships. In the subsequent studies, I emphasized place-based approaches within problem identification, context review, and study design (Fig. 5.4). Thus, my social and ecological studies shared a strongly unified theoretical foundation and a common location, locale, and sense of place. The decision to utilize rigorous, discipline-specific methods within each study for data collection and analysis, however, means that these later phases of the research process were less unified, despite their shared place-based approach. The use of unifying themes—plants, maintenance, and community involvement—provided an opportunity for shared interpretation of findings across studies but did not succeed at fully integrating data collection or analysis. A major challenge in this area is the incompatibility of data generated through various methodologies, particularly across disciplinary boundaries. Further exploration into approaches for handling this remains a priority in the study of human-environment relationships.

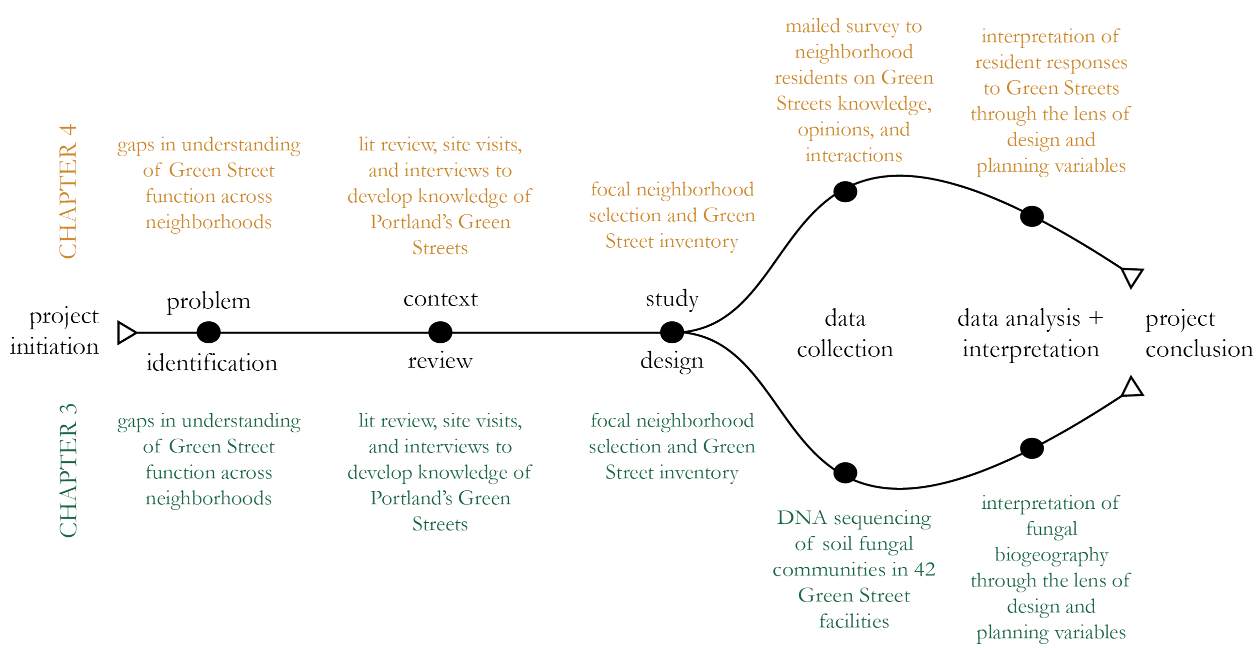

Figure 5.4. Conceptual diagram of the place-based research process used to integrate Chapter 3 and Chapter 4 studies. Place-based approaches facilitated closely coupled methods from problem identification through study design; methods diverged at the data collection phase and were only partially reintegrated during data interpretation.

In the introduction to this dissertation, I proposed the Place-Based Human-Environment Relationship Framework as a model for understanding the role of place in interdisciplinary human-environment research. I successfully employ this model to articulate each independent study within this dissertation (Figs. 5.1, 5.2, and 5.3, above); these study-specific models offer further insights into some of the challenges faced in the co-interpretation of social and ecological results. Each of these studies focused on a different suite of human and environmental factors and emphasized different aspects of the notion of place. Thus, while Chapter 3 focused on locational and contextual factors, Chapter 4 emphasized sense of place in addition to context. This lack of alignment between place-based aspects and their associated human and environment factors offers one perspective on the challenge of integrating social and ecological findings across studies. Considering these factors more specifically within study design (particularly sampling strategy, data collection, and data analysis methods development) will be important in future interdisciplinary studies which employ a place-based approach. The framework may provide a useful guide in this regard, operating as an evaluative tool for ensuring appropriate alignment of place, human, and environmental factors in future study design.

The notion of scale embedded within the framework offers a final area of consideration for future place-based landscape studies. Both environmental and human factors can occur across a range of spatial scales and the grain and extent of interest have substantial bearing on sampling strategies and data collection methods. A unified neighborhood scale was selected for this study which allowed for a shared understanding of context and co-located sampling. However, because this scale was not the primary unit of analysis for either the social or the ecological study, it did not fully resolve the challenges of integrating social and ecological data. Ecological data was collected at the scale of the planter, with the assumption that ecological communities were largely self-contained within these individual sites. Social data was collected at the scale of the household, and while each household was located close to a specific Green Street, it could not be assumed that human experience was limited to their immediate proximity. As such, connecting human responses directly to experiences of individual Green Streets is speculative at best. The difficulty of connecting intangible human experiences and considerations to locational aspects of place is a challenge which requires thoughtful study design to address. I suggest that the scale-based aspects of the framework are a particularly ripe area for future work and the relationship between place and scale warrant further exploration.

Concluding Remarks on Urban Ecology and Environmental Justice

The field of urban ecology is explicit in its acknowledgement of human processes as integral parts of ecological system dynamics (Alberti et al., 2003, Childers et al., 2015, Pickett et al., 2005). Our findings reaffirm this in showing how human choice, action, and behavior have a demonstrable effect on the structure of Green Street microbial communities. With virtually every element of the green infrastructure ecosystem under human control—from plant community composition, maintenance and disturbance regimes, successional dynamics, and physical properties of engineered soil mixes—there is potential to design with soil bioecology in mind. While at present the limited knowledge and awareness of how various factors contribute to microbial diversity and function may limit detailed design guidance, the critical role of microbial agents in an array of important processes from nutrient cycling to pollutant degradation to plant mutualisms implies that planning with microbes in mind is a fruitful avenue of continued investigation. While microbial actors contribute valuable functional benefits to the urban ecosystem, our own actions shape these communities and their attendant capacities to provide the ecosystem services which green infrastructure is prized for. From the urban ecological perspective, in designing our own sociocultural systems and behaviors in urban areas, we are implicitly designing the conditions which set bioecological processes in motion.

At the same time, we found that many people are highly aware of and present with the experience of these ecological systems, reporting high levels of appreciation for plant diversity and a recognition of the importance of Green Streets as functional as well as aesthetic spaces. However, even among these aware and interested individuals, active engagement with Green Streets was very low. Past studies have suggested that Portland residents struggle to see Green Streets as examples of "nature" (Church, 2015). While sidestepping the ontological debate of what constitutes a "natural" system, our findings of tangible anthropogenic impacts on Green Street microbiota on some level supports this idea, namely that Green Street bioecology is not separable from human sociocultural dynamics. However, far from removing these systems from their status as "natural," designers and managers might consider how interpretation around these facilities can make use of contemporary urban ecological theory to present the duality of these spaces as emergent social-ecological landscapes.

Environmental justice provides a lens for understanding the differential risk and privilege which may arise from uneven environmental conditions. Contemporary perspectives on environmental justice which see inequity not as a static condition but rather as an ongoing process (Pellow, 2018) share this emphasis on anthropogenic processes with urban ecological theory. The recognition that microbial communities respond to anthropogenic factors in the built environment re-emphasizes the importance of sociocultural processes in shaping resilient, equitable, and functional urban ecosystems, as well as the importance of embedding concepts of equity within societal definitions of "resilience" and "function." While microbial factors may seem far afield from environmental justice considerations, there is increasing evidence of the importance of the urban microbiome to human health and well-being (Mills, 2019, Robinson et al., 2018, Rook et al., 2014). Though research into the connection between microbiome and equity is still nascent, the recognition that anthropogenic factors can and do influence microbial community structure is a step towards developing strategies for designing with microbial equity in mind.

While the benefits associated with green infrastructure lead most designers and policymakers to consider them a community amenity by default, an environmental justice perspective would suggest that the process by which they are installed and the interests and values which they serve (or are perceived to serve) are critical for understanding community experience of these landscapes. Our survey results strongly suggest that green infrastructure systems do not interest and engage all neighbors evenly and that process-based elements such as communication and engagement may be particularly important in creating green infrastructure landscapes which are supported by communities, and which avoid ecological gentrification. Given the potential tangible impacts on these systems from human interactions, creating urban green infrastructure landscapes that communities are invested in can be seen as both a contribution to urban equity and as well as to ecological resilience and function.

The traditional epistemologies of the biological and social science disciplines do not easily facilitate interdisciplinary collaboration. The emerging emphasis on the validity of place-based approaches to research across fields provides an opportunity to use the specificity of a single location, along with its attendant context and meanings, to reflect upon the intertwined elements of social-ecological landscape systems. Throuhg this work, I hope to offer a precedent for scholars in landscape architecture to transcend disciplinary boundaries in the study of human-environment relationships, with ecological resilience and environmental justice in mind.

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APPENDIX

DATA COLLECTION MATERIALS:

PORTLAND GREEN STREETS NEIGHBORHOOD ENGAGEMENT AND PERCEPTION SURVEY

Dear East Portland Resident,

Have you seen something like this in your neighborhood? These are Green Streets! Our research team at the University of Oregon is studying the communities -- both human and environmental -- of Green Streets.

We hope that you will help us understand how Portland residents (like you!) feel about Green Streets by completing this survey. Your thoughts matter even if you don't know much about Green Streets!

Green Streets are small planted areas built along roads. They are public spaces like sidewalks or parks that are managed by the City. Green Streets provide many benefits to both humans and the natural environment. The City of Portland installs them to help manage stormwater (water from rain storms) and provide green space in the city.

Green Streets are built in many neighborhoods around Portland. Every neighborhood has different assets which make it unique -- assets like social connections, natural amenities, and cultural identities. Our research team is curious how these qualities shape how people feel about Green Streets. What we learn from this survey can help city planners and designers build more livable and inclusive neighborhoods for everyone!

How to complete this survey: Anyone in your household (above age 18) may complete this survey. The survey includes three short sections. The first has questions about you and your neighborhood to help us understand what makes your neighborhood unique. The second section asks you to share your thoughts about Green Streets. The last section includes optional demographic questions to help us analyze our data. We expect the survey will take you less than 15 minutes to complete. ***You may have received a copy of this survey in another language based on your neighborhood's demographics; you may complete the survey in whichever language you prefer.***

We appreciate you taking the time to share your thoughts with us! If you have any questions about this study please feel free to contact me at estaple2@uoregon.edu.

Sincerely, Elizabeth Stapleton

Elizabeth Stapleton, Principal Investigator

NEIGHBORHOOD GREEN STREETS SURVEY

I. In this section, we'd like to learn about you and your neighbors. These questions help us understand the values and resources that make your neighborhood unique.

1. Please rate how much you agree with the following statements about you and your neighborhood:
(1=strongly disagree, 2=somewhat disagree, 3=no opinion, 4=somewhat agree, 5=strongly agree)

	Strongly Disagree	Somewhat Disagree	No opinion	Somewhat Agree	Strongly Agree
I feel safe as a pedestrian and/or cyclist in my neighborhood	1	2	3	4	5
There is not much litter in my neighborhood	1	2	3	4	5
It is easy to purchase fresh fruits and vegetables in my neighborhood	1	2	3	4	5
My neighborhood is well-connected to public transit	1	2	3	4	5
The homes in my neighborhood are beautiful or interesting to look at	1	2	3	4	5

1

(continued on page 2)

(continued from page 1)

	Strongly Disagree	Somewhat Disagree	No opinion	Somewhat Agree	Strongly Agree
I can easily walk to a park or natural area from my house	1	2	3	4	5
I chose to live in my neighborhood partially because of how green it is	1	2	3	4	5
There is not much shade in my neighborhood	1	2	3	4	5
There are places in my neighborhood with beautiful views	1	2	3	4	5
Children in my neighborhood have places to play outside	1	2	3	4	5
Neighbors wave or greet each other in my neighborhood	1	2	3	4	5
Most residents of my neighborhood have lived here for many years	1	2	3	4	5
When I visit businesses in my neighborhood I see people I know	1	2	3	4	5
My neighborhood has public spaces that don't require spending money	1	2	3	4	5
My neighbors and I are connected by a sense of neighborhood pride	1	2	3	4	5
I have time to volunteer in my community	1	2	3	4	5
I am concerned about climate change	1	2	3	4	5
I often think about how my actions and choices affect the natural environment	1	2	3	4	5
I know the names of the trees in my neighborhood	1	2	3	4	5
Many of my neighbors work in their gardens	1	2	3	4	5
I employ someone to work in my home (cleaner, nanny, landscaper, etc.)	1	2	3	4	5
The city invests in programs and infrastructure in my neighborhood	1	2	3	4	5
There are locally owned businesses in my neighborhood	1	2	3	4	5
Homes for sale in my neighborhood are usually bought quickly	1	2	3	4	5
There are vacant buildings in my neighborhood	1	2	3	4	5
Political yard signs are common in my neighborhood	1	2	3	4	5
Local politicians support the interests of my neighborhood	1	2	3	4	5
I always vote in local and national elections	1	2	3	4	5
I feel uncomfortable or unsafe around law enforcement	1	2	3	4	5
Protests, pickets, or demonstrations have happened in my neighborhood	1	2	3	4	5
Many languages besides English are spoken in my neighborhood	1	2	3	4	5
My neighborhood hosts cultural events or festivals	1	2	3	4	5
My neighborhood celebrates its history	1	2	3	4	5
I feel like my neighbors and I have a similar lifestyle and shared values	1	2	3	4	5

2. Please check the box next to the community activities you participate in:

- ☐ I attend a place of worship
- ☐ I am involved in political activism
- ☐ I engage in community service/volunteering
- ☐ I am a member of a service club or fraternal organization (Shriners, Elks, etc.)
- ☐ I am a member of an athletic team or recreation club
- ☐ I participate in a discussion group or book club
- ☐ I am involved with my neighborhood association
- ☐ I am involved with a community arts group or cultural organization (community theater, garden club, etc.)

3. "Neighborhood" can mean different things to different people. Use this map to outline the area you personally consider your neighborhood (you may skip this question if you aren't sure).

II. In this section we'd like to hear your thoughts and opinions about Portland's Green Streets. (It's okay if you don't know much about Green Streets, we're still interested in your opinions!)

4. Were you familiar with Portland's Green Streets before receiving this survey?

☐ Yes, very familiar ☐ Yes, a little familiar ☐ No, I had never heard of them

5. Please rate how much you agree with each of the following statements about Green Streets
(1=strongly disagree, 2=somewhat disagree, 3=no opinion, 4=somewhat agree, 5=strongly agree)

	Strongly Disagree	Somewhat Disagree	No opinion	Somewhat Agree	Strongly Agree
Green Streets are beautiful	1	2	3	4	5
Green Streets are a safety hazard	1	2	3	4	5
Green Streets look messy	1	2	3	4	5
Green Streets aren't worth the cost of maintenance and installation	1	2	3	4	5
Green Streets in my neighborhood improve my quality of life	1	2	3	4	5
I don't like how Green Streets have changed my neighborhood	1	2	3	4	5
My community has a voice in whether Green Streets are installed	1	2	3	4	5
I'm glad there are Green Streets in my neighborhood	1	2	3	4	5

6. How would you describe your opinion of Green Streets in your neighborhood overall?

- [ ] Very negative
- [ ] A little negative
- [ ] No opinion
- [ ] A little positive
- [ ] Very positive

7. "The one thing that would most improve my opinion of Green Streets is…"

- [ ] If they were better maintained
- [ ] If they were privately funded
- [ ] If the city involved the community more
- [ ] If there were better information on their purpose
- [ ] If they had more interesting plants in them
- [ ] None of these would change my opinion

8. Plants are an important part of Green Streets. Please rate how much you agree with each of the following statements about plants:
(1=strongly disagree, 2=somewhat disagree, 3=no opinion, 4=somewhat agree, 5=strongly agree)

	Strongly Disagree	Somewhat Disagree	No opinion	Somewhat Agree	Strongly Agree
It's important to me that Green Streets plants look neat and tidy	1	2	3	4	5
I like when there are many different types of plants in Green Streets	1	2	3	4	5
I care more about how Green Streets function than about how the plants look	1	2	3	4	5
I don't really notice the plants in Green Streets	1	2	3	4	5

9. People interact with Green Streets in different ways. Please rate how often you participate in the following activities:
(1=never, 2=less than once a year, 3=several times a year, 4=once a month or more, 5=once a week or more)

	never	less than once a year	several times a year	once a month or more	once a week or more
walk/bike past a Green Street	1	2	3	4	5
remove litter or weeds from a Green Street	1	2	3	4	5
talk about Green Streets with a friend/neighbor	1	2	3	4	5
volunteer time to help maintain a Green Street	1	2	3	4	5
stop to look at plants or animals in a Green Street	1	2	3	4	5
read about, attend a meeting on, or learn more about Green Streets	1	2	3	4	5
think about how Green Streets impact my neighborhood	1	2	3	4	5

10. Do you help maintain a Green Street?

- [ ] Yes, I am part of the Green Street Stewards program (skip question 11)
- [ ] Yes, I help care for a Green Street but I am not part of the Green Street Steward program (skip question 11)
- [ ] No, I do not help maintain a Green Street (answer question 11)

11. If you responded "No, I do not maintain a Green Street," which of the following best describes your feelings?

- ☐ I am too busy to help maintain Green Streets
- ☐ I feel unsafe or am not physically able to help maintain Green Streets
- ☐ I've intended to help but haven't gotten around to it yet
- ☐ I'm just not very interested in helping maintain Green Streets
- ☐ I don't like Green Streets and don't want to support their maintenance
- ☐ I didn't know about the Green Street Stewards program but might participate now that I know of it

12. Green Streets can provide many important functions in cities. Based on your current understanding, please rate how helpful you think Green Streets are for:

	very helpful	somewhat helpful	not at all helpful	no opinion
preventing urban flooding	☐	☐	☐	☐
keeping our waterways clean	☐	☐	☐	☐
making neighborhoods more pleasant	☐	☐	☐	☐
providing habitat for wildlife	☐	☐	☐	☐
combating climate change	☐	☐	☐	☐
improving property values	☐	☐	☐	☐
teaching people about the environment	☐	☐	☐	☐

III. This section helps us learn a little more about you and your household. You may leave any of these questions blank if you would prefer not to answer.

13. Which describes your home ownership status?

- ☐ I own my home
- ☐ I rent my home

14. How long have you lived in this home?

- ☐ Less than a year
- ☐ 1-5 years
- ☐ 6-10 years
- ☐ 11-15 years
- ☐ 16-20 years
- ☐ 20+ years

15. What languages are spoken in your household? (select all that apply)

- ☐ English
- ☐ Chinese
- ☐ Russian
- ☐ Spanish
- ☐ Vietnamese
- ☐ Other:__________________

16. What is your age?

- ☐ 18 - 24
- ☐ 25 - 34
- ☐ 35 - 44
- ☐ 45 - 54
- ☐ 55 - 64
- ☐ 65+

17. What is your educational background?

- ☐ Some high school or less
- ☐ High school diploma/GED
- ☐ Some college
- ☐ Associate degree or vocational schooling
- ☐ Bachelor's degree
- ☐ Graduate degree

18. How do you identify racially/ethnically? (select all that apply)

- ☐ Asian
- ☐ Black/African-American
- ☐ Hawaiian/Pacific Islander
- ☐ Hispanic
- ☐ Indigenous American/American Indian
- ☐ Latino/a
- ☐ White/Caucasian
- ☐ Other:___________________

19. What is your annual household income?

- ☐ Less than $15,000
- ☐ $15,000 to $24,999
- ☐ $25,000 to $34,999
- ☐ $35,000 to $49,999
- ☐ $50,000 to $74,999
- ☐ $75,000 to $99,999
- ☐ $100,000 to $149,999
- ☐ $150,000 or more

If you would like to be entered in a drawing for one of five $10 Fred Meyer gift cards as a thank you for your time, please provide a phone number or email address here (we won't contact you for any other reason).

Phone/Email: ____

Questions? More thoughts you'd like to share?

If you have additional comments or questions you'd like to share with our research team, please feel free to email principle investigator Elizabeth Stapleton at estaple2@uoregon.edu.

Thank you so much for taking the time to participate!

ID: LPG________