Governing Green Infrastructure:

Multi-Level Dynamics Shaping Climate Resilience and Equity in Toronto

By:

Jack Walsh

Supervised by:

Mark Winfield

A Major Paper submitted to the Faculty of Environmental and Urban Change in partial fulfillment of the requirements for the degree of Master in Environmental Studies

York University, Toronto, Ontario, Canada

July 31, 2026

ABSTRACT

Green infrastructure has emerged as a central planning approach for addressing climate change, biodiversity loss, and urban livability. However, its growing popularity has also resulted in considerable conceptual ambiguity, as governments and practitioners define and implement the concept in different ways. This paper examines how differing definitions and governance arrangements across federal, provincial, regional, and municipal levels influence the implementation of green infrastructure in Toronto and considers the implications for climate resilience and equity. Drawing on Urban Political Ecology, spatial justice, and the broader literature, the research develops a working definition of green infrastructure that emphasizes climate resilience, equitable distribution, and conceptual clarity. A classification system of green infrastructure typologies is used alongside the working definition to systematically evaluate government publications and assess how each level defines green infrastructure, employs related terminology, identifies qualifying typologies, and frames the intended functions and benefits of the approach. Illustrative examples of intergovernmental projects are subsequently examined to demonstrate how differing conceptualizations shape implementation in practice. The findings reveal variation and incompleteness in how green infrastructure is defined, inconsistent relationships with overlapping concepts such as natural infrastructure, nature-based solutions, and low impact development, and minimal guidance on its physical forms and functions. This ambiguity constrains the range of features that can be included and ultimately limits the scope of ecosystem services that can be realized through implementation. These differences complicate collaboration and create uncertainty regarding eligible interventions and intended outcomes. The paper concludes that improving conceptual clarity, while preserving sufficient flexibility for local contexts, would strengthen coordination across governments and support more equitable and climate-resilient implementation of green infrastructure in Toronto and across Canada.

KEY WORDS: Green infrastructure, climate resilience, social equity, definitional ambiguity, intergovernmental collaboration.

FOREWARD

This Major Paper fulfills the final requirement for the Master in Environmental Studies (Planning) Program at York University. My Plan of Study focuses on how cities can better prepare for the immense and varied challenges posed by climate change. Together with the coursework completed throughout the program, the three core components of my Plan of Study are satisfied through the completion of this paper.

The first component, 'Urban Planning,' is addressed through an in-depth examination of the features of green infrastructure, the ways planners integrate these features into built environments, and the review of how these solutions can further integrate community perspectives for a more socially inclusive process to improve the cultural benefits that come with the approach. The second component, 'Climate Resilience, Mitigation, and Adaptation,' is fulfilled by the developed understanding of the local impacts of climate change and the ecosystem services provided by green infrastructure to help cities both adapt to changing weather patterns and mitigate future risks. Lastly, the third component, 'Policy and Governance Systems,' is satisfied through engagement with government publications central to the conceptualization of green infrastructure in Toronto, and through analysis of how policies across municipal, regional, provincial, and federal orders of government align to identify opportunities for improved coordination for the purposes of climate resilience and social equity.

ACKNOWLEDGEMENTS

Thank you to York University and its faculty for welcoming me into this program and providing the space to learn, grow, and prepare for my future beyond my graduate studies.

I extend my sincere gratitude to my research supervisor, Mark Winfield, whose quick responses, thoughtful guidance, and steady encouragement strengthened not only my research but also my confidence in my ability to complete this project. I am also grateful to my advisor, Liette Gilbert, for her support in keeping me on track throughout my degree, and for taking me on late despite an already full supervisory load.

Thank you to my family, partner, and friends for their curiosity about my research and for providing the support I needed outside of my project, which made it possible for me to complete the work required within it.

TABLE OF CONTENTS

1. Introduction 1

2. Literature Review 3

3. Methodology and Research Design 15

4. Government Document Analysis 23

4.1 Government of Canada 23

4.2 Government of Ontario 29

4.3 Toronto and Region Conservation Authority 32

4.4 City of Toronto 36

5. Illustrative Examples of Green Infrastructure Projects in Toronto 40

6. Conclusions and Paths Forward 45

6.1 Summative Discussion 45

6.2 Constructive Paths Forward 48

6.3 Broader Implications 51

6.4 Limitations of Research 52

References 54

APPENDIX A 60

APPENDIX B 62

LIST OF FIGURES

Figure 1. Spatial Distribution of Green Infrastructure Projects in Toronto Compared to Green Infrastructure Equity Index..... 41

Figure 2. Hierarchical Organization of Green Infrastructure Terminology..... 49

Figure A1. Green Infrastructure Typologies by Average Regulating and Cultural Service Scores..... 61

Figure B1. Assessment Matrix Used to Create the Classification System..... 62

Figure B2. Principal Component Analysis of Green Infrastructure Typologies..... 63

Figure B3. Relationship Between Green Infrastructure Typologies and Application Scales..... 64

Figure B4. Normalized Matrix Used for Classification System..... 65

LIST OF TABLES

Table 1. Summary of Green Infrastructure Projects Included in the Analysis..... 42

Table A1. Decision Making Process for Selecting Classification System Typologies..... 60

Table A2. Classification System of Green Infrastructure Publications..... 61

Table B1. AGEL Scores for 14 Green Infrastructure Types and 22 Ecosystem Services..... 66

LIST OF ABBREVIATIONS

BGI – Blue Green Infrastructure

BMPs – Best Management Practices

DMAF – Disaster Mitigation and Adaptation Fund

ECCC – Environment and Climate Change Canada

EPA – Environmental Protection Agency

GHG – Greenhouse Gas

GOCAAP – Government of Canada Adaptation Action Plan

IPCC – Intergovernmental Panel on Climate Change

LCP – Living City Policies

LID – Low Impact Development

MA – Millennium Ecosystem Assessment

NAS – National Adaptation Strategy

NBS – Nature-Based Solutions

NIA – Neighbourhood Improvement Area

NIF – Natural Infrastructure Fund

PPS – Provincial Policy Statement

SUDS – Sustainable Urban Drainage Systems

TRCA – Toronto and Region Conservation Authority

UHI – Urban Heat Island

UPE – Urban Political Ecology

WSUD – Water Sensitive Urban Design

1. Introduction

Populations worldwide are shifting toward cities. The United Nations' World Urbanization Prospects (UN DESA, 2025) reports that in 1950, just one-fifth of the world's population lived in cities. Cities overtook the collective populations of rural areas by the mid-1970s, and the same was true of towns in 1996. By 2025, cities accounted for 45 percent of the world's 8.2 billion people and are projected to account for 68 percent in 2050. Canada's cities reflect global trends, with over 31 million people, or approximately 76 percent of the country's population, residing in urban centres with at least 100,000 people (Statistics Canada, 2026).

As Canada's largest city, Toronto faces the same climate-related pressures that are affecting urban areas worldwide, as population growth is accompanied by a growth in climate-related risks. Cities are increasingly responsible for preparing for and adapting to the accelerating changes in natural systems and the global climate. The Intergovernmental Panel on Climate Change (IPCC, 2021) warns that human influence has warmed the climate at a rate unprecedented in at least the last 2,000 years. Each of the past four decades has been warmer than the last, with rising greenhouse gas (GHG) concentrations driving rapid and widespread shifts in the atmosphere, oceans, and cryosphere. Human-induced climate change is intensifying extreme weather, including more frequent heatwaves, heavy rainfall, and agricultural droughts. At the same time, urbanization and the extensive land cover of cities have disrupted the balance between built environments and natural ecosystems, heightening the vulnerability of both urban populations and the ecological systems that support them (Zarei & Shabab, 2025). Dense built form, extensive impervious cover, and localized pollution already exacerbate climate-related hazards in cities, and these effects are expected to intensify significantly by mid-century, further amplifying the health risks faced by urban populations (Kumar, 2021).

Cities themselves are major contributors to global GHG emissions, accounting for an estimated 67-72 percent of the global total in 2020 (Lwasa et al., 2022). As a result, urban areas are not only on the front lines of climate impacts but are also central drivers of the warming that intensifies them. Current emissions trajectories indicate that global surface temperatures will continue to rise until at least 2050, likely exceeding 1.5°C and 2°C thresholds without substantial reductions in carbon output (IPCC, 2021). Although Toronto is taking action to reduce emissions by committing to a 2040 net-zero target (City of Toronto, 2026c), the city remains exposed to both internal and external forces of global climate change. As a result, Toronto must also pursue strategies that enhance its ability to adapt to changing climate conditions and build resilience to these increasingly unavoidable risks.

One measure Toronto and many other cities are taking to reduce the impacts of climate change is the implementation of green infrastructure. Green infrastructure is widely understood to be an effective strategy for decreasing the vulnerability of urban environments to extreme weather events and harmful environmental conditions, while also providing social and cultural benefits that support overall well-being. However, despite its growing prominence and recognition for these environmental and socio-cultural benefits, it remains a contested term that has frequently been described as ambiguous, conceptually fragmented, and geographically dependent (Matlser et al., 2021). This issue is not merely semantic; the way green infrastructure is defined directly shapes policy design, implementation, and the distribution of benefits. This lack of definitional clarity can hinder effective governance, as policymakers and practitioners may struggle to coordinate programs, allocate resources, or evaluate outcomes when the concept itself is inconsistently understood.

To examine how policy shapes Toronto's green infrastructure programs, this study is guided by the following research question: *How is green infrastructure defined and governed across federal, provincial, regional, and municipal levels in Toronto, and what are the implications for climate resilience and equity in the city?*

To answer this question, this study analyzes publications from the Government of Canada, the Government of Ontario, the Toronto and Region Conservation Authority (TRCA), and the City of Toronto. Each level is assessed on how green infrastructure is defined, the contexts in which it appears, the physical examples it includes, the benefits attributed to it, and the issues it is intended to address. These findings are then compared across levels of government to evaluate alignment, divergence, and the extent to which multi-level governance structures support or hinder climate and social equity goals in Toronto.

A review of relevant literature was first conducted to compile information on the history, evolution, purposes, and challenges of green infrastructure and its vast array of typologies. The literature informs a classification system used to analyze the characteristics of green infrastructure typologies across government levels, including their scale, functional category, and the ecosystem services they provide. A framework combining Urban Political Ecology (UPE) and spatial justice is also used to establish a working definition of green infrastructure to determine criteria for what effective definitions should include. The classification system and working definition support the evaluative framework used to assess how each level of government defines green infrastructure, what priorities are emphasized, and what elements are missing. Examples of green infrastructure projects in Toronto are then used to explore how variation in policy and governance structures shape the on-ground implementation. The findings from the policy review and case examples are synthesized to assess the coherence of Toronto's green infrastructure governance, including the ways the concept is articulated, the priorities it advances, and the arrangements that shape

implementation. Ultimately, the study offers recommendations for strengthening green infrastructure policy to better support climate resilience and social equity targets.

This research addresses several gaps in the current understandings of green infrastructure policy. While attention to the importance of definitional clarity has grown in recent years, and Conway et al. (2020) have examined divergent meanings of the concept in the Greater Toronto Area, no study has yet compared how the multiple levels of government in Canada define and govern green infrastructure in relation to the country's largest city. This study also contributes methodologically by developing a classification system that synthesizes several organizational approaches found in the literature. By integrating multiple ways of categorizing green infrastructure typologies, the system enables a more comprehensive assessment of how specific interventions are framed in policy and what goals they implicitly advance. Moreover, while several studies document inequities in the distribution of green infrastructure in Toronto, far fewer examine how policy frameworks themselves shape these inequities, which is a focus of this research through the UPE and spatial justice framework. Furthermore, as research advances, climate change accelerates, and government priorities shift, the policy materials shaping green infrastructure are constantly evolving, demonstrating the need for updated analysis.

This study is significant because it translates commonly cited concerns regarding green infrastructure into actionable insights. It provides a base for policymakers and planners to build on by clarifying how green infrastructure is understood across the institutions that shape Toronto's climate response. The research seeks to offer insights into where governance structures support or constrain equitable and resilient implementation so policy coherence can be strengthened overall. More broadly, the research provides a framework that can be replicated in other Canadian cities or adapted to international contexts, contributing to ongoing efforts to align urban climate resilience strategies with social and environmental equity goals. As climate impacts intensify, green infrastructure represents a critical and immediate tool for buffering cities against worsening environmental conditions, complementing long-term mitigation efforts, and serving as a foundation for urban resilience and well-being.

2. Literature Review

This literature review examines how green infrastructure has evolved conceptually and functionally within urban planning, climate governance and other related fields. To appreciate why the contemporary use of the term can produce confusion and misalignment between researchers, policymakers, and practitioners, it is necessary to trace its historical development and evolution from previous concepts, its vast array of physical forms, its transforming applicability to modern urban challenges, and its fragmented and contested terminology.

The term “green infrastructure” is reported to first be recorded in academic literature in 1995. Seiwert and Rößler (2020) explain that two American papers published that year titled “Greenways and the making of urban form” and “Green infrastructure and landscape architects help design a statewide greenways network for Florida,” broke ground for the concept in academic debate. However, a 1996 article titled “The search for the sustainable city in 20th century urban planning” references green infrastructure as early as 1994, and credits John T Lyle, an American planner interested in combining regenerative elements with natural water systems, for the invention of the term. By the end of the decade, green infrastructure had already gained significant traction and was seen as an important strategy for sustainable development in the United States.

Since early explorations of the concept are tied to an American context centred on the nascent development of greenways, the United States’ first comprehensive and integrative attempts at green infrastructure are said to have begun before the term was created in 1990 in Maryland. One year later, similar efforts emerged in Florida as part of the nationwide greenway initiative, which aimed to protect open space and connect urban and rural landscapes with a primary focus on leisure and recreation (Seiwert & Rößler, 2020). While the term is inextricably tied to greenways, green infrastructure’s underlying principles date further back than the 1990s. A commonly cited precursor to green infrastructure discussion in planning is the garden city model. Developed by Ebenezer Howard, a British social reformer, the garden city is argued to serve as a framework for modern day green infrastructure solutions (Asibey et al., 2024). In response to the late 19th century’s rapid urbanization and industrialization of European cities, Howard envisioned a new way to plan cities; instead of sprawling urban development, garden cities would be surrounded by a greenbelt to prevent experienced overcrowding, reduce health concerns, and preserve nature. As Absibey et al. (2024) explain, garden cities, just like green infrastructure, emphasize interconnected greenery and protected open spaces to prioritize public health and environmental quality, and argue that natural features cannot be an afterthought to traditional infrastructure.

There are, however, earlier renditions of green infrastructure that precede garden cities, and are commonly credited for shaping more modern planning approaches and policy language (Seiwert & Rößler, 2020). Frederick Law Olmsted was an American landscape architect who is widely considered a primary founder of the professional urban planning movement in the United States. Eisenman (2013) notes that Olmsted’s career was dedicated to addressing the “lamentable living conditions” caused by urbanization, such as contaminated water and polluted air. Olmsted, alongside Calvert Vaux, is credited for the design of Central Park in New York City in 1858. Having learned from his work on Central Park, Olmsted, recognizing the limitations of a single park’s benefits, created a revolutionary interconnected park system in Buffalo, and continued similar work in Boston.

Because of his work in American cities, Olmsted's intuitive understanding of the link between nature and human well-being has him recognized as an originator of green infrastructure who laid the legacy work for the development of ecosystem services, a concept now central to green infrastructure, long before either term ever existed.

Today, there is a great focus on the ecosystem services that green infrastructure provides as way to quantify the benefits of the planning tool. While Olmstead, Howard, and others who progressed the field of environmental planning understood the benefits nature can provide to humans in urban settings, the origins of the modern history of ecosystems services did not emerge until the 1960s and 1970s. During this time of environmental revolution, Gómez-Baggeth et al. (2010) describe the shift in the framing of the functions of natural capital as a way to increase public support in biodiversity conservation. While this greater attention on the connection between humans and their natural environments grew, it was not until 1981 that Paul and Anne Ehrich coined the term "ecosystem services".

A key event in the timeline of defining ecosystem services in a more systematic and policy-relevant way was the Millennium Ecosystem Assessment (MA), a United Nations-mandated global scientific initiative launched in 2001, which involved more than 1,300 experts from 95 countries. Its overarching aims were to improve decision-making related to ecosystem management and human well-being, and to build global capacity for conducting large-scale environmental assessments (Millennium Ecosystem Assessment, n.d.). The synthesis report published in 2005 by the MA formalized the now-standard four categories of ecosystem services to help identify priorities for conservation and sustainable use.

The first outlined category is provisioning services, which are the tangible products obtained from ecosystems. This includes food, water, timber, and other important resources. The MA outlines regulating services next, which are described to be the regulating benefits obtained from ecosystem processes, such as climate and disease regulation, flood control, water purification, heat mitigation, and waste treatment. The report also outlines cultural services, which are described to be the spiritual, cognitive developmental, recreational, and aesthetic experiences provided by nature. Lastly, supporting services are also identified, which are the services necessary for the production for all other ecosystem services. Supporting services are described to be often indirect and occur over longer periods of time, including the formation of soil, photosynthesis, and nutrient cycling (Millenium Ecosystem Assessment, 2005). Seiwert and Rößler (2020) highlight how, following the formalization of ecosystem services, green infrastructure became increasingly linked to the concept as the physical and spatial representation through which ecological functions provide ecosystem services, given that ecosystem services themselves have no direct spatial reference.

Although the concepts of ecosystem services and green infrastructure had not yet become closely linked in the literature in the late 20th century, the earliest and strongest connection between them lay in cultural services, as greenways and other early forms of green infrastructure emphasized recreation, social cohesion, and scenic beauty. While researchers still explore a wide range of benefits provided by green infrastructure, much of the attention has since shifted toward the approach as a climate change strategy. Despite regulating ecosystem services provided by green infrastructure being more complex, impacts of climate change and extreme weather events have brought them to greater attention as cities seek solutions (Hanna et al., 2023). This pattern is reflected in a review by Choi et al. (2021), who discovered when identifying green infrastructure studies which explicitly state climate-related benefits, that only five of the 1,376 studies reviewed were published before 2007. The rate of publications addressing the climate benefits of green infrastructure has increased even more sharply since then, with 80% of the studies in their dataset published after 2015.

This shift in focus reflects the growing urgency of climate-related challenges in urban areas, where the built environment both contributes to and exacerbates environmental stressors, and where green infrastructure is positioned as a means of addressing these concerns. For example, Liao and Kim (2024) highlight how green infrastructure can significantly reduce air pollution, though they note this benefit is less relevant in a North American context, since 12 of the 15 most particulate polluted cities are found in Asia. In coastal regions, green infrastructure is credited with reducing erosion, slowing wetland loss, and buffering storm surges (Rodrigues et al., 2025). Because the concept has long emphasized the importance of interconnected ecological networks, green infrastructure policy is also frequently concerned with habitat fragmentation (Conway et al., 2020), as the approach is used to confront persistent urban challenges such as biodiversity loss of both flora and fauna (Morpurgo et al., 2023).

While these regulating ecosystem services provided by green infrastructure are important across many regions, two of the most significant climate-related challenges facing Toronto, which are also commonly emphasized in contemporary literature, are the urban heat island (UHI) effect and flooding caused by stormwater runoff. These challenges are particularly relevant to discussions of green infrastructure because they illustrate the growing need for climate-responsive urban planning approaches.

The UHI effect, as explained by Kadić et al. (2025), is the phenomenon of cities having higher average temperatures than rural counterparts. The effect is caused by the composition and structure of built environments, as urban surfaces absorb more thermal and radiation energy. The variations in the intensity of the UHI effect are linked to differences in urban characteristics, including how much evapotranspiration can occur, how efficiently heat is transferred away by air movement, how much radiation the city absorbs, the amount of anthropogenic heat it releases, and how much heat its built materials store (AzariJafari et al.,

2021). In Toronto, asphalt and concrete alone account for nearly 30% of the city's surface area, excluding rooftops, indicating the extent to which the urban landscape is dominated by heat-absorbing, impervious materials (Wang et al., 2016). Toronto, particularly its urban core, is dominated by low-albedo high-rise buildings that reduce what is known as the Sky View Factor, causing heat to become trapped within the city, especially at night when buildings release stored solar energy (Wang et al., 2016). Toronto's ten warmest recorded years have all occurred since 1998; average temperatures between 1991-2020 were 0.8°C warmer than 1961-1990, with the number of days above 30°C per year increasing from an average of ten to 14 (TRCA, 2024). Heat-related deaths occur at an average of 120 per year, with this mortality rate expected to double by 2050 (Wang et al., 2016). For these reasons, green infrastructure is viewed as an important strategy Toronto must continue to invest in, as many features reduce air and surface temperatures through shading and evapotranspiration, effectively diminishing the urban heat island effect (Anderson & Gough, 2021).

The other major climate change induced hazard in Toronto, which is another major focus in the literature, is surface runoff and flooding. Alamdari and Hogue (2022) connect population growth and urbanization with urban flooding, as these factors decrease water's ability to permeate into the ground. Furthermore, climate change can alter precipitation rates, its spatial distribution, and increase the number of extreme events per year. These compounding realities have led to many cities' stormwater control measures to be overwhelmed during storm events. As Johns (2019) explains, many Canadian cities are already experiencing an "infrastructure deficit," as aging traditional sewage systems are unable to manage the increasing volumes of stormwater currently occurring and projected to intensify over the coming decades. For example, massive flooding in 2013 has been noted as the most costly natural disaster in Ontario's history, and Toronto has experienced several weather events since then which have exceeded the 100-year storm threshold in parts of the city (TRCA, 2024). In addition to climate-driven intensity, Toronto's management of runoff is hampered by urban form with 60–80% imperviousness and clay soils that naturally resist infiltration (Johns, 2019). The consequences of such flooding include damage to public spaces and homes, as well as increased runoff that accelerates pollutant washoff in lakes and rivers, aquatic dead zones due to elevated nutrient levels, and furthered erosion and channel scour in local watersheds (Alamdari & Hogue, 2022). Since the assumption of stationary hydrological conditions is no longer valid under climate change, planners in Toronto and other cities facing similar events are looking to green infrastructure to optimize the built environment for stormwater (Johns, 2019).

The rise in popularity of green infrastructure's natural qualities for addressing changing climate and weather patterns in cities is attributed to its ability to help urban areas both adapt to emerging climatic conditions and mitigate the drivers of these changes, thereby contributing to a location's overall climate

resilience. Anderson and Gough (2021) provide an understanding of the terms, stating that climate change adaptation is "an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities," whereas climate change mitigation is "human intervention to reduce anthropogenic forcing of the climate system, including strategies to reduce net greenhouse gas emissions". As explained by Kadić et al. (2025), mitigation techniques have historically received more attention in climate action plans as governments first attempted to address the drivers of climate change. This involves efforts to sequester carbon, reduce pollution, and increase energy efficiency; all of which green infrastructure is capable of addressing. In more recent years, however, adaptation techniques are seen as equally essential, since many climate events are now considered inevitable. Adaptation methods can range from providing shade and reducing surface air temperatures to managing stormwater runoff at the source.

Of the 141 articles in the Choi et al. (2021) literature review, 90% focused on adaptation benefits, demonstrating the growing, largely reactive popularity of green infrastructure in cities to address climate change concerns. This dual capacity to support both mitigation and adaptation efforts has increasingly positioned green infrastructure within broader discussions of climate resilience. Although climate resilience lacks a universally accepted definition, it is commonly understood as a system's ability to prepare for, respond to, and recover from climate-related disturbances (Meerow & Stults, 2016). Green infrastructure is therefore frequently framed as a resilience-building approach because of its multifunctional ability to simultaneously reduce climate risks while helping urban areas adapt to changing environmental conditions (Kadić et al., 2025; Liao & Kim, 2024).

In just thirty years since the term's inception, green infrastructure has become a widespread and well-known tool for governments, developers, and practitioners to use. However, because the concept has spread so widely and so rapidly across the planning field, there has been little time for holistic reflection on the underlying meaning of the approach (Seiwert & Rößler, 2020). When reviewing green infrastructure's long and varied history, it becomes clear that the strategy has been shaped, stretched, and refocused to fit different contexts. Its ubiquitousness is dependent on several factors: who is employing the concept, for what benefits, at what moment in time, and in which geographic or political setting all influence what green infrastructure can mean, how it is built, and the purposes it is intended to serve.

As the field of planning opens its doors to a broader set of voices and strengthens its engagement with environmental and social concerns, green infrastructure has increasingly been used as a blanket solution to many urban challenges. As Seiwert and Rößler (2020) suggest, it is no surprise then that there is not a single definition capable of capturing the multifunctionality of green infrastructure and the range of benefits it can provide. The risk, however, is that green infrastructure has become a "generalizing" term

that can undermine its own usage and practical impact, as the concept must balance the need to encompass multiple purposes without simultaneously becoming so vague that it leads to confusion or diminished usefulness. Mell and Clement (2019) credit temporal, geographic, scalar, and disciplinary variation as the causes for the confusion which surrounds present-day green infrastructure. Their analysis reveals that the process of turning green infrastructure into a planning approach that effectively integrates ecosystems, biodiversity, socio-economic, and political factors has been disjointed based on these four axes.

As discussed, the necessity for a tool like green infrastructure is not a new idea, despite the term being quite new itself. Green infrastructure's evolution has not followed a linear path; its applications, the purposes it is expected to serve, and convergence with concepts that better explain its effectiveness, such as ecosystem services, have unfolded gradually over time and thus its definition has changed to reflect these shifts. Viewing the strategy through a temporal perspective helps identify the planning approaches that have shaped the usage of the concept throughout its existence, providing explanation as to why it remains a contested topic today (Mell & Clement, 2019).

As Seiwert & Rößler (2020) explain, one of the earliest formal definitions comes from the Florida Greenways Commission in 1994, which describes green infrastructure as "the system of native landscapes and ecosystems that support native plants and animal species; sustains clean air, water, fisheries, and other natural resources." This definition reflects how, in its early stages, green infrastructure was closely aligned with greenways and ecological preservation, with a primary focus on biodiversity and environmental protection. At this point, the term is said to have not yet been developed as a practical planning tool.

Benedict and McMahon's (2002) article titled "Green Infrastructure: Smart Conservation for the 21st Century" is often cited as foundational for expanding the concept, as it describes green infrastructure as "an interconnected network of green space that conserves natural ecosystem values and functions and provides associated benefits to human populations." This definition is said to synthesize the initial commentary that had previously been scattered across landscape and ecological sciences (Mell & Clement, 2019). Accompanying Benedict and McMahon's definition were a set of guiding principles that established ideas of connectivity, multifunctionality, and the integration of socio-economic and ecological benefits. While certain elements common in contemporary definitions were still absent, such as explicit reference to ecosystem services, the emphasis on networks helped establish green infrastructure as part of a broader system. It is important, however, to note that not all green spaces or environmental features necessarily qualify as green infrastructure, as the element must possess specific qualities and provide the functions required to be considered an essential component of an interconnected network (Seiwert and Rößler, 2020).

Although these early definitions continue to be cited, they also reveal why temporal variation contributes to present-day confusion. Green infrastructure has never had a fixed or stable definition. Instead, new priorities, functions, and expectations have been layered onto earlier interpretations without replacing them. At the same time, expectations surrounding the governance, management, and evaluation of green infrastructure have also evolved. As environmental governance has increasingly shifted toward more collaborative, networked approaches, green infrastructure literature has placed greater emphasis on questions regarding how, where, and by whom green space should be managed (Mell & Clement, 2019). Consequently, discussions have expanded beyond whether investment in green infrastructure is beneficial to broader considerations regarding implementation, long-term maintenance, monitoring, and the effective delivery of ecosystem services (Mell & Clement, 2019). As a result, the term now carries multiple eras of meaning at once, ranging from social cohesion and conservation-focused origins to contemporary associations with climate adaptation, stormwater management, public health, and social equity. The coexistence of these overlapping interpretations created over the past three decades can create governance challenges, as policymakers and practitioners may operate with differing assumptions regarding what green infrastructure includes, what objectives it should prioritize, and how its benefits should be evaluated and implemented.

Another explanation behind the ambiguity of green infrastructure is the geographic location which the strategy is employed. Green infrastructure is underpinned by the understandings of landscape, which Mell and Clement (2019) explain can vary across international contexts as well as at smaller scales, such as at a national or regional level. How planners interpret and prioritize the ecosystem services provided by green infrastructure is highly dependent on context, as different locations frame the concept based on their unique environmental challenges, planning traditions, and regulatory frameworks.

In the United States, for example, contemporary green infrastructure practice has become strongly associated with stormwater management. Johns (2019) explains that this association was reinforced by a 2007 memorandum from the United States Environmental Protection Agency (EPA), which formally recognized green infrastructure as an acceptable approach for municipalities seeking to reduce runoff and prevent sewage-contaminated overflows from entering local waterways. These regulatory priorities are further shaped through the Clean Water Act, which provides funding structures and statutory environmental requirements that guide green infrastructure water management approaches in the United States (Mell & Clement, 2019). Reflecting the government's stormwater position, the EPA 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 evapotranspiration stormwater and reduce flows to sewer systems or to surface waters" (Conway et al., 2020).

While the United States' current framing of green infrastructure adopts a primarily hydrological interpretation, Conway et al. (2020) argue that this results in green infrastructure projects that do not emphasize a holistic or connective planning process. In contrast, Europe offers a broader perspective, defining green infrastructure as a planning approach that must be socially inclusive, collaborative, and strategic. This is reflected in the European Commission's definition of green infrastructure as a "strategically planned network of natural and semi-natural areas designed to deliver a broad range of ecosystem services while enhancing biodiversity, environmental quality, and human well-being" (Rodrigues et al., 2025).

However, despite this broader policy framing, scholars note that a gap remains between definition and implementation. Morpurgo et al. (2023) argue that although multifunctionality is embedded within European green infrastructure discourse, practical application at the country level often fails to fully account for complex relationships between biodiversity and ecosystem services, partly due to inconsistent classification systems between the European Commission and individual member states. This limits monitoring capabilities and long-term planning goals, and Mell and Clement (2019) add that convergence between different approaches to green infrastructure has largely occurred only in the context of European Union funding programs supporting specific initiatives. Therefore, although the European Union is often praised for its flexible and comprehensive framing of green infrastructure, and scholars agree that this approach should be adapted at more local scales, confusion and inconsistency still emerge when actors in different jurisdictions hold divergent views about which ecosystem services green infrastructure should prioritize and which typologies qualify as green infrastructure, particularly given ongoing variation in whether non-vegetated features are considered 'green'.

A similar trend has been observed in Canada, where Conway et al. (2020) note that the Government of Ontario's definition of green infrastructure, which emphasizes living features, has historically not aligned with the Government of Canada's more engineering- and energy-focused definition that targets the retrofitting of grey infrastructure, meaning conventional built systems, for resilience goals. Overall, it is clear that consensus regarding what constitutes green infrastructure is not uniformly achieved across geographic contexts, as planning traditions between countries, as well as within broader governance systems such as provinces in Canada and member states within the European Union, often differ, thereby increasing the conceptual inconsistency surrounding the topic (Mell & Clement, 2019).

Beyond the temporal and geographic dimensions contributing to divergent understandings of green infrastructure, scale also creates ambiguity in how the concept is interpreted and applied. Green infrastructure interventions can operate at regional, community, neighbourhood, or site-specific scales (Johns, 2019), ranging from small site-level features, such as green bus stops (Czyża & Kowalczyk, 2024),

to regional systems like city-wide greenbelts (Amati & Taylor, 2010). When policies do not specify the scales at which green infrastructure operates, and therefore the typologies included within its definition, implementation becomes significantly more difficult.

This scalar variation is reflected within definitions found in the academic literature. For example, the same green infrastructure typology, such as green roofs, may be framed in one article as "urban green infrastructure" (Hanna et al., 2023), while another refers to it simply as "green infrastructure" (Anderson & Gough, 2021). These differing classifications demonstrate how the same intervention can be interpreted through different spatial lenses, raising questions about whether smaller-scale typologies, such as green roofs, are inherently considered green infrastructure by governments whose policies extend beyond urban areas, or are only included within the concept when definitions explicitly reference urban contexts.

Some academic definitions explicitly define that green infrastructure operates at multiple scales, such as Choi et al. (2021), who describe it as "a hybrid network of natural, semi-natural, and engineered features within, around and beyond urban areas at all scales, which is planned and managed to provide multiple ecosystem services and benefits." In contrast, other definitions, such as Liao and Kim's (2024), describe green infrastructure more generally as "an integrated planning tool for promoting sustainable development, forming an interconnected network of natural and artificial elements to protect ecosystem functions, enhance environmental quality, and provide various benefits to human society," without specifying the scales at which these features exist.

Mell and Clement (2019) further explain that green infrastructure cannot always be neatly classified into fixed scalar categories but instead exists along a continuum of scales that shape its function and investment priorities. Large-scale green infrastructure interventions may prioritize ecological connectivity and biodiversity, while smaller-scale interventions are often more closely associated with localized socio-cultural functions or site-specific environmental benefits such as stormwater retention. Consequently, scalar ambiguity does not arise simply because green infrastructure exists at multiple scales, but because definitions and planning approaches do not always clarify how these scales relate to one another or what role individual interventions are intended to serve within broader frameworks. Explicitly identifying the intended scales of green infrastructure interventions therefore helps clarify both the benefits they are expected to provide and the planning objectives they intend to support.

The final axis contributing to inconsistent understandings and applications of green infrastructure is its development across multiple disciplines. Like the concepts of resilience and sustainability, a strength of green infrastructure is its ability to function as a boundary object; its variability encourages dialogue between different groups and allows flexible interpretation depending on their expertise and understanding

(Mell & Clement, 2019). However, as Matsler et al. (2021) suggest, green infrastructure may rather function as a "proto-boundary object," meaning it lacks the coherence and shared understanding needed to operate effectively across disciplines. This reality instead can limit collaboration and constrain consensus-building across disciplines.

The fields of urban planning, urban forestry, ecology, engineering, landscape architecture, and law are said to have diverging "starting points" of what their vision of green infrastructure should include (Matsler et al., 2021). For instance, green infrastructure can be used as a greenspace planning concept, born out of ideas of garden cities, greenbelts, and greenways. This vision focuses on the spatial patterns of how natural areas are woven into urban fabrics to provide social and environmental benefits. There are definitions derived from urban ecology, which specifically analyze the ecological functions and ecosystem services provided by natural systems. Thirdly, stormwater management perspectives define green infrastructure more narrowly as engineered systems designed to mimic natural hydrological processes. While greenspace planning and urban ecology often view green infrastructure more broadly as a network of vegetated land, stormwater management definitions typically focus on site-level designs which may not include vegetation, such as permeable pavement.

These three disciplinary interpretations, although partially overlapping with one another in different ways, each provide a unique starting point for the understanding of the concept. When these disciplinary differences are left unaddressed, they can lead to "dramatically different implementation and benefit provision," as each field emphasizes different scales, functions, and typologies of green infrastructure, contributing to varying metrics of what successful implementation looks like (Matsler et al., 2021). Because many academic articles do not define green infrastructure, such as 41% of those examined by Matsler et al. (2021), authors often assume that readers already share their implicit understanding of the term. This assumption contributes to "siloing," where knowledge becomes fragmented and sometimes contradictory as disciplines continue to work within their own frameworks.

However, it is not only the definitions of green infrastructure which can become fragmented, but the concept itself is known to be splintered, furthering inconsistencies in stakeholder understanding. This conceptual fragmentation has not just grown out of the disciplinary axis, but as well as the temporal, geographic, and scalar factors shaping green infrastructure definitions. Green infrastructure has evolved from a variety of other terms, such as ecosystem infrastructure, natural infrastructure, and sustainable infrastructure (Johns 2019). This evolutionary history means that the term carries the baggage of multiple traditions, which is why it is still frequently used interchangeably with several terms. For example, terms like "low impact development" (LID) in North American planning and engineering commonly overlap

green infrastructure's space (Johns, 2019), which is a concept also noted to be used in China (Matsler et al. 2021).

While these two regions share this similarity, stormwater-oriented green infrastructure is also labelled differently across these contexts, including "best management practices" (BMPs) in North America (Choi et al., 2021) and as the "sponge city" model in Asia (Matsler et al., 2021). In Europe, "sustainable urban drainage systems" (SUDS) is primarily used when referring to this type of green infrastructure, and "water sensitive urban design" (WSUD) is common in Australia (Matsler et al., 2021). If these concepts are not explained to be embedded within the broader concept of green infrastructure, stakeholders may interpret them as separate or competing approaches rather than as related components of the same planning framework, reinforcing fragmentation and making cross-jurisdictional alignment even more difficult.

When the term green infrastructure is used alone, additional variations of the concept, such as "Blue-Green Infrastructure" (BGI), may also emerge. Common in the United Kingdom, Italy, and Sweden, BGI incorporates water-based features that some green infrastructure definitions may exclude, such as streams, rivers, and canals (Matsler et al., 2021; Krivtsov, 2025). These systems are intended to provide multiple functions concurrently, including water purification, carbon absorption, aesthetic enhancement, and mitigation of the urban heat island effect (Czyża & Kowalczyk, 2024). While many of these functions overlap with conventional green infrastructure objectives, authors do not consistently clarify whether blue features are included within their definitions of green infrastructure. Some studies, such as Hanna et al. (2023), explicitly incorporate blue elements into their understanding of green infrastructure, whereas others distinguish BGI as a separate category altogether. As a result, uncertainty can emerge regarding which typologies are intended to fall within the scope of green infrastructure in different planning and policy contexts.

Lastly, the term "Nature-based solutions" (NBS) has significantly grown in popularity in Europe, but is also being adopted in other parts of the world since. The International Union for Conservation of Nature describes NBS as "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (Anderson & Gough, 2021). The concept emerged in 2008 to promote innovative approaches that align the benefits of nature with societal well-being (Lozano et al., 2025). The IPCC advocates for increased investments in NBS, such as green infrastructure (Rodrigues et al., 2025), since green infrastructure is considered a core component of NBS (Lozano et al., 2025).

At the same time, however, the relationship between NBS and green infrastructure is not consistently defined within the literature. Some authors position green infrastructure as a component of

broader NBS strategies (Lozano et al., 2025), while others describe NBS as an approach that should be integrated into green infrastructure planning (Zarei & Shabab, 2025). Since Anderson and Gough (2021) use NBS when discussing green infrastructure for mitigating Toronto's urban heat island effect, and Zarei and Shabab (2025) identify Toronto-based resilience studies that frame wetland restoration as NBS, its growing use in a Canada context can introduce additional ambiguity if not explained how it relates to the tool, as the term is alternately used as a substitute for green infrastructure, as an umbrella category that contains it, or as a complementary but distinct planning approach.

When LID, BMPs, Sponge Cities, SUDS, WSUD, BGI, NBS, and other concepts are not well defined or are used interchangeably with green infrastructure, Matsler et al. (2021) reference scholars as "ships in the night," as they reduce geographic and disciplinary cross-collaboration and risk overlooking important scientific developments in effective urban climate resilience. While "interpretive flexibility" has helped green infrastructure and its alternative terms grow in popularity, "productive flexibility" can only exist if planners and policymakers are specific and explicit about their definitions (Matsler et al., 2021).

As demonstrated through both the historical evolution and contemporary application of the concept, green infrastructure has developed into a flexible but highly contested planning approach shaped by varying temporal, geographic, scalar, and disciplinary interpretations. While this flexibility has contributed to the concept's widespread adoption across planning and environmental governance, it has also complicated efforts to establish consistent definitions, implementation strategies, and evaluation frameworks. Nevertheless, despite these tensions, green infrastructure remains one of the most effective strategies for aligning socio-cultural needs with the provision of ecosystem services and ecological connectivity (Mell & Clement, 2019). Its multifunctionality purposes surpass what one-dimensional grey infrastructure projects often provide and is increasingly recognized as an "essential requirement for life and work in cities" (Seiwert & Rößler, 2020). As climate risks intensify, the need for coherent, connected approaches to green infrastructure becomes even more urgent, and clarifying the concept is a necessary prerequisite for Toronto's green infrastructure efforts, since the planning, funding, and implementation of green infrastructure are shaped by multiple levels of government. Without alignment across these levels, Toronto's green infrastructure projects cannot reach their full potential as an equitably distributed climate resilience tool.

3. Methodology and Research Design

This study has three primary objectives. First, it develops a working definition of green infrastructure grounded in Urban Political Ecology, spatial justice, and contemporary green infrastructure literature to reduce conceptual ambiguity. Second, it applies this definition, together with a supporting classification system, to evaluate how the Government of Canada, the Province of Ontario, the Toronto and

Region Conservation Authority, and the City of Toronto conceptualize green infrastructure within policy documents and guidance materials. Finally, it examines illustrative intergovernmental projects to demonstrate how these differing conceptualizations influence the implementation of green infrastructure in Toronto.

To evaluate how the City of Toronto, the Toronto and Region Conservation Authority, the Province of Ontario, and the Government of Canada's conceptualization of green infrastructure compare to one another and influence climate resilience and equity outcomes in Toronto, the methodology is split into two components. First, a framework grounded in Urban Political Ecology (UPE) and spatial justice is established to develop a working definition of green infrastructure that aligns with the social and environmental outcomes which this research argues should guide green infrastructure implementation in Toronto. This framework also supports broader applications of green infrastructure across Canada, empowering the multifunctionality of the approach, by clarifying how its range of benefits can be understood without reducing the strategy to a narrow or 'one-size-fits-all' tool.

Second, a classification system was developed from academic literature to organize common green infrastructure typologies, their physical characteristics, and their associated ecosystem service functions. This system provides a consistent lens for interpreting how government documents reference, prioritize, or exclude different forms of green infrastructure. This research design enables systematic evaluation of government documents, supports the identification of illustrative examples of green infrastructure shaped by intergovernmental dynamics, and establishes the foundation for recommendations to improve the coherence of green infrastructure in Canada in support of more equitable and climate-resilient policy and management.

The foundations of political ecology were laid by Blaikie and Brookfield (1987) in *Land Degradation and Society*, which argued that environmental issues such as land degradation cannot be understood solely through ecological or physical processes, but instead must be recognized as social problems, altered by political, economic, and cultural forces. Although political ecology initially focused on rural contexts, its concerns were extended to urban environments in the early 21st century (Zimmer, 2010). Heynen et al. (2006) describe Urban Political Ecology as an approach that examines the "myriad transformations and metabolisms that support and maintain urban life" as "infinitely connected physical and social processes."

Within this framework, metabolism refers to the dynamic relationships between humans and nature that collectively produce the urban environment. From this perspective, a green infrastructure intervention can be viewed as a metabolic product that embodies these "socio-natural entanglements." For example, the

physical, chemical, and biological characteristics of a park, including its capacity to absorb stormwater or mitigate heat, interact with social, political, and economic processes such as policy definitions, government objectives, and funding structures. These processes shape the park's existence, as well as its specific location and composition, which in turn influence the types of benefits it can provide as a green infrastructure strategy and the communities who are positioned to receive those benefits.

Heynen et al. (2006) argue that cities are not socially or ecologically neutral. Social, cultural, political, and economic conditions, along with the institutions that accompany them, shape what cities look like and for whom they are built. These non-neutral processes, as a result, often expose certain groups to heightened socio-environmental vulnerability while simultaneously enabling powerful individuals and groups to consolidate advantages.

As Heynen et al. (2006) explain, physical processes, like gravity and photosynthesis, are not socially produced, however "their powers are socially mobilized in particular bio-chemical and physical metabolic arrangements to serve particular purposes." These objectives, they suggest, are invariably connected to the strategies groups use to maintain their social and economic positions, reflecting the fluid and unequal power dynamics that dictate how urban space is organized. The authors frame UPE as a political project concerned with uncovering the dynamics that produce and reproduce socio-economic conditions within cities, since investigating who produces what kinds of urban environments, and in whose interests, enables more democratic approaches to environmental governance.

Since Urban Political Ecology positions cities as the locations experiencing climate change most acutely, and treats sustainability as fundamentally political by asking what should be sustained and how it can be maintained (Heynen et al., 2006), it provides an appropriate framework for reviewing green infrastructure policy. In this research, UPE is used to examine how policy definitions of green infrastructure shape implementation outcomes, including which interventions are prioritized, where they are located, which benefits are emphasized, and which communities are positioned to gain or lose. By analyzing how different levels of government define green infrastructure and examining illustrative projects shaped by these definitions, this study identifies the institutional priorities and governance processes that structure the urbanization of nature in Toronto and influence climate resilience and equity outcomes.

Other studies have similarly applied the UPE framework to review green infrastructure governance, such as a Finewood's (2016) examination of the struggle between competing epistemologies of water management in Pittsburgh. The EPA, through the Clean Water Act, required the city to incorporate green infrastructure and meaningful community engagement into its water management planning. Although the federal government rejected the city's 2014 plan for failing to meet these standards, the revised plan

ultimately adopted the language of green infrastructure without undergoing a substantive shift in practice. Instead, Pittsburgh's municipalities, represented by the Allegheny County Sanitary Authority, filtered green solutions through a traditional engineering lens, resulting in a coopted plan that remained "almost exclusively grey," which continued to prioritize an underground network of stormwater tunnels rather than the transformative potential green infrastructure offers. Through a UPE framework, Finewood (2016) argues that this approach failed to democratize urban water governance and reinforced the authority of dominant actors.

While community advocates viewed green infrastructure as a means to address environmental justice issues such as flash flooding and basement backups that disproportionately affect low-income neighborhoods, Pittsburgh's municipal plan focused on "visible priorities" that served regional rebranding and waterfront development. These decisions are argued to have furthered uneven urban landscapes under a green cover, as status quo remained and underlying socio-environmental concerns of the city's most vulnerable communities were left unaddressed. This case is relevant to the present methodology because it demonstrates how an Urban Political Ecology lens reveals the political, institutional, and spatial implications of green infrastructure policy definitions and divergent implementation priorities.

While Heynen et al. (2006) assert that UPE moves beyond spatial or socio-environmental justice perspectives, which are described to narrowly focus on uneven environmental distributions without fully examining how these conditions are produced, scholarship that uses justice-oriented lenses remains valuable for diagnosing inequities and informing policy recommendations. Justice frameworks have increasingly incorporated questions about the social, political, and economic processes that generate environmental inequalities, and this literature provides important insights for understanding how green infrastructure is distributed and experienced in Toronto.

Using an environmental justice lens, Regier and Conway (2022) developed a Green Infrastructure Equity Index to analyze how built-environment factors in Toronto, such as tree canopy and impermeable surfaces, intersect with socio-economic vulnerabilities, including income and race, which leaves certain neighbourhoods often lacking the resilience solutions necessary to mitigate extreme heat and urban flooding. The authors argue that achieving environmental justice in Toronto requires planners to prioritize investments in communities where social and physical risks overlap most severely. Bu et al. (2024) extend this work by measuring "Heat Vulnerability Indices" in Toronto based on exposure to heat, sensitivity to heat based on factors like age and surface materials, and adaptive capacity, which includes socio-economic features such as income and education. Their study revealed that high vulnerability areas, particularly low-income tower block communities, generally had fewer green spaces.

Bu et al. (2024) recommend expanding green spaces and increasing canopy coverage in these areas and suggest the city adopt a spatial equity lens when planning climate adaptation strategies to avoid "green gentrification;" the phenomenon that occurs when municipal strategies to restore degraded urban environments or deploy climate-adaptive green infrastructure improves a neighbourhood's attractiveness, resulting in increased property values, rising housing process, and the displacement of working-class residents and racialized groups (Anguelovski et al., 2022).

To ensure that green infrastructure policy promotes spatial justice by supporting equitable distribution in ways that reduce the risk of green gentrification, Zarei & Shabab (2025) suggest five critical criteria: (1) equality of opportunities to ensure all individuals have access to green infrastructure; (2) participation that engages citizens and the private sector in management of these approaches; (3) outcome assessments to track both the positive and negative impacts of the infrastructure; (4) recognition of merit, which balances social capabilities with ecological continuity; and (5) the prioritization of public benefit by analyzing the specific structural challenges of a neighborhood. These criteria place the physical and social needs of populations at the forefront and leverage local knowledge and lived experiences to shape how green infrastructure is used and maintained, thereby promoting equitable distribution of the resilience benefits provided by green infrastructure as well as dimensions of social interaction, learning, and the enjoyment of nature.

The core principles from Urban Political Ecology and spatial justice, in combination with insights from academic literature on green infrastructure, inform a working definition of the approach that aligns with the social and environmental outcomes needed for successful projects in Toronto. Through this framework, green infrastructure is defined as:

"*a strategically planned and community-informed system of natural, semi-natural, and engineered features of any scale, within, around, and beyond urban areas, that either contain ecological components or directly support ecological processes, and that are designed to deliver multiple ecosystem services that enhance climate resilience and should also support biodiversity and resident well-being, with these features and their benefits equitably distributed according to the specific needs of local communities."*

The working definition of green infrastructure developed in this study is shaped by three central factors: its connection to climate resilience, its grounding in social equity, and the need to reduce ambiguity. The definition directly references green infrastructure's capacity to enhance a location's resilience, which has become the dominant rationale for its use globally. The definition incorporates ecosystem services, a term that has become largely inseparable from green infrastructure, to clarify the mechanisms through which the approach helps cities mitigate and adapt to climate change. Because the definition states that

green infrastructure enhances climate resilience, regulating ecosystem services are an essential component of any feature included in the approach, even though their relevance and effectiveness may vary. To improve clarity in application, the definition can be supported by descriptions of the climate challenges relevant to a given geography and the regulating services commonly cited as responses. For example, a Toronto-specific definition may explicitly reference the urban heat island effect and flooding, explaining how green infrastructure mitigates heat and manages water flow, contributing to the area's resilience.

The working definition also stresses that green infrastructure must be community-informed and equitably distributed according to the needs of local populations. This reflects the importance of collaborative planning processes that incorporate local knowledge and lived experience, ensuring that green infrastructure responds to community priorities and supports residents' ability to remain in place. Well-being is also directly referenced in the definition to reflect the important cultural ecosystem services associated with green infrastructure, since the approach should also be understood as encompassing elements that influence mental and physical health, social interaction, and community bonding, which are among the most visible ecosystem services it provides and which should be accessible to all residents rather than limited to certain areas.

The components of resiliency and equity in the definition are grounded in Urban Political Ecology and spatial justice, which emphasize that green infrastructure must be understood not only as a technical intervention concerned with the ecological or physical processes that address climate change, but also as a socio-political process shaped by power, distributional equity, and the lived realities of communities.

Reducing ambiguity is the third key objective and is informed by green infrastructure scholarship. Conway et al. (2020) note the frequent use of the term without an accompanying definition, and even when one is provided, it is frequently interpreted as "varied, vague, or exceptionally broad." Mell and Clement (2019) similarly call for definitions that balance flexibility with clarity, and the working definition responds to this by specifying the wide range of sizes, components, and purposes green infrastructure can encompass while still restricting what qualifies under the approach. It states that green infrastructure can include natural, semi-natural, and engineered features that contain ecological components or support ecological processes. This phrasing captures the full spectrum of eligible typologies, from parks to permeable pavement, and reflects the green–blue–grey continuum identified in the literature, as green infrastructure commonly includes biological land and water components, as well as elements of built infrastructure. It also clarifies that green infrastructure varies in scale and may be located within or beyond urban areas, consistent with definitions such as Choi et al. (2021).

The two remaining components of ecosystem services, supporting and provisioning, are not expanded in the working definition like regulating and cultural services because they are not the focus of the paper, although they remain important to acknowledge since green infrastructure is widely understood as a multifunctional approach. The definition does, however, explicitly include biodiversity to counter anthropocentric interpretations that obscure the ecological functions of green infrastructure (Seiwert & Rößler, 2020). Following the European Commission's definition, biodiversity is referenced to emphasize that ecosystem services extend beyond human benefits (Morpurgo et al., 2023).

To further reduce ambiguity, policy documents can also support this definition by clarifying how green infrastructure relates to overlapping terms such as low impact development and nature-based solutions, and ensuring these terms are also defined when used to reduce confusion caused by conceptual fragmentation. Definitions can also be complemented by a list of typologies which are relevant to the policy context they intend to serve.

The working definition as a whole is intended to reduce ambiguity by being specific enough to illustrate what green infrastructure can look like across different forms and scales, while remaining general enough to be adopted across policy contexts in Canada. By also explicitly linking green infrastructure to climate resilience and equitable distribution, the definition provides a holistic analytical standard for evaluating government publications. Definitions from government publications will be assessed based on three factors: the inclusion of resilience language, the acknowledgement of equity concerns and the understanding that all communities require access to essential ecosystem services, and the extent to which the definition reduces ambiguity by clearly explaining the range of forms green infrastructure can take. This enables comparison of priorities, clarity, and coherence within and across levels of government, and it highlights how different conceptualizations of green infrastructure can either advance or undermine Toronto's resilience and equity goals.

Because explicit definitions of green infrastructure are not always provided, the analysis also examines the individual typologies that appear in policy texts, whether or not they are formally identified as green infrastructure. These typologies serve as a proxy for how governments operationalize the approach. To support this analysis, a classification system was developed that synthesizes 12 typologies and nine ecosystem service functions from the literature, as well as the categories that each feature falls within, and the scale at which it is implemented. Details on the development of the classification system, the system itself, and supporting figures are provided in Appendix A, while external figures and tables referenced during its creation are included in Appendix B.

Although not included in the 12 typologies, greenbelts (Amati & Taylor, 2010) and ravines (Oviedo et al., 2022) are identified as integral components of Toronto's green infrastructure landscape. They are said to deliver a broad range of ecosystem services, including cultural services such as recreation and socialization, as well as regulating services that support Toronto's adaptation to and mitigation of local climate change impacts. Their inclusion in the document search ensures that the analysis captures other green infrastructure forms that are spatially, socially, and politically significant in Toronto, even if they fall outside the narrower typology list used in the classification system.

When evaluating government initiatives related to green infrastructure, the analysis searches for the 12 typologies, as well as greenbelts and ravines, to assess how each level understands the physical manifestations of green infrastructure. For elements outside the classification system, the working definition will be used to determine whether the infrastructure element qualifies as green infrastructure based on two criteria: whether it contains ecological components or directly supports ecological processes, and whether it enhances climate resilience, even if this is not its primary function. For example, despite permeable pavement not possessing ecological components in its design, it directly supports ecological processes through water infiltration and contributes to climate resilience by improving water quality and reducing surface runoff. In contrast, electric vehicle chargers, while contributing to a greener transportation ecosystem (Alsharif et al., 2025), do not meet the working definition of green infrastructure. Electric vehicle chargers do not contain ecological components or directly support ecological processes, and although they may indirectly reduce emissions, the infrastructure does not provide any regulating services itself.

Beyond typologies, the terminology used in policy documents also reveals how governments conceptualize green infrastructure. Because conceptual fragmentation is common in this space, the document search also identifies overlapping or synonymous terms such as "nature-based solutions," "resilience infrastructure," "ecological infrastructure," and "low impact development" and evaluates whether they are defined and whether their relationship to green infrastructure is explained. The search also notes instances where green infrastructure is replaced by "greenspace" or "vegetation," reflecting what Matsler et al. (2021) describe as the recurring tendency to equate green infrastructure with generic greenery. These substitutions can obscure the broader infrastructural, socio-political, and ecosystem service dimensions of green infrastructure when left unexplained how they relate to green infrastructure and therefore warrant systematic attention in the analysis.

The working definition and the supporting classification system group to make the overall evaluative framework. This analysis is organized into five components: (1) identifying and assessing definitions of green infrastructure against the three core elements of the working definition; (2) examining the use of alternative terminology and whether its relationship to green infrastructure is clarified; (3)

contextualizing the benefits attributed to green infrastructure and related terms throughout the document; (4) capturing references to greenbelts, ravines, classification system typologies, and other components associated with the classification system, including specific ecosystem services and biodiversity support; and (5) evaluating whether additional features qualify as green infrastructure according to the two tests established by the working definition. Together, these steps assess how semantic content shapes understandings of the concept and how policy language influences resilience and equity outcomes in Toronto.

The analytical approach adopted in this study aligns closely with the framework proposed by Seiwert and Rößler (2020). The analysis considers many of the dimensions identified by the authors, including what green infrastructure is (definitions), why it is used (rationales for action), what it is intended to achieve (benefits and functions), and how it is implemented (physical elements and planning approaches). These dimensions provide a useful point of comparison that reinforces the study's examination of how different governments conceptualize and operationalize green infrastructure within Toronto's multi-level governance system.

The government publications include webpages and documents that are currently in use and reflect how each level of government conceptualizes, communicates, or guides the implementation of green infrastructure. Where necessary, historically significant documents that are no longer in force are also included when they provide important context for understanding the evolution of green infrastructure policy and terminology. These publications either contain the term “green infrastructure” or use alternative terminology that the respective level of government identifies as being linked to green infrastructure. Examining these publications helps assess the coherence of green infrastructure policy and terminology both within and across levels of government.

4. Government Document Analysis

4.1 Government of Canada

The 2016 federal budget was the first to include funding specifically designated for green infrastructure (Conway et al., 2020). Since then, federal programs administered through Housing, Infrastructure and Communities Canada, Natural Resources Canada, and climate strategy documents from Environment and Climate Change Canada (ECCC) have shaped the federal government’s position on green infrastructure. Analyzing federal definitions, alternative concepts, and typologies through the evaluative framework reveals that inconsistencies in terminology, conceptual hierarchy, and departmental framing create uncertainty about what constitutes green infrastructure, how related terms interact, and which types of projects federal policy and funding programs are intended to support.

The Government of Canada's (2023) *National Adaptation Strategy* (NAS) establishes the country's long-term vision, goals, and priorities for climate adaptation, guiding decision-making across federal departments and encouraging collaboration with provinces, municipalities, and other stakeholders. The NAS identifies five interconnected systems needed for a climate-resilient Canada: disaster resilience, health and well-being, nature and biodiversity, infrastructure, and economy and workers. Despite the NAS being a central federal policy for climate resilience, the term green infrastructure appears only within the glossary definition of natural infrastructure, which is described as "the interconnected set of natural and constructed ecological systems, green spaces and other landscape features. It includes planted and indigenous trees, wetlands, parks, green open spaces and original grassland and woodlands, as well as possible building and street-level design interventions that incorporate vegetation." The definition adds that "green infrastructure provides services and functions in the same way as conventional infrastructure," which treats natural and green infrastructure as interchangeable concepts, although the NAS itself consistently uses natural infrastructure throughout the document. The Government of Canada's (2024b) *Adaptation Action Plan* (GOCAAP) update document, which outlines how the federal government contributes to achieving NAS goals, adopts the same definition but titles it "Green/Natural Infrastructure," further reinforcing the federal tendency to merge the two concepts.

When comparing Environment and Climate Change Canada's explanation of green and natural infrastructure found in the NAS and the GOCAAP to the working definition used in this paper, it is evident that the federal definition does not satisfy the resilience or equity requirements, as it does not specifically explain how green infrastructure is necessary as a climate resilience strategy, nor does it indicate how implementation should occur in ways that benefit all residents. It does, however, indirectly meet the third criterion by reducing ambiguity through examples of features that exist at multiple scales and across categories in the classification system, although this clarity requires a separate knowledge of green infrastructure typologies. For example, the description mentions that ecological components can be natural or constructed and provides examples from the classification system which fall under green elements such as parks, blue elements such as wetlands, and likely combined elements such as "street-level design interventions that incorporate vegetation". It also includes a range of scale by including both trees and wetlands, for instance, which operate at local and city scales respectively.

Outside of the glossary definition, natural infrastructure in the *National Adaptation Strategy* is more clearly connected to climate resilience, as it is described as reducing pollution, sequestering carbon, and managing stormwater. However, the strategy still does not address the importance of equitable implementation, nor does it directly link natural infrastructure to other concepts central to green

infrastructure such as biodiversity, well-being, or ecosystem services, even though ecosystem services are defined elsewhere in the document.

Alternative terminology in the NAS extends beyond natural infrastructure. “Nature-based infrastructure assets” is used in the document, although it is never defined. It also uses and defines “nature-based solutions” (NBS) as “actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services and resilience and biodiversity benefits.” Despite the overlapping functions of NBS and green (or natural) infrastructure, the policy does not explain how these concepts differ or relate to one another. Low impact development (LID) is also referenced without clarification of its relationship to green or natural infrastructure. The NAS notes that LID reduces flooding and lists techniques such as permeable pavement, rain gardens, and trees, all of which appear in the classification system, but the connection between LID and the strategy remains unstated.

The only features of green infrastructure identified in the NAS that fall outside the typologies in the classification system appear within the definition of natural infrastructure. These include “green open spaces,” “original grassland and woodlands,” and “street level design interventions that incorporate vegetation.” All of these features qualify as green infrastructure under the working definition because they pass the two-part test: they contain ecological components or support ecological processes, and they directly enhance resilience to some degree. This indicates that the *National Adaptation Strategy*, despite prioritizing the term natural infrastructure, remains broadly aligned with the working definition’s conceptualization of green infrastructure and with the general academic literature.

The Government of Canada’s (2024b) *Adaptation Action Plan* follows the same pattern by prioritizing natural infrastructure but provides few examples that fit within the classification system beyond parks and wetlands. Although the document calls for equitably distributed climate resilient infrastructure, it does not explicitly connect this requirement to natural infrastructure, which reinforces the spatial justice concerns identified in the evaluative framework. The GOCAAP does further identify “urban forests” and “salt marshes” as features of natural infrastructure, both of which qualify as green infrastructure under this paper’s framework. However, the document continues to fragment the conceptual landscape by introducing terms such as “natural solutions” and NBS without explaining how they relate to green infrastructure.

NBS is defined differently yet conceptually aligned to the definition in the NAS, as it is said to be “actions to protect, sustainably manage and restore natural or modified ecosystems which address societal challenges effectively and adaptively, simultaneously providing human well-being, ecosystem resilience

and biodiversity benefits." Natural infrastructure is rather frequently paired with hybrid infrastructure, particularly when describing projects eligible for programs such as the Disaster Mitigation and Adaptation Fund (DMAF), although hybrid infrastructure also remains undefined. This adds further uncertainty about what is included within natural infrastructure, since the definition of natural infrastructure already encompasses both "natural and constructed ecological systems."

Another ECCC document relevant to the federal conceptualization of green infrastructure is the Government of Canada's (2024a) *2030 Nature Strategy*, which outlines a roadmap for preventing further biodiversity loss and identifying strategies to reverse it. Similar to the NAS and GOCAAP, natural infrastructure is the primary concept used throughout the document, although this time no formal definition is provided. As a result, green infrastructure is not clearly connected to natural infrastructure in the document, despite NAS and GOCAAP treating the two as synonymous. The only uses of green infrastructure occur when referencing "green infrastructure programs" that Canada has expanded to support biodiversity protection and when noting the role of "green bonds" in financing green infrastructure and nature conservation projects.

Although the *2030 Nature Strategy* does not define natural infrastructure, it also frequently groups the term with hybrid infrastructure and identifies features such as urban forests, wetlands, floodplains, coastal zones, as well as the classification system typology of stormwater ponds. The strategy also states that natural infrastructure provides climate resilience, improves access to nature, and enhances biodiversity. It calls for the benefits of natural infrastructure to be shared by all Canadians, including those in lower income communities, which acknowledges the importance of equitable distribution. However, the document does not address community consultation or participatory processes, which limits alignment with the spatial justice criteria.

As in the other federal documents, NBS is used in the *2030 Nature Strategy*. The definition is the same as in NAS, although this document identifies it as originating from United Nations Environment Assembly Resolution 5.2. Notably, natural infrastructure is described as a subset of NBS, which establishes a hierarchical relationship between the concepts for the first time. The document also references "nature-based climate solutions," and natural infrastructure is again positioned as an example of this term. Although nature-based climate solutions are not defined, the phrasing and functional overlap suggest that the term is used as a synonym for NBS. This reinforces the federal climate and nature policy pattern of terminology use that lacks reasoning behind its variation, as evident with green and natural infrastructure.

Conceptual ambiguity is further apparent in the discussion of Target 12, which focuses on "urban green and blue spaces." Natural infrastructure assets are described as elements that can be included within

these spaces, but this causes a functional tension by positioning natural infrastructure both as tangible assets to be "implemented into" these spaces and as features, such as urban forests and wetlands, that are themselves examples of natural infrastructure elsewhere in the document. The Strategy states that NBS can enhance urban green and blue spaces and earlier notes that enhancements to urban green and blue spaces provide several regulating and cultural ecosystem services identified in the classification system, including improved air quality, physical health, and stress reduction. However, the connections among natural infrastructure and NBS to urban green and blue spaces is presented in a disjointed manner and demonstrates the generic greening substitutes of green infrastructure identified by Matsler et al. (2021). The document therefore demonstrates an understanding of the benefits associated with these approaches, but it does not articulate their relationships clearly or consistently.

The review of the *National Adaptation Strategy*, the *Adaptation Action Plan*, and the *2030 Nature Strategy* shows that federal policy provides broad support for interventions related to green infrastructure but can lack consistent definitions, hierarchical organization, and conceptual clarity. The frequent conflation of terms and the absence of clear distinctions among related concepts contribute to confusion about how green infrastructure should be interpreted and applied. Beyond the examples already noted, the documents do not reference the remaining typologies in the classification system, nor do they acknowledge key Toronto green infrastructure features such as ravines and greenbelts. This gap further limits alignment with the working definition and reduces the usefulness of federal guidance for local implementation.

A positive finding is that the framing of natural infrastructure is consistent across federal documents, and all features associated with natural or hybrid infrastructure pass the working definition's test for qualifying as green infrastructure. However, complications arise when reviewing federal funding programs identified in these documents that operationalize these concepts. For instance, ECCC's *Adaptation Action Plan* and *2030 Nature Strategy* reference the Natural Infrastructure Fund (NIF) and the DMAF. These funds, provided by Housing, Infrastructure and Communities Canada, are initiatives designed to support projects that mitigate climate-related risks across the country.

Although the NIF webpage provides a definition of natural infrastructure similar to ECCC's, it diverges in one important respect: ECCC defines natural infrastructure as including both natural and constructed ecological systems, whereas the NIF restricts natural infrastructure to natural systems and places constructed ecological features under hybrid infrastructure, which is said to incorporate "elements of engineered grey infrastructure to enhance or support natural infrastructure and/or the use of ecosystem processes" (Government of Canada, 2024d). Under the NIF's categorization, green roofs and green walls, which are two typologies referenced for the first time at the federal level, are considered only hybrid infrastructure, whereas ECCC includes constructed ecological systems within natural infrastructure. The

inconsistent treatment of constructed ecological systems across federal departments illustrates how the continued use of multiple overlapping terms that are often conflated with one another contributes to conceptual fragmentation in federal climate and nature policy.

The DMAF webpage similarly allocates part of its budget to natural infrastructure projects, as these initiatives are described as a way to increase the resilience of communities affected by climate-change-induced natural disasters (Government of Canada, 2026a). However, the page does not clarify what natural infrastructure entails or which policy frameworks it aligns with; the DMAF is promoted within ECCC climate and nature policy documents, and the GOCAAP has helped support investments through the fund, yet the program is administered by Housing, Infrastructure and Communities Canada, which provides its own definition of the concept. By not explaining what natural infrastructure means, the webpage reinforces ambiguity for municipalities seeking funding through the program, as applicants must interpret how their proposed projects align with a federal funding stream that leaves one of its primary supported project types undefined.

Another concern arises from the fact that Housing, Infrastructure and Communities Canada has a separate page titled *Investing in Canada Plan funding stream: Green infrastructure* (Government of Canada, 2024c). This program supports climate adaptation and mitigation efforts and includes water management projects that align with the natural and hybrid infrastructure framing used by ECCC. However, the program also funds electric vehicle charging stations, which do not meet the working definition's criteria for green infrastructure because they do not contain or support ecological processes and do not directly contribute to climate resilience. This interpretation aligns more closely with Natural Resources Canada's (Government of Canada, 2026b) *Green infrastructure programs*, which treat the term as referring to low carbon infrastructure such as energy efficient buildings and zero emission vehicles rather than vegetated or ecologically functional systems.

Overall, the federal review shows that Canada supports many interventions that qualify as green infrastructure under the working definition, yet the policy language across NAS, GOCAAP, and the *2030 Nature Strategy* does not establish a coherent conceptual foundation for the strategy. Green infrastructure is inconsistently defined, frequently merged with natural infrastructure, and occasionally separated into natural and hybrid categories without clear justification. Related concepts such as NBS, nature-based climate solutions, LID, and natural solutions appear throughout federal documents, but their relationships to green infrastructure are often not explained.

This fragmented terminology obscures how federal strategies are intended to interact and which types of projects should be prioritized. Although the features associated with natural and hybrid

infrastructure generally align with the working definition and contribute to climate resilience, the absence of explicit equity requirements and the narrow set of typologies weaken alignment with the evaluative framework. The conceptual inconsistency becomes more pronounced when federal funding programs apply the term green infrastructure to projects that do not meet the criteria of ecological function or direct resilience benefits, such as electric vehicle charging stations. Combined, these issues create ambiguity that complicates policy interpretation, reduces clarity for implementation, and limits the federal government's ability to guide coherent and equitable green infrastructure planning in contexts like Toronto.

4.2 Government of Ontario

The provincial government of Ontario's use of green infrastructure began with its inclusion in the *2014 Provincial Policy Statement* (Conway et al. 2020). It was later incorporated into regional land use plans by the province in 2017 and has since been added to other provincial policy and planning documents. The 2014 Statement was updated in 2020 and was subsequently replaced by the *2024 Provincial Planning Statement* (PPS). Issued under the Planning Act, the Government of Ontario's (2024) PPS provides current policy direction on matters of provincial interest related to land use planning and development.

The PPS defines green infrastructure as the "natural and human-made elements that provide ecological and hydrological functions and processes. Green infrastructure can include components such as natural heritage features and systems, parklands, stormwater management systems, street trees, urban forests, natural channels, permeable surfaces, and green roofs." Similar to the federal government's definition of "Green/Natural Infrastructure," the province's definition does not satisfy the working definition's criterion of explicitly identifying green infrastructure as a tool for building climate resilience. There is also no mention, either within or outside the definition, of planning green infrastructure through community consultation or ensuring its equitable distribution.

However, parks, which are identified as a green infrastructure feature within the classification system, are described as a component of "complete communities," which are intended to provide equitable access to the necessities of daily living. The definition better satisfies the working definition's criterion of reducing ambiguity by explicitly stating that green infrastructure encompasses both natural and human-made elements and by providing examples from the classification system that include green (street trees), combined (green roofs), and unvegetated (permeable pavement) infrastructure. Although the definition does not acknowledge the range of spatial scales at which green infrastructure can occur, it does provide examples of both local and site-scale features within the classification system.

While ecosystem services are not explicitly mentioned, green infrastructure throughout the document is linked to functions that would be classified as regulating services such as water flow

management, erosion control, and improved air quality. It also promotes green infrastructure as an approach to reducing greenhouse gas emissions and preparing for climate change. This indicates that the Government of Ontario views green infrastructure as a climate resilience strategy despite excluding that language from the definition itself. However, the document makes no connection between green infrastructure and heat reduction, social or health benefits, biodiversity enhancement, or many of the other functions commonly associated with green infrastructure in the literature.

Although there is no use of the term nature-based solutions, "low impact development" is presented as an important policy tool for the province. LID is defined as an "approach to stormwater management that seeks to manage rain and other precipitation as close as possible to where it falls to mitigate the impacts of increased runoff and stormwater pollution. It typically includes a set of site design strategies and distributed, small-scale structural practices to mimic the natural hydrology to the greatest extent possible through infiltration, evapotranspiration, harvesting, filtration, and detention of stormwater." Within the PPS, LID is promoted alongside green infrastructure as an approach to reducing GHG emissions, preparing for climate change, and improving air quality. Municipalities are also encouraged to undertake watershed planning which includes LID.

Although the definition of LID includes several green infrastructure typologies identified within the classification system, such as bioswales, permeable pavement, and rain gardens, the PPS does not clarify whether these features are also considered green infrastructure or how the relationship between LID and green infrastructure should be understood. Green roofs appear in both definitions, yet the PPS does not indicate whether they function differently as LID practices or green infrastructure, which leaves their conceptual placement uncertain. Stormwater management systems, which are listed as a type of green infrastructure, may also encompass LID practices based on its definition, but the document does not define this feature or make the relationship explicit. As a result, the conceptual hierarchy between LID and green infrastructure remains unclear within the PPS.

Other examples of green infrastructure that are not explicitly categorized within the classification system nevertheless align with the working definition. These include "natural channels" and "natural heritage features," which encompass wetlands, woodlands, and other significant areas of natural and scientific interest. Beyond the features explicitly associated with green infrastructure or LID, however, the PPS identifies few additional typologies contained within the classification system, although it does acknowledge the role of the Greenbelt Plan in addressing environmental challenges within its geographic area.

Another provincial policy text important to recent planning and growth management direction in the Toronto region is the *Growth Plan for the Greater Golden Horseshoe*, with its most recent office consolidated version including the concept of green infrastructure (Government of Ontario, 2020). Although the *Growth Plan* was repealed with the introduction of the *2024 Provincial Planning Statement*, its definition of green infrastructure, originally derived from the *2020 Provincial Policy Statement*, is identical to that contained in the current PPS and is still relevant for examination due to its role in shaping green infrastructure projects which current exist in the city. The *Growth Plan* also adopts the same definition of LID, with the addition of a sentence clarifying that LID does not always but often does include vegetation. It further notes that the specific form of LID will vary depending on local conditions and community character. While this recognizes that implementation should respond to local contexts, the document still does not indicate that communities should be involved in the planning process.

Within the *Growth Plan*, green infrastructure is almost exclusively paired with low impact development. The strategies are encouraged to be adopted into municipal stormwater master plans and are said to increase resiliency of "complete communities" to climate change by, for example, the mitigation of GHG emissions and the adaptation to extreme weather events. The document does not provide additional clarification regarding what constitutes the green infrastructure feature of "stormwater management systems." It also introduces the concept of best management practices (BMPs), which Matsler et al. (2021) identify as being associated with both green infrastructure and LID, but it neither defines BMPs nor explains their relationship to these concepts. The *Growth Plan* likewise does not introduce additional green infrastructure typologies beyond those identified in the PPS. However, it does connect natural heritage systems, which are identified as a green infrastructure feature, to ecosystem services and biodiversity enhancement.

The PPS and *Growth Plan* are two of the most important provincial policy documents that have guided recent planning decisions in Toronto. They are conceptually aligned, provide definitions of green infrastructure and LID, and promote both strategies as tools for climate resilience. However, they do not explore how these strategies interact with one another or with related terms such as BMPs, and provide examples of green infrastructure which are broad and may be left unexplained, such as stormwater management systems. A document released between the PPS and *Growth Plan*, titled the *Draft LID Stormwater Management Guidance Manual*, however, provides more clarity on how green infrastructure functions within Ontario's policy landscape. The *Guidance Manual* offers municipalities, developers, and other practitioners' information on the benefits of managing rain and snowmelt where it falls, complements existing provincial design guidelines, and serves as a reference for stormwater management application review under the Ontario Water Resources Act (Government of Ontario, 2022).

The *Guidance Manual* includes the same definition of green infrastructure as the PPS and *Growth Plan* but expands it by identifying "LID (BMPs)" as examples of green infrastructure, thereby clarifying how the concepts interact. The text also explains that BMPs are the specific physical features, engineered systems, or design strategies which are used to implement LID. Although the document focuses on water management, it also identifies additional functions of green infrastructure such as supporting community sustainability objectives, creating habitat, providing recreational green space, and reducing the urban heat island effect. While the definition again does not include an equity requirement, the manual emphasizes that stormwater management must meet the needs and abilities of local communities and that planning decisions in general should involve input from residents.

The *Guidance Manual* provides the most comprehensive description of green infrastructure and its relationship to LID and BMPs among the provincial documents reviewed. This clarity is important for municipalities and other stakeholders who must determine which features to implement in specific situations. However, the manual remains a draft document and had still not been adopted as of July 2025 (Government of Ontario, 2025), leaving municipalities without a formal source that clearly defines the relation of concepts. Furthermore, although the manual identifies additional benefits of green infrastructure, it reinforces the Government of Ontario's strong focus on the strategy as primarily a water management tool, with attention on preserving water balance, protecting water quality, and preventing erosion and flooding. This emphasis is expected given the document's focus on LID and the need for climate events such as flooding to be addressed in the province, but it also highlights a broader pattern in Ontario's policy landscape which may neglect the use of green infrastructure in other meaningful ways.

Overall, these documents show that green infrastructure has long been present in provincial policy and is treated as an important component of municipal planning. The province's approach aligns more closely with the academic literature, as it employs the concept of green infrastructure rather than natural infrastructure. However, the absence of a clear hierarchical distinction between green infrastructure and LID, and lack of definition for BMPs or what kind of stormwater management systems are included in green infrastructure across adopted provincial documents has resulted in a less coherent conceptualization. Furthermore, while Ontario's description of green infrastructure is more aligned with the evaluative framework and the literature than the federal government's, the consistent pattern of pairing green infrastructure with low impact development limit the promotion of typologies that are less water centric but equally relevant in climate resilience and social equity, such as allotments and city farms.

4.3 Toronto and Region Conservation Authority

The Toronto and Region Conservation Authority (TRCA) derives its legal authority from the *Conservation Authorities Act* to regulate development and activities in areas where natural hazards such as

flooding, erosion, and unstable slopes may be present (Government of Ontario, 2026). The body also carries broader watershed management responsibilities, including environmental planning, stewardship, and providing technical advice to municipalities.

A key document shaping TRCA's vision of green infrastructure in Toronto and its surrounding area is the *Living City Policies* (2014). The *Living City Policies* (LCP) outline how TRCA carries out its legislated responsibilities in development review, infrastructure planning, and permitting processes (TRCA, n.d.f). Despite being more than a decade old, the LCP presents a detailed approach to green infrastructure, offering comprehensive definitions, clear relationships to alternative terminology, an extensive range of typologies, and a coherent use of associated concepts drawn from international planning and ecological practice. At the same time, the LCP also reveals the central tension explored in this section: TRCA demonstrates a deep understanding of green infrastructure across its documents and programs, yet its formal definitions do not fully satisfy the criteria of the evaluative framework and are not consistently carried forward across its more recent materials.

In the glossary of the *Living City Policies*, green infrastructure is defined as "natural vegetation, vegetative systems, soil in volumes and qualities adequate to sustain vegetation and absorb water, and supportive green technologies that replicate ecosystem functions." This definition does not satisfy any of the three criteria of the evaluative framework. It does not identify green infrastructure as a climate resilience tool, does not reference social equity or community-informed planning, and does not reduce ambiguity by clarifying how green infrastructure exists across different scales or types. The glossary does, however, direct readers to two related terms, "natural green elements" and "built green elements," which provide additional clarity.

Natural green elements are described as "traditional natural features such as trees, wetlands, riparian areas, buffers, and agricultural soils" that contribute to water retention within natural heritage systems. This definition is clear on what constitutes a natural green element, but by emphasizing that these features are to be implemented within natural heritage systems, it effectively positions those systems as both a green infrastructure typology identified by the provincial government (and later the City of Toronto) and as a land-cover category that provides the physical space in which these forms of green infrastructure are intended to function.

Built green elements are defined as "human-created systems and technologies that are designed to mimic ecological functions to reduce environmental impacts from human activities," and includes features such as stormwater management ponds, green roofs, green walls, permeable pavement, and rainwater harvesting. Although these two categories are unique to TRCA, they serve a similar conceptual role to the

distinction between natural and hybrid infrastructure used by the federal government's *Natural Infrastructure Fund* webpage.

Unlike the conceptualizations provided by the Government of Canada's *National Adaptation Strategy* or the *Adaptation Action Plan*, TRCA's approach, like the NIF webpage, clearly separates ecological features from engineered systems rather than conflating multiple concepts under the umbrella of green or natural infrastructure. When applied consistently, this separation into subcategories provides a stronger foundation for planners and practitioners because it allows policy to specify which types of green infrastructure should be prioritized in particular contexts.

A stronger and more detailed understanding of green infrastructure outside the definition appears throughout the document, where it is identified as one of the pathways to achieving "The Living City." In the LCP, green infrastructure is framed primarily as a water management strategy, consistent with TRCA's watershed mandate, and is described as being rooted in the philosophy that water sustains life and green infrastructure sustains water. Although, the text also details the multifunctional benefits of natural or built green elements beyond reducing flooding and filtering water by including the provision of "additional ecosystem services" that are not water-based, such as moderating of the UHI effect and offering recreational space.

Green infrastructure is explicitly identified as a climate resilience tool that must be planned for as urbanization intensifies within the LCP. The document also reduces conceptual ambiguity outside its green infrastructure definition by consistently using the natural and built green element categories and by clearly addressing scale for the first time, noting that green infrastructure can be implemented at "multiple scales, ranging from regional networks of open spaces and natural areas to site-specific practices such as green roadways and streetscapes, green roofs, porous pavements, and rain gardens." The LCP highlights biodiversity benefits and is the only document reviewed to list all twelve typologies in the classification system, along with ravines and greenbelts, many of which are directly identified as features of green infrastructure.

The *Living City Policies* additionally provides the most coherent treatment of terminology that also appears across provincial and federal documents. The LCP positions "low impact development" as a form of "best management practice" that exists within broader stormwater management systems, and LID is also explained to be a built green element type within the larger green infrastructure category. These distinctions strengthen the relationship between concepts and positions them clearly within a hierarchy, providing a path for municipalities like Toronto to be clearly aligned with, whether or not it is followed.

One limitation of the LCP is its lack of explicit social equity considerations tied to green infrastructure. Although the document frames the creation of "The Living City" as a collaborative effort requiring community engagement, it does not connect this collaboration to the planning or distribution of green infrastructure, nor does it acknowledge the inequities in green infrastructure access documented in Toronto by scholars, as demonstrated in analyses by Bu et al. (2024) and Regier and Conway (2022). This omission reflects a broader absence of equity language across key frameworks from TRCA, Ontario, and the Government of Canada, despite equity being a core criterion of the evaluative framework in an effort to reflect the essential necessity for the strategy to be planned through a lens that considers these factors. TRCA's (n.d.e) *Green infrastructure solutions* webpage, however, demonstrates that equity concerns are present in practice by the authority. The Sustainable Neighbourhood Action Program is identified as an initiative that builds neighbourhood resilience by engaging communities vulnerable to climate impacts such as heat stress and stormwater challenges. While this indicates that TRCA strives toward social equity objectives, the absence of explicit equity language being tied to green infrastructure in the LCP may limit the extent to which these goals are embedded in formal planning processes.

Although the LCP was written in 2014, the conservation authority's webpages, including the *Ecosystem services and valuation* page (TRCA, n.d.b) and the *Green infrastructure* page (TRCA, n.d.c) demonstrate that the authority continues to advocate for green infrastructure and presents its benefits in ways that closely mirror the LCP. The *Ecosystem services and valuation* webpage complements the LCP's conceptualization by outlining the four categories of ecosystem services and highlights TRCA's ongoing work to quantify and map these services across green infrastructure projects in the region. The *Green infrastructure* webpage identifies "climate change mitigation and adaptation" benefits such as stormwater pollutant and runoff reduction and improved air quality through green infrastructure, while also identifying its ability to enhance biodiversity and provide spaces which better physical and mental health. It also references many typologies found in the classification system, including parks, city farms, green roofs, green walls, and street trees, reinforcing TRCA's continued emphasis on a multifunctional understanding of green infrastructure.

The *green infrastructure* webpage provides its own definition of the concept as "the natural vegetation and green technologies that collectively provide society with a multitude of economic, environmental, health, and social benefits." Although similar in principle to the *Living City Policies*, this definition notably drops the earlier distinction between natural and built green elements and instead prioritizes "green technologies." While the LCP states that "green buildings" contain green technologies such as solar panels, green roofs, and grey-water systems, the distinction made in the glossary definition is that these technologies are only considered green infrastructure if they "replicate ecosystem functions."

Considering this distinction is not made on the webpage, nor are there examples of what is included in green technologies, its use creates conceptual ambiguity, raising questions about whether all green technologies, like the solar panels and grey-water systems identified in the LCP, are now considered green infrastructure, despite both failing to meet the criteria of the evaluative framework and previous depictions of green infrastructure from TRCA.

More recent TRCA documents, such as the *Green Stormwater Infrastructure Asset Management Resources Toolkit* (TRCA 2021), further complicates the authority's interpretation of green infrastructure, as it combines the *2014 Provincial Policy Statement* definition with the City of Toronto's concept of green streets. Together, this variation suggests that while TRCA demonstrates a sophisticated understanding of green infrastructure across its programs and webpages, its formal definitions are not applied consistently. Shifting away from the natural and built green element categories without defining green technologies, for example, increases ambiguity rather than reducing it and makes it difficult to determine which conceptualization practitioners should rely on.

4.4 City of Toronto

Toronto has long been a leader in adopting practices now associated with green infrastructure. The City's 2003 *Wet Weather Flow Management Master Plan* demonstrates an early adoption of these ideologies, as it treated vegetation and soil as tools to manage rainfall and snowmelt where it fell (City of Toronto, 2003). The amendment to the 2006 *Official Plan* enabling the 2009 green roof by-law for the purposes of water and energy conservation positioned Toronto as the first North American city to require green roofs on new buildings (City of Toronto, 2009; City of Toronto, 2017a). Although these initiatives were not explicitly labelled as "green infrastructure" at the time, they illustrate Toronto's longstanding reliance on the strategy well before the term entered municipal policy language. Since then, however, Toronto's use of green infrastructure has evolved to include varied terminology and definitions, which complicates its innovative inclusion of these ecological tools. According to the City's *Green Infrastructure Resources* webpage, the province, the TRCA, and the City share responsibility for promoting and expanding green infrastructure, supported by legislation, policies, and design standards that advance resilience and quality of life. However, the cohesion and clarity within Toronto and across these levels of government shows that a shared commitment does not necessarily translate into a shared understanding of the concept or a consistent approach to its implementation.

The June 2015 office consolidation of the *Toronto Official Plan* is the first version of the plan to reference the concept of green infrastructure (City of Toronto, 2015). However, the term appears without a definition and is used only in passing, primarily to describe the goal of balancing multiple users and functions within the right-of-way of city streets and, at times, as a synonym for the City's "parks and open

space system." Although the plan references several features that align with the classification system, such as bioswales, green roofs, stormwater management ponds, allotments, permeable pavement, wetlands, and ravines, none are explicitly connected to green infrastructure. As a result, the term functions less as a clear policy tool and more as a catch-all term, offering little guidance on how green infrastructure should be understood or applied.

The 2015 version of the *Official Plan* instead includes features of green infrastructure, like parks and wetlands, as components of Toronto's "green space system," which is described in a way that overlaps with many of the functions typically attributed to green infrastructure, including biodiversity flourishment, social and physical recreation, the improvement to air and water quality, and the mitigation of flooding (City of Toronto, 2015). The City of Toronto's (2017b) *Toronto Ravine Strategy*, a currently used document which outlines a plan to balance protection and use of the spaces for pressures stemming from population growth, new development, and climate change, connects several of these concepts by describing ravines as part of both the green space system and natural heritage system, and is designated as parks and open spaces, while also being a feature of green infrastructure.

However, the strategy follows the same pattern of not defining green infrastructure, despite using the concept to categorize ravines as a typology, along with trees, gardens, and green roofs. This demonstrates that the concept is being used but with considerable overlap among related terms and without clear distinctions between them. The *Ravine Strategy* cannot be directly compared to the working definition because it does not provide one of its own, yet its references to climate change events such as flooding and air pollution, and its attention to animating ravines and nearby green spaces in low-income neighbourhoods for social equity purposes show that the term was being used implicitly rather than through a clearly articulated policy framework.

Another key document created in an effort to enhance the city's adaptation capacity is *Toronto's First Resilience Strategy* (City of Toronto, 2019). Unlike any Canadian policy to this point, this document uses the term "green and blue infrastructure" and defines it as the "use of nature as infrastructure to meet specific goals and service targets," such as filtering stormwater, reducing storm surges, and mitigating the urban heat island effect. Unlike earlier municipal documents, the *Resilience Strategy* sees it as important to distinctly emphasize that green infrastructure includes blue elements, despite the general understanding being that this is implicitly the case in North America. The text also explains that this concept is synonymous with both natural infrastructure and resilient infrastructure, further adding to unclarity regarding the purpose of related terminology. The definition does not meet the evaluative framework's criteria because climate resilience, although implied through references to resilient infrastructure and examples of regulating services, is not directly included. Social equity considerations are also absent from

the definition, and the description is broad and lacks examples that would reduce ambiguity, unlike what was demonstrated at higher levels of government.

The *Resilience Strategy* does, however, emphasize the importance of these criteria throughout the document. One of its aims is to expand the use of green and blue infrastructure as a method to improve the city's resilience to climate shocks, demonstrating that the city does view the concept as an adaptation and mitigation tool essential to future development. Equity is also a major component of the strategy. The document seeks to develop a "resilience lens" for infrastructure projects that incorporates the City's existing "equity lens," prioritizing how projects affect vulnerable groups, acknowledging that reliable infrastructure is not equitably distributed across Toronto, and emphasizing the need to move away from top-down planning toward greater community involvement.

The *Resilience Strategy* does not contribute further fragmentation beyond equating green infrastructure to natural and resilient infrastructure, as the text does not include, for example, LID or NBS. The strategy also does not address the spatial scales at which green and blue infrastructure operate, and only a few typologies within the classification system are directly associated with the concept, including bioswales, wetlands, and ravines. The document also highlights urban forestry and "green streets" as additional examples, although green streets are described as a typology rather than a program that integrates green infrastructure features such as bioswales, which is inconsistent with the City's *Green Streets* webpage (City of Toronto, n.d.). Other typologies in the classification system, such as rain gardens, city farms, and greenbelts are mentioned but not positioned as features of the concept.

Overall, Toronto's *First Resilience Strategy* is consistent in its use of the term green and blue infrastructure, although this distinction is generally viewed as redundant in the literature on green infrastructure. The definition does not acknowledge the common depiction of green infrastructure as also containing built elements, such as permeable pavement, but its inclusion of bioswales, a feature that falls under the "Combined" category in the classification system, further obscures the concept's meaning within the document. While the strategy is not contradicting or altering any established municipal understanding of the term since no definition existed from Toronto at this point, it reflects the same pattern seen in previous documents, where the concept is applied in practice without a clearly articulated or consistently defined policy framework.

The March 2022 office consolidation of the *Toronto Official Plan* provides a new definition of green infrastructure that is identical to the Government of Ontario's from the 2020 *Provincial Policy* Statement, which was later carried into the 2024 PPS (City of Toronto, 2022c). Because Toronto's 2022 *Official Plan* adopts the same definition of green infrastructure used in Ontario's planning and policy

statements, it meets the evaluative framework in exactly the same way by providing clear examples in the definition that reduce ambiguity but failing to identify green infrastructure as a climate-resilience tool, to reference equity or community-informed planning, or to acknowledge its full range of spatial scales. Outside of the definition, the plan does not connect green infrastructure to resilience or equity efforts, nor does it elaborate on concepts such as ecosystem services or contributions to biodiversity, leaving little explanation beyond the Ontario-borrowed definition.

Although the plan does not use terms such as natural infrastructure, resilient infrastructure, low impact development, or nature-based solutions, it continues to rely on the concept of "green space systems," which overlaps significantly with green infrastructure but whose relationship to it is not explained. The plan also continues to identify "stormwater management systems" as a feature of green infrastructure, but it does not clarify what this entails or whether all stormwater management systems are examples of the tool. Therefore, the 2022 definition aligns Toronto with Ontario's conceptualization, which can be seen as a positive step toward consistency, but it provides little explanation beyond the definition and also contrasts with the framing used in the *First Resilience Strategy* which said the approach only includes natural elements and not a combination of green and blue with grey. As a result, the *Official Plan* does not provide planners with a clear or comprehensive understanding of how green infrastructure should be interpreted or applied within the broader municipal policy landscape.

The 2022 *Official Plan* definition, as part of Toronto's most important policy document, influences the City's mandatory green infrastructure requirements found in its latest building standards and frameworks. The City's fourth version of the *Toronto Green Standard*, released in the same year as the latest *Official Plan* consolidation, requires both low-rise and mid- to high-rise development to incorporate green infrastructure in its site design, primarily said to be as a stormwater management tool (City of Toronto, 2022a; City of Toronto, 2022b). The on-site green infrastructure mandatory for mid-to high-rise, for example, must include at least one of the following: an enhanced green roof, an enhanced landscape using pollinator plants, a bioretention facility, or a reforested area, all of which classify as green infrastructure through the evaluative framework. This requirement demonstrates that understandings from Toronto's primary policy vehicle can translate into actionable implementation for developers despite the *Official Plan* offering minimal conceptual direction.

Furthermore, the *Wet Weather Flow Master Plan* has been updated to explicitly include the concept of green infrastructure into the city's design approach, despite features of the strategy existing since 2003 (City of Toronto, 2023). The current plan identifies typologies such as bioswales, rain gardens, and permeable pavement, but it does not include its own definition, implying reliance on the *Official Plan*'s meaning of the term which is noted as lacking important criteria outlined in the working definition.

Overall, Toronto's approach to green infrastructure has progressed from early practice-based adoption to a more formalized policy framework, yet the city's documents continue to apply the concept inconsistently and without clear definitions. While the 2022 *Official Plan* aligns Toronto with Ontario's definition and informs mandatory implementation through the *Toronto Green Standard*, the policy landscape still lacks clear direction for how green infrastructure should be interpreted, planned, and applied in an equitable manner that serves as a core resilience component.

5. Illustrative Examples of Green Infrastructure Projects in Toronto

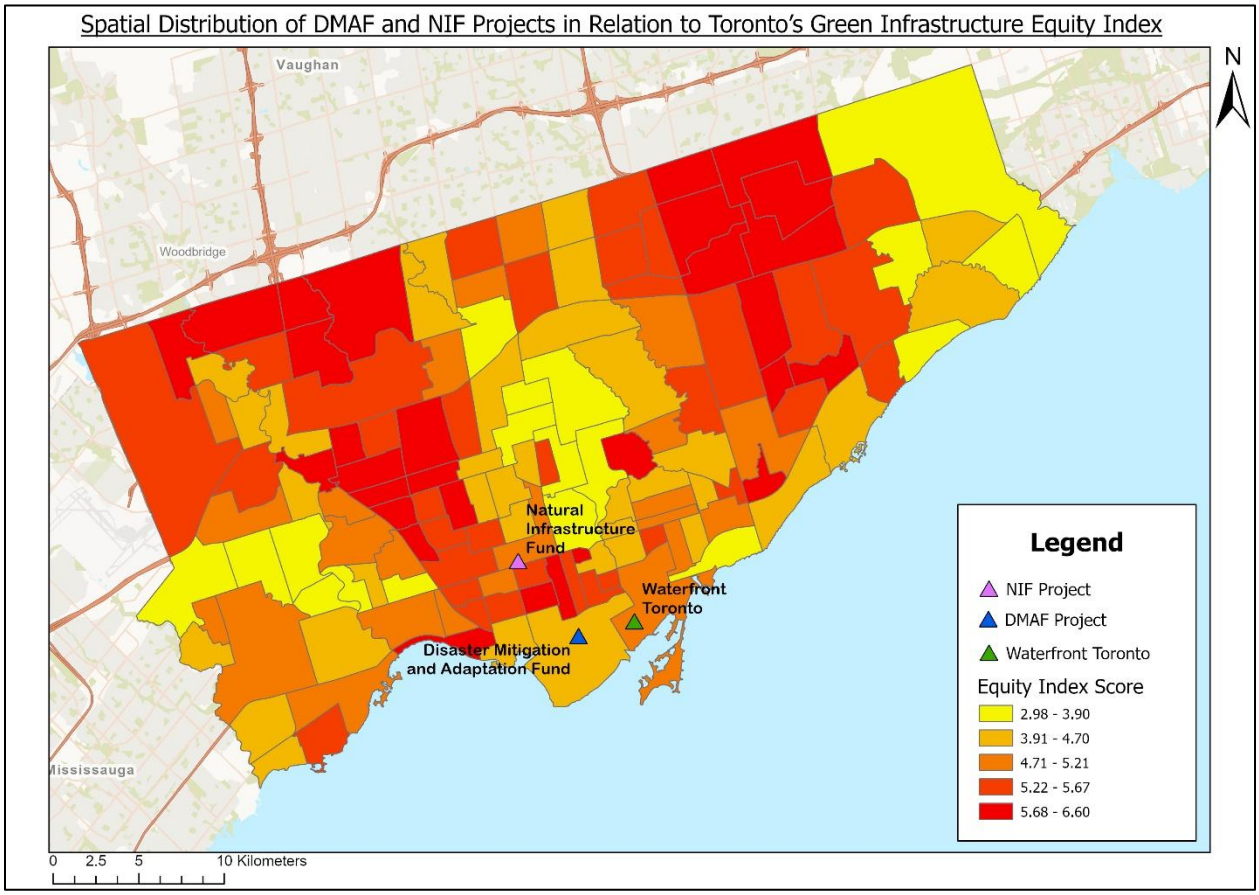
Illustrative examples of intergovernmental coordination between the Government of Canada, the Government of Ontario, the Toronto and Region Conservation Authority (TRCA), and the City of Toronto are selected to examine how green infrastructure and related terminology are translated into implementation. To ensure consistency across cases, the examples focus on projects that received federal funding, two of which that were mentioned in the examined federal policy. These initiatives require collaboration across multiple levels of government and reveal how federal priorities and funding interact with policies from Ontario, the TRCA, and the City of Toronto. These jointly delivered examples show how government understandings of green infrastructure, including the typologies it encompasses, the purposes it is intended to serve, the ecosystem services it is expected to provide, and the priorities emphasized in policy, are reflected in the types of green infrastructure projects implemented in Toronto and in the ways these interventions are distributed across the city.

To identify where these federally supported projects are found within Toronto's municipal boundaries, a map was created using Regier and Conway's (2022) green infrastructure equity index applied to the 140 Social Planning Neighbourhoods defined by the City of Toronto. The index combines four built environment factors with five socio-economic factors to place each neighbourhood on a scale from 0 to 9, with 9 representing the highest level of vulnerability. For built criteria, higher scores were given to neighbourhoods which are less protected from extreme heat and flooding by measuring the amount of impermeable surfaces, tree canopy cover, park provision, and green roofs in the area. For socio-economic factors, a population was identified as more vulnerable if the neighbourhood had high levels of visible minority populations, low-income residents, individuals with low education, renters, and seniors over the age of 65. These criteria were selected because these groups are said to often lack the financial resources, political capital, or legal agency required to implement protective measures, while certain demographics, like seniors, face significantly higher health risks during climate-related events such as extreme heat (Regier & Conway, 2022).

Neighbourhood scores from Regier and Conway (2022) range from Black Creek's value of 6.60 to Bridle Path Sunnybrook-York Mills' score of 2.98, with a median of 5.14. The illustrative examples of coordinated green infrastructure projects are mapped where possible, meaning only when governments provide sufficient detail to identify project locations. These mapped examples appear in Figure 1. Table 1 supports the figure by presenting neighbourhood equity index scores from Regier and Conway (2022) alongside project details for Natural Infrastructure Fund and Disaster Mitigation and Adaptation Fund initiatives reported by the Government of Canada (2026c), as well as Waterfront Toronto (2025).

Figure 1

Spatial Distribution of Green Infrastructure Projects in Toronto Compared to Green Infrastructure Equity Index



Note. Map created by the author using project location data from Government of Canada (2026c) and Waterfront Toronto (2025) and the Green Infrastructure Equity Index developed by Regier and Conway (2022).

Table 1

Summary of Green Infrastructure Projects Included in the Analysis

Map Symbol	Neighbourhood	Green Infrastructure Equity Index Score	Funding Program	Project Name	Completion Status	Total Estimated Cost	Federal Program Contribution (%)	Source
Purple Triangle	Annex	6.19	Natural Infrastructure Fund	KESKUS International Estonian Centre Green Roof	In Progress	$1,000,000	59	(Government of Canada, 2026c)
Not Mapped	Not Defined	Not Defined	Natural Infrastructure Fund	Toronto's Ravine Strategy Project	In Progress	$20,000,000	59	(Government of Canada, 2026c)
Green Triangle	South Riverdale	4.91	Waterfront Toronto	Port Lands Flood Protection Project	In Progress	$465,000,000	33	(Waterfront Toronto, 2025)
Blue Triangle	Waterfront Communities – The Island	4.21	Disaster Mitigation and Adaptation Fund	Repair, Remediate, and Enhance Resilience of Toronto's Tree Canopy and Waterfront Shoreline Structures to Protect Against Future Flooding and Storm Events	In Progress	$11,989,186	40	(Government of Canada, 2026c)

Note. Table summarizes the projects shown in Figure 1. One Natural Infrastructure Fund project is not mapped because its site boundaries are undefined in the federal dataset. Information compiled from Government of Canada (2026c) and Waterfront Toronto (2025).

The Government of Canada's (2024d) Natural Infrastructure Fund (NIF) is one mechanism through which the federal government allocates resources to municipalities. Announced in 2021, the federal government has completed its distribution of $120 million to large municipalities such as Toronto through this fund. The NIF supports projects delivered collaboratively with lower levels of government that use "natural or hybrid approaches" to increase climate change resilience. These approaches include the mitigation of carbon emissions and the contribution to the purification of air and water, as well as protecting biodiversity, and promoting access to nature (Government of Canada, 2024d).

Housing, Infrastructure, and Communities Canada's interactive map of its initiatives displays two projects within Toronto that have received funding through the NIF. One project is a green roof that is currently being built on the KESKUS International Estonian Centre, which is described as primarily for

stormwater management (Government of Canada, 2026c). This project falls within the "Combined" category found within the classification system at the "Particular" scale and provides limited benefits beyond the regulating service of water flow management, reflecting the purpose outlined in the federal government's description. The green roof is located in the Annex neighbourhood, which has an equity index score slightly above the median at 5.19 (Regier and Conway, 2022), although it is not designated as a "Neighbourhood Improvement Area" (NIA) or an emerging neighbourhood by the City (Government of Canada, 2026c).

The second contribution through the NIF supports the *Toronto Ravine Strategy* by funding 59% of projects that either improve trails to increase access to ravines or enhance the infiltration and detention of stormwater capabilities in these systems through stream restoration (Government of Canada, 2026c). This continues the emphasis on water flow management within NIF initiatives. The specific locations of these projects are not provided and therefore cannot be mapped in Figure 1 or assigned an equity index score. However, the City of Toronto explains that these projects, which are delivered collaboratively with the province, TRCA, and federal government are intended to be located in ravines that fall within NIAs. Implementation is further said to be guided by residents in these more vulnerable communities, highlighting the need to protect all residents in ways that respond to their specific contexts (City of Toronto, 2026b).

Both projects supported by the NIF are considered green infrastructure according to the evaluative framework. Although examples from this fund are limited, the two projects are notably centred on increasing Toronto's resilience to flooding, but neglect to prioritize other important ecosystem services or the enhancement of biodiversity. Despite the federal and municipal governments often failing to state clearly in policy that natural infrastructure or green infrastructure should involve community collaboration or target areas that require greater support, both projects advance these ideas, as one is located in a neighbourhood with a vulnerability score above the median, and the other explicitly focuses on directing green infrastructure interventions toward more vulnerable communities.

The Disaster Mitigation and Adaptation Fund (DMAF) is another allocation system established by the Government of Canada to support resilience-building initiatives in municipalities such as Toronto. Since 2018, the fund has allocated its entire $3.7 billion, and all projects are expected to be completed by March 2035 (Government of Canada, 2026a). Unlike the Natural Infrastructure Fund, which is intended to support projects that qualify as green infrastructure, several initiatives funded through the DMAF increase Toronto's resilience in ways that would not be classified as green infrastructure.

These initiatives that are not classified under the approach also primarily focus on stormwater management. Examples include, for instance, upgrading culverts and adding floodwalls in Rockcliffe-

Smythe, expanding the Jane Street Bridge to reduce flooding risk from the Humber River, reducing flooding at the Lower Simcoe Underpass by upgrading traditional sewage systems, and other grey infrastructure projects designed to manage runoff (Government of Canada, 2026c). These projects demonstrate that federal resilience funding, even while encouraging more natural solutions in policy, continues to prioritize water flow management through interventions that do not expand Toronto's repertoire of green infrastructure.

Additionally, there are DMAF collaborations in progress whose methods are unclear in how the goals of the project are to be achieved. For example, the "Toronto Region Ravine Erosion Risk Management and Hazard Mitigation Project" delivered by the federal government, the TRCA, and the City of Toronto, does not specify how "erosion control and slope stabilization works" will be achieved (TRCA, n.d.a). These measures could involve green infrastructure such as vegetation or grey infrastructure such as retaining walls, but because the project does not identify which approach will be used, it is not included as an illustrative example of green infrastructure in the city. These projects highlight the persistent gap between policy statements that emphasize the importance of green infrastructure and the ways resilience measures are implemented, which are frequently either deprioritized or left sufficiently broad that it is unclear whether they constitute green infrastructure.

Despite the Government of Canada (2024a; 2024b) identifying the Disaster Mitigation and Adaptation Fund as a key strategy to implementing natural and hybrid infrastructure projects, there is only one initiative in Toronto supported by the fund that clearly qualifies as green infrastructure according to the evaluative framework. The main example that aligns with the evaluative framework is the Government of Canada's (2026c) tree canopy and waterfront shoreline structures project. The purpose of this multi-faceted initiative is to improve the capacity of the Waterfront Communities neighbourhood to mitigate further flooding, erosion, saturated soils, and weakened root systems. The project combines "shoreline infrastructures, waterfront parks, beaches, embankments, trails and pathways" and additional tree planting. While the DMAF webpage does not specify which "shoreline infrastructures" are being constructed, it does reference two typologies within the classification system: parks and urban trees. Both parks and trees fall within the "Green (with trees)" category of the classification system and are at "City" and "Local" scales respectively. While parks and trees do provide the mitigation of flooding, heat mitigation is once again excluded as a stated benefit of these features, reinforcing the pattern of green infrastructure in Toronto being heavily oriented toward controlling hydrological processes. Although any neighbourhood in the city can benefit from green infrastructure regardless of its equity index score, it is noted that the Waterfront Communities neighbourhood has a lower-than-average score of 4.21 and may therefore be less vulnerable than other areas of Toronto.

Another project along Lake Ontario that incorporates green infrastructure through collaboration between the municipal, provincial, and federal governments is the Port Lands project, delivered through the joint taskforce known as Waterfront Toronto. Waterfront Toronto was established in 2001 in recognition of the level of coordination required to address longstanding concerns in the area (Waterfront Toronto, n.d.). One of its major initiatives is the *Port Lands Flood Protection* project, which protects 174 hectares of land in the Port Lands and eastern waterfront from flooding, and, once complete, will provide residence for over 15,000 people. In addition to the re-naturalized mouth of the Don River, the project contains several green infrastructure projects to boost the location's climate resiliency, including parks and a wetland (Waterfront Toronto, 2025). Parks are in the "Green (with trees)" category in the classification system, and wetlands are considered "Blue," while both are features of the "City" scale. The *Flood Protection* project is located within the South Riverdale neighbourhood, which has an equity score of 4.91. Although this score is slightly below the citywide average, the Port Lands remains a critical geography for resilience planning, reflected in its status as a $1.4 billion tri-government investment.

These examples of projects supported by the Natural Infrastructure Fund, Disaster Mitigation and Adaptation Fund, and Waterfront Toronto show that intergovernmental coordination in Toronto consistently supports projects intended to strengthen climate resilience, yet the types of interventions reveal a narrow interpretation of the benefits of green infrastructure, as there is an overwhelming focus on managing hydrological processes, particularly flooding, while other ecosystem services such as heat mitigation, air purification, social interaction support, or biodiversity enhancement receive comparatively limited attention. At the same time, several federally supported projects either do not specify whether natural or hybrid approaches will be used or describe their methods so broadly that it is unclear whether green infrastructure is involved at all. Even when projects do align with the evaluative framework, they are not consistently directed toward the neighbourhoods with the highest vulnerability scores, such as in Black Creek, Kensington-Chinatown, or Glenfield-Jane Heights (Regier & Conway, 2022). Overall, the examples illustrate both the importance placed on green infrastructure in policy rhetoric and the persistent gaps, ambiguities, and hydrological bias that shape how green infrastructure is implemented through intergovernmental collaboration in Toronto.

6. Conclusions and Paths Forward

6.1 Summative Discussion

The document analysis and illustrative examples demonstrate that, although governments across Canada increasingly recognize green infrastructure and related approaches as important tools for addressing climate change, substantial inconsistencies remain in how these concepts are discussed, defined, and

operationalized. Across the documents reviewed, three overarching patterns emerged. First, governments employ inconsistent and overlapping terminology without clearly explaining the relationships among concepts. Second, definitions frequently vary in their completeness, often offering only partial descriptions of what green infrastructure encompasses or the multiple purposes it can serve, which limits understanding of the regulating and cultural services that distinguish it from conventional infrastructure. Finally, the illustrative examples show that these concerns extend beyond documents and into implementation, as cross-government green infrastructure projects are limited in number and narrow in the ecosystem services they identify, demonstrating that policy language changes how green infrastructure is interpreted and applied in practice, and therefore can influence the extent to which Toronto residents are protected from climate change and supported in their overall well-being.

The first concern is that green infrastructure is not consistently used across government bodies when they appear to be referring to the same types of interventions. The federal government frequently uses "natural infrastructure" as a synonymous term for green infrastructure but provides little explanation as to why this term is preferred or how it differs, which contributes to uncertainty about what the approach entails and how it should be interpreted. The City of Toronto also diverges from the term green infrastructure by using "green and blue infrastructure" in its resilience strategy, despite adopting a provincial definition that already includes 'blue' features in other publications. These inconsistencies in terminology are further complicated by the widespread use of related concepts that are often referenced without clear explanation as to how they relate to or differ from green infrastructure, such as nature-based solutions (NBS) at the federal level and low impact development (LID) for the province and Toronto. When left unexplained or contradictory, these variations weaken conceptual clarity and make it more difficult for practitioners to understand which interventions fall under the approach and how they should be applied.

Greater care is also needed in how the term itself is currently applied in government publications. Green infrastructure should not be treated as a substitute for generic greenspace or vegetation, nor should it be conflated with broader policy concepts such as "urban green and blue spaces," as seen in the *2030 Nature Strategy*, or "green space systems," as seen in Toronto's *Official Plan.* These terms often refer to different planning objectives and equating them with green infrastructure weakens the conceptual precision of the approach. Similar caution is required when identifying typologies of green infrastructure, since a feature should not be considered both a typology of green infrastructure and a location where green infrastructure is intended to be implemented, as illustrated by the treatment of "natural heritage systems" in Ontario's policy landscape.

A second pattern is that, although many definitions successfully acknowledge that green infrastructure can be entirely natural, human-made, or a combination of both, they rarely differentiate what

green infrastructure does more effectively than grey infrastructure. For instance, the Government of Ontario's (2024) *Provincial Planning Statement* notes that green infrastructure can support hydrological processes yet does not emphasize that green infrastructure manages stormwater where it falls rather than simply transferring runoff elsewhere. Similarly, the Government of Canada's definitions in the *National Adaptation Strategy* and the *Adaptation Action Plan* state that "green infrastructure provides services and functions in the same way as conventional infrastructure" (2023; 2024b). This framing diminishes the multiple co-benefits provided by green infrastructure, blurs the distinction between the two approaches, and leaves planners, developers, and others consulting these official definitions with little incentive to promote these solutions where not required.

Another component often missing from government definitions is scale. Only the TRCA's *Living City Policies* (2014) explicitly state that green infrastructure can exist at a variety of scales and landscapes, although this is not in the definition itself either. Scale is essential for understanding how different typologies function and where they can be applied. Furthermore, although green infrastructure is widely understood to be a climate resilience tool, Canadian definitions rarely state this directly, which limits its visibility as a unique and highly effective strategy for mitigation and adaptation. Equity considerations are also absent from definitions, even though sometimes publications note that the approach can address uneven vulnerabilities by providing regulating and cultural services to communities most in need, while even fewer acknowledge that projects should be planned in accordance with community members.

Lastly, the illustrative examples reveal that inconsistent terminology and incomplete definitions have consequences for implementation. Only three federally supported green infrastructure projects are identified through major programs such as the Natural Infrastructure Fund (NIF) and the Disaster Mitigation and Adaptation Fund (DMAF), and these initiatives, along with Waterfront Toronto's *Port Lands Flood Protection* project, narrowly emphasize water flow management while not identifying other ecosystem services that features can provide. For example, the DMAF project that includes street trees and Waterfront Toronto's project that includes parks do not highlight the ability of these features to remove air pollution or mitigate heat. When benefits are not explicitly stated in project descriptions or required in funding applications, interventions may be designed too narrowly to deliver the full range of regulating and cultural services associated with green infrastructure. This concern may partly stem from the fragmented and ambiguous use of green infrastructure and related terminology identified throughout Canadian policy, which may help explain why the majority of DMAF initiatives in Toronto focus on upgrading conventional stormwater management through grey infrastructure rather than integrating green infrastructure more fully into the landscape.

Overall, these patterns demonstrate that this observed conceptual ambiguity is not a superficial concern but a structural barrier that shapes how green infrastructure is understood, prioritized, and implemented across Toronto. Inconsistent terminology, incomplete definitions, and narrow interpretations of ecosystem services collectively limit the effectiveness of green infrastructure as a climate resilience and equity strategy. These issues highlight the need for clearer, more coherent policy foundations that can support coordinated action across governments and enable interventions to deliver their full multifunctional potential.

6.2 Constructive Paths Forward

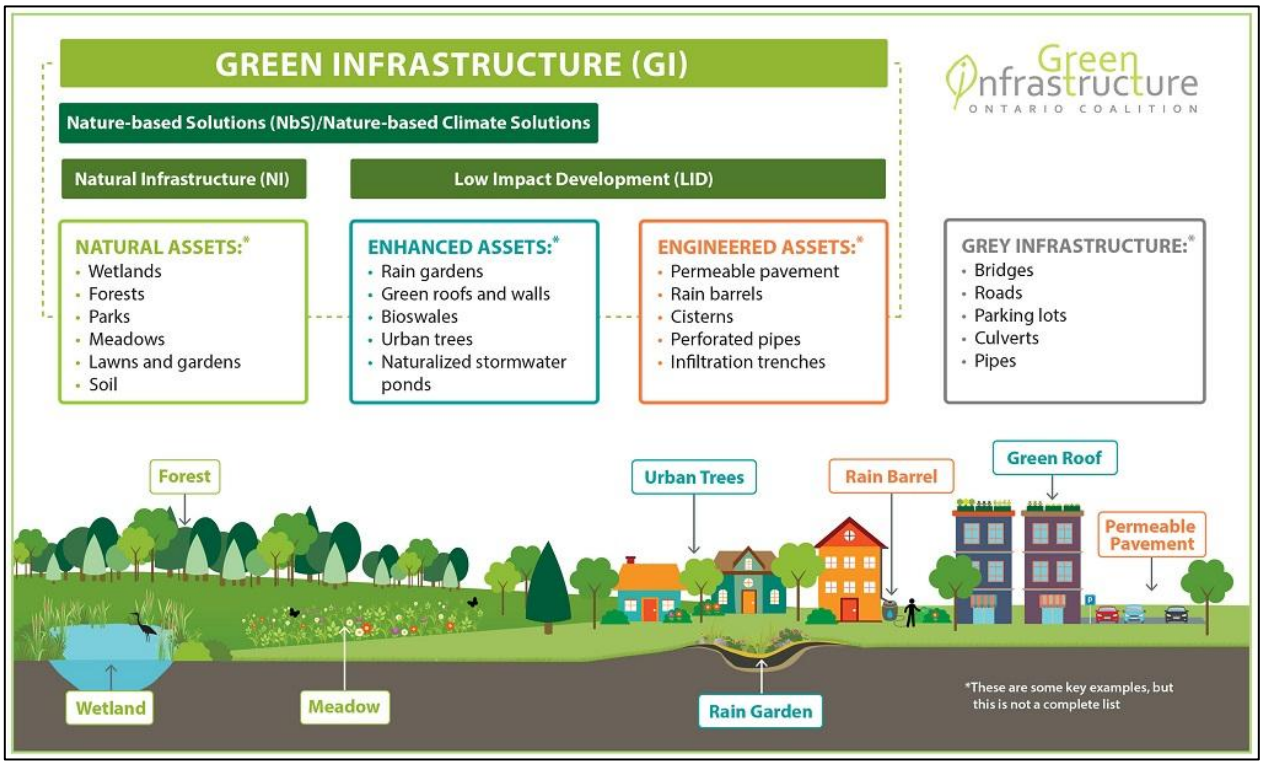
These three core findings establish a foundation for identifying constructive paths forward. They highlight where conceptual clarity is most needed and provide direction for strengthening policy so that planning, implementation, and evaluation can occur more consistently across levels of government.

Green infrastructure is one of the primary tools used across Canada to support climate resilience, but to maximize the potential benefits provided by the approach, a more standardized use of the concept is a necessary first step. Consistent terminology helps ensure that governments are referring to the same types of interventions, which strengthens coordination and reduces the risk of fragmented or contradictory approaches. Using terminology more carefully strengthens the application of green infrastructure across levels of government and helps ensure the concept is treated as a distinct and essential form of infrastructure, similar to other traditional building practices, rather than as a generalized or interchangeable symbolic label.

A clearer hierarchy of related terms would further support this consistency by explaining how concepts overlap and how they differ. The Green Infrastructure Ontario Coalition (2021), which has collaborated with the TRCA since 2009 (TRCA, 2014), provides an example of how terminology can be organized, as illustrated in Figure 2. The hierarchy positions green infrastructure as the umbrella term, shows that NBS include any intervention with a natural element, and clarifies that “natural infrastructure” refers only to features without constructed components. It also demonstrates that LID includes “Combined” typologies in the classification system such as green roofs and green walls, as well as entirely “engineered assets” such as permeable pavement. This type of structure offers greater specificity in policy because concepts can be used tactically to indicate particular use cases. All orders of government should have a consistent understanding of what each term means and how they fit within one another, which may require publications to be updated to reflect these changes. For example, if this specific hierarchy were adopted, the federal government would need to revisit its own definition of natural infrastructure since its current version includes “constructed ecological systems” under the concept.

Figure 2

Hierarchical Organization of Green Infrastructure Terminology



Note. Image from the Green Infrastructure Ontario Coalition (2021) depicting the relationship between green infrastructure categories and examples of their typologies.

To complement a clearer terminology hierarchy, policy can also incorporate a classification system similar to the one developed in this paper, but with a more expansive list of typologies and ecosystem services. A classification system that identifies the category each typology falls under alongside its ecosystem services would strengthen understanding of how different features are organized, the scales at which they operate, and the benefits they provide. For example, "naturalized stormwater ponds," if included in a classification system, could be designated as an "enhanced asset," categorized as a type of "low impact development," and recognized as an example of a "nature-based solution," all within the broader umbrella of "green infrastructure." A system of this kind provides practitioners with clearer guidance on how interventions relate to one another in policy and supports more consistent decision making about which features of green infrastructure are most appropriate for specific targets.

Along with more consistent use of green infrastructure, there also needs to be a re-evaluation of how the concept is defined in Canada. The working definition developed in this paper, grounded in Urban Political Ecology (UPE), spatial justice, and insights from academic literature, identifies several components that should be integrated into government definitions but are currently missing from most publications.

The working definition addresses gaps in government publications by explaining that green infrastructure is designed to deliver multiple ecosystem services, which highlights its multifunctionality and distinguishes it from grey infrastructure that typically serves a single purpose. It also narrows the range of interventions that qualify as green infrastructure by specifying that features must contain ecological components or directly support ecological processes. This distinction, for example, separates conventional stormwater systems that move water across a city from features that promote infiltration and groundwater recharge. Also, by including scale and ecosystem services within green infrastructure definitions, governments would more clearly articulate how interventions function across sites, neighbourhoods, and cities, and how these multi-scalar tools collectively support climate resilience and well-being for Canadian populations.

As Zarei and Shabab (2025) argue, cities facing climate change, urban inequality, and environmental degradation require planning practices that are participatory, context-sensitive, and adaptive. However, since definitions do not make the important distinction that green infrastructure should be an inclusive strategy, projects may not be designed to meet specific wants and needs of communities and may be distributed in an inequitable manner. By following the path of the working definition and including equity within definitions of green infrastructure, it strengthens the concept's ties with just implementation and better addresses the concerns identified in the literature.

Principles from the working definition enable green infrastructure to remain flexible enough to be workable while avoiding ambiguity that risks turning it into what Matsler et al. (2021) describe as a "proto-boundary object." Grounded in UPE, spatial justice, and contemporary arguments from the literature, the working definition enhances conceptual clarity by stating the increasing role of green infrastructure as a strategy for climate adaptation, a pathway for reducing inequity, and a form of infrastructure with specific functions rather than an abstract concept detached from real implementation. By combining a strong definition with consistent and deliberate use of the concept and its related terminology, governments can provide clearer guidance for practitioners implementing green infrastructure within and beyond urban areas. This coherence strengthens climate resilience and equity efforts across Canada and supports cities such as Toronto in advancing Official Plan targets, including becoming "more inclusive and adapted to climate change" (City of Toronto, 2026a).

To address concerns noted through the illustrative examples, future federal funding criteria should require applicants to identify the ecosystem services their projects are intended to provide and demonstrate how these services align with local needs. This requirement would encourage projects that deliver a wider range of regulating services, cultural services, and biodiversity enhancement. Clearer expectations at the federal level would support more comprehensive implementation in Toronto and other cities and provide

essential guidance for municipalities with fewer resources to develop their own green infrastructure strategies. Federal programs should therefore apply stricter selection criteria to ensure that funded projects align with updated definitions and with the more deliberate use of green infrastructure recommended in this paper.

Johns (2019) notes that, unlike the United States' federally mandated green infrastructure approach under the Clean Water Act, Canada lacks comparable regulatory drivers, which contributes to uneven implementation across cities. In support of these recommendations, establishing a multi-level working group may serve as a practical step to promote coherent policy development and ongoing alignment across governments. Cappell et al. (2022) argue that addressing climate change in Canada requires coordination across all orders of government, which involves not only funding allocation but also improved intergovernmental data sharing and legislative support. They recommend breaking down administrative silos and creating a national "trilateral intergovernmental table" for climate policy, since achieving climate resilience depends on aligning local initiatives with broader national strategies. This concept can be applied specifically to a green infrastructure coordination council comprised of representatives from each level of government, along with conservation authorities, planners, and academic experts. This council could facilitate data exchange, coordinate terminology, and work toward commonly desired outcomes. It could also monitor emerging global best practices and incorporate them into Canadian policy frameworks to ensure definitions and implementation strategies remain current. Over time, these shared perspectives could be advanced through legislative channels to encourage greater consistency and standardization across jurisdictions. Integrating a common glossary and conceptual hierarchy into policy and planning processes at each level of government would help ensure that future practitioners apply green infrastructure terminology with greater clarity and coherence.

These paths forward illustrate how clearer terminology, stronger definitions, and more deliberate policy structures can support Toronto and other Canadian cities in realizing the full potential of green infrastructure. By aligning conceptual foundations with implementation practices, governments can design interventions that deliver broader ecosystem services, respond more effectively to local needs, and advance climate resilience and equity in a more coordinated and sustained manner.

6.3 Broader Implications

Green infrastructure is increasingly recognized across the Government of Canada, the Government of Ontario, the Toronto and Region Conservation Authority, and the City of Toronto as an important tool for addressing the pressures of climate change and urbanization. The document analysis and illustrative examples show, however, that its full potential is not yet realized. Strengthening conceptual clarity, adopting a coherent hierarchy and classification system, updating definitions to reflect its multifunctionality, diverse

typologies, and as a strategy for resilience and equity, and aligning federal funding criteria with these improvements would provide a more stable foundation for implementation.

Evidence from outside Toronto reinforces these concerns. A review of municipal documents across the Greater Toronto Area from Conway et al. (2020) revealed that the specific term "green infrastructure" was included in only 28% (7 out of 25) of municipal official plans. The researchers found that nearly half of the official plans that used the term failed to provide any explicit or implicit definition, and where definitions did exist, they were often characterized as vague. This pattern demonstrates that conceptual ambiguity is not confined to the City of Toronto's policy landscape; it reflects a broader regional challenge and suggests that similar inconsistencies likely exist in other parts of Canada. When a term capable of delivering multiple ecosystem services is inconsistently used or undefined, its ability to function as an integrated climate resilience strategy is weakened.

This paper illustrates the need for a nationally aligned effort to make green infrastructure a more accessible, understandable, and actionable tool for urban areas across Canada. With clearer expectations, more deliberate use of the concept, and consideration of equity, governments can better work across jurisdictions and design projects that deliver the full range of benefits green infrastructure is understood to provide to all residents experiencing the current and future challenges of urban life. These steps are essential for ensuring that green infrastructure contributes meaningfully to more resilient, equitable, and healthy communities across Toronto and the rest of Canada.

6.4 Limitations of Research

Although the analysis provides meaningful insight into how green infrastructure is conceptualized and implemented across governments, several limitations should be acknowledged to clarify the boundaries of the study. While many relevant plans, strategies, policy documents, and webpages are reviewed from each level of government, inevitably other publications related to green infrastructure from the Government of Canada, the Province of Ontario, the Toronto and Region Conservation Authority, and the City of Toronto were not captured. There is also difficulty in identifying all possible synonyms or related terms for green infrastructure, as well as all typologies that could reasonably be interpreted as green infrastructure but are not explicitly included in official definitions. Despite government publications offering an accessible entry point for analyzing conceptualizations of green infrastructure, they do not capture informal practices, unpublished or non-public policy work, or internal decision-making processes that also influence how the concept is understood and applied.

The study further acknowledges that additional green infrastructure initiatives in Toronto were not examined, whether they are supported by the Natural Infrastructure Fund or Disaster Mitigation and

Adaptation Fund but are not publicly available, supported through different federal programs, or exist only through collaborations between Toronto, the TRCA, and the Government of Ontario, which fall outside the scope of this analysis but represent important components of cross-government implementation.

Since this study assesses success only through alignment with the core concepts of the evaluative framework in policy, other evaluative measures outside its scope are needed to determine whether green infrastructure projects are successful in real-world circumstances. Future research could assess particular projects through qualitative methods, such as surveys and interviews, and quantitative methods, such as field sampling, to evaluate the degree to which cultural services and regulating and supporting services are being provided respectively (Hanna et al., 2023). Other additional work might involve economic assessments to determine whether upfront investments in green infrastructure result in long-term savings compared to conventional systems, as argued by Anderson and Gough (2021).

Lastly, the study acknowledges that the working definition developed in this paper is interpretive and grounded in specific theoretical frameworks. While it provides a structured way to evaluate conceptual clarity, it is only one possible approach among many for green infrastructure definitions to be refined and expanded.

Despite these limitations, the study provides a comprehensive review of how green infrastructure is conceptualized and operationalized across federal, provincial, regional, and municipal governments. By identifying patterns in terminology, definitions, and implementation, it offers insight into how policy language shapes practice and how clearer, more coherent guidance can strengthen equitably distributed solutions that contribute to climate resilience and community well-being. These findings contribute to broader discussions on the future of green infrastructure in Canada and provide a foundation for further research and policy development within the country or internationally.

References

Alamdari, N., & Hogue, T. S. (2022). Assessing the effects of climate change on urban watersheds: A review and call for future research. *Environmental Reviews, 30*(1), 61–71. https://doi.org/10.1139/er-2021-0003

Alsharif, M. H., Alsaif, F., Singla, M. K., Manna, S., & Kim, M.-K. (2025). Techno-economic optimization and environmental analysis of a solar-powered electric vehicles (EVS) charger system for a Greener Transportation Ecosystem. *Energy Reports*, *13*, 5803–5814. https://doi.org/10.1016/j.egyr.2025.05.040

Amati, M., & Taylor, L. (2010). From green belts to green infrastructure. *Planning Practice & Research, 25*(2), 143–155. https://doi.org/10.1080/02697451003740122

Anderson, V., & Gough, W. A. (2021). Nature-based cooling potential: A multi-type green infrastructure evaluation in Toronto, Ontario, Canada. *International Journal of Biometeorology, 66*(2), 397–410. https://doi.org/10.1007/s00484-021-02100-5

Anguelovski, I., Connolly, J. J., Cole, H., Garcia-Lamarca, M., Triguero-Mas, M., Baró, F., Martin, N., Conesa, D., Shokry, G., del Pulgar, C. P., Ramos, L. A., Matheney, A., Gallez, E., Oscilowicz, E., Máñez, J. L., Sarzo, B., Beltrán, M. A., & Minaya, J. M. (2022). Green gentrification in European and North American cities. Nature Communications, 13(1). https://doi.org/10.1038/s41467-022-31572-1

AzariJafari, H., Xu, X., Gregory, J., & Kirchain, R. (2021). Urban-scale evaluation of cool pavement impacts on the urban heat island effect and climate change. *Environmental Science & Technology, 55*(17), 11501–11510. https://doi.org/10.1021/acs.est.1c00664

Benedict, M. A., & McMahon, E. T. (2002). Green infrastructure: Smart conservation for the 21st century. Sprawl Watch Clearinghouse.

Blaikie, P., & Brookfield, H. (1987). Defining and debating the problem. In *Land degradation and society* (1–26). Routledge.

Cappell, E., Johnston, S. A., & Winter, J. (2022). The municipal role in climate. Institute on Municipal Finance and Governance, School of Cities, University of Toronto. https://imfg.org/wp-content/uploads/2022/08/imfgwdw_no3_climatepolicy_august_25_2022.pdf

Choi, C., Berry, P., & Smith, A. (2021). The climate benefits, co-benefits, and trade-offs of Green Infrastructure: A Systematic Literature Review. *Journal of Environmental Management, 291.* https://doi.org/10.1016/j.jenvman.2021.112583

City of Toronto. (2003). *Wet weather flow management policy.* https://www.toronto.ca/wp-content/uploads/2017/11/8a0e-ecs-specs-wwfmp-wwfmmp_policy.pdf

City of Toronto. (2009). *By-law No. 583-2009*. https://www.toronto.ca/legdocs/bylaws/2009/law0583.pdf

City of Toronto. (2015). *Toronto official plan June 2015 office consolidation.* https://www.toronto.ca/wp-content/uploads/2022/11/96fd-city-planning-official-plan-consolidation-march-2022.pdf

City of Toronto. (2017a). *Green roof overview.* https://www.toronto.ca/city-government/planning-development/official-plan-guidelines/green-roofs/green-roof-overview/

City of Toronto. (2017b). *Toronto ravine strategy.* https://www.toronto.ca/wp-content/uploads/2017/10/9183-TorontoRavineStrategy.pdf

City of Toronto. (2019). *Toronto's first resilience strategy.* https://www.toronto.ca/ext/digital_comm/pdfs/resilience-office/toronto-resilience-strategy.pdf

City of Toronto. (2022a). *TGS version 4.0 checklist: Mid- to high- rise residential and all new non-residential development.* https://www.toronto.ca/wp-content/uploads/2022/04/9758-TGSV4-2022-MHR-Tier1-ChecklistApril222022.pdf

City of Toronto. (2022b). *TGS version 4.0 checklist: Low-rise development.* https://www.toronto.ca/wp-content/uploads/2022/04/9758-TGSV4-2022-MHR-Tier1-ChecklistApril222022.pdf

City of Toronto. (2022c). *Toronto official plan March 2022 office consolidation.* https://www.toronto.ca/wp-content/uploads/2022/11/96fd-city-planning-official-plan-consolidation-march-2022.pdf

City of Toronto. (2023). *2023 Wet weather flow master plan implementation update.* https://www.toronto.ca/legdocs/mmis/2023/ie/bgrd/backgroundfile-236773.pdf

City of Toronto. (2024). *Green infrastructure resources.* https://www.toronto.ca/services-payments/streets-parking-transportation/enhancing-our-streets-and-public-realm/green-streets/green-infrastructure-resources/

City of Toronto (2026a). *Official Plan: Chapter 1 Making Choices.* https://www.toronto.ca/city-government/planning-development/official-plan-guidelines/official-plan/chapters-1-5/official-plan-chapter-1/#:~:text=The%20Official%20Plan%20is%20our,and%20transit%2C%20our%20green%20spaces

City of Toronto. (2026b). *Ravine strategy 2026 implementation update.* https://www.toronto.ca/legdocs/mmis/2026/ie/bgrd/backgroundfile-264848.pdf

City of Toronto. (2026c). *TransformTO net zero strategy.* https://www.toronto.ca/services-payments/water-environment/environmentally-friendly-city-initiatives/transformto/

City of Toronto. (n.d.). *Green streets.* https://www.toronto.ca/services-payments/streets-parking-transportation/enhancing-our-streets-and-public-realm/green-streets/

Conway, T. M., Khan, A., & Esak, N. (2020). An analysis of green infrastructure in municipal policy: Divergent Meaning and terminology in the Greater Toronto Area. *Land Use Policy, 99*, 104864. https://doi.org/10.1016/j.landusepol.2020.104864

Czyża, S., & Kowalczyk, A. M. (2024). Applying GIS in blue-green infrastructure design in urban areas for better life quality and climate resilience. *Sustainability, 16*(12), 5187. https://doi.org/10.3390/su16125187

Elliott, R. M., Motzny, A. E., Majd, S., Chavez, F. J., Laimer, D., Orlove, B. S., & Culligan, P. J. (2019). Identifying linkages between urban green infrastructure and ecosystem services using an expert opinion methodology. *Ambio, 49*(2), 569–583. https://doi.org/10.1007/s13280-019-01223-9

Gómez-Baggethun, E., de Groot, R., Lomas, P. L., & Montes, C. (2010). The history of ecosystem services in economic theory and practice: From early notions to markets and payment schemes. *Ecological Economics, 69*(6), 1209–1218. https://doi.org/10.1016/j.ecolecon.2009.11.007

Government of Canada. (2023). *National adaptation strategy: Building resilient communities and a strong economy.* https://www.canada.ca/content/dam/eccc/documents/pdf/climate-change/climate-plan/national-adaptation-strategy/23062.06%20NAS%20Report_EN_v03.pdf

Government of Canada. (2024a). *Canada's 2030 nature strategy: Halting and reversing biodiversity loss in Canada*. https://publications.gc.ca/collections/collection_2024/eccc/en4/En4-539-1-2024-eng.pdf

Government of Canada. (2024b). *Government of Canada adaptation action plan*. https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/national-adaptation-strategy/action-plan.html

Government of Canada. (2024c). *Investing in Canada Plan funding stream: Green infrastructure*. https://housing-infrastructure.canada.ca/plan/gi-iv-eng.html

Government of Canada. (2024d). *Natural Infrastructure Fund*. https://housing-infrastructure.canada.ca/nif-fin/index-eng.html

Government of Canada. (2026a). *Disaster mitigation and adaptation fund: Overview.* https://housing-infrastructure.canada.ca/dmaf-faac/index-eng.html

Government of Canada. (2026b). *Green infrastructure programs*. https://natural-resources.canada.ca/climate-change/green-infrastructure-programs

Government of Canada. (2026c). *Housing and Infrastructure Project Map.* https://housing-infrastructure.canada.ca/gmap-gcarte/index-eng.html

Government of Ontario. (2020). *A Place to grow: Growth plan for the greater Golden Horseshoe*. https://files.ontario.ca/mmah-place-to-grow-office-consolidation-en-2020-08-28.pdf

Government of Ontario. (2022). *Low impact development stormwater management guidance manual*: *Draft for Consultation*. https://ero.ontario.ca/public/2022-01/Draft%20LID%20Stormwater%20Management%20Guidance%20Manual%202022.pdf

Government of Ontario. (2024). *Provincial planning statement, 2024*. https://www.ontario.ca/files/2024-10/mmah-provincial-planning-statement-en-2024-10-23.pdf

Government of Ontario. (2025). *Low impact development stormwater management guidance manual (ERO notice 019-4971).* https://ero.ontario.ca/notice/019-4971

Government of Ontario. (2026). *Conservation Authorities Act, R.S.O. 1990, c. C.27*. https://www.ontario.ca/laws/statute/90c27

Hanna, E., Bruno, D., & Comín, F. A. (2023). The ecosystem services supplied by urban green infrastructure depend on their naturalness, functionality and imperviousness. *Urban Ecosystems, 27*(1), 187–202. https://doi.org/10.1007/s11252-023-01442-9

Heynen, N., Kaika, M., & Swyngedouw, E. (2006). Urban political ecology: Politicizing the production of urban natures. In N. Heynen, M. Kaika, & E. Swyngedouw (Eds.), *In the nature of cities: Urban political ecology and the politics of urban metabolism* (pp. 1–20). Routledge.

Intergovernmental Panel on Climate Change (IPCC). (2021). *Climate change 2021: The physical science basis: Summary for policymakers*. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf

Johns, C. M. (2019). Understanding barriers to green infrastructure policy and stormwater management in the City of Toronto: A shift from grey to green or policy layering and conversion? *Journal of Environmental Planning and Management, 62*(8), 1377–1401. https://doi.org/10.1080/09640568.2018.1496072

Jones, L., Anderson, S., Læssøe, J., Banzhaf, E., Jensen, A., Bird, D. N., Miller, J., Hutchins, M. G., Yang, J., Garrett, J., Taylor, T., Wheeler, B. W., Lovell, R., Fletcher, D., Qu, Y., Vieno, M., & Zandersen, M. (2022). A typology for Urban Green Infrastructure to guide multifunctional planning of nature-based solutions. *Nature-Based Solutions, 2,* 100041. https://doi.org/10.1016/j.nbsj.2022.100041

Kadić, A., Maljković, B., Rogulj, K., & Pamuković, J. K. (2025). Green Infrastructure's role in climate change adaptation: Summarizing the existing research in the most benefited policy sectors. *Sustainability, 17*(9), 4178. https://doi.org/10.3390/su17094178

Krivtsov, V. (2025). Green and blue-green infrastructure – benefits, trade-offs, and optimisation of Ecosystem Services: An overview with perspectives for research and Management. *Plant Ecology & Diversity, 18*(5–6), 267–285. https://doi.org/10.1080/17550874.2025.2585476

Kumar, P. (2021). Climate change and cities: Challenges ahead. *Frontiers in Sustainable Cities*, *3*. https://doi.org/10.3389/frsc.2021.645613

Lwasa, S., Seto, K. C., Bai, X., Blanco, H., Gurney, K. R., Kılkış, Ş., Lucon, O., Murakami, J., Pan, J., Sharifi, A., & Yamagata, Y. (2022). *Urban systems and other settlements*. In P. R. Shukla et al. (Eds.), *Climate change 2022: Mitigation of climate change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. https://doi.org/10.1017/9781009157926.010

Matsler, A. M., Meerow, S., Mell, I. C., & Pavao-Zuckerman, M. A. (2021). A 'green' chameleon: Exploring the many disciplinary definitions, goals, and forms of "green infrastructure." *Landscape and Urban Planning, 214*, 104145. https://doi.org/10.1016/j.landurbplan.2021.104145

Meerow, S., & Stults, M. (2016). Comparing conceptualizations of urban climate resilience in theory and Practice. *Sustainability, 8*(7), 701. https://doi.org/10.3390/su8070701

Millennium Ecosystem Assessment. (2005). *Ecosystems and human well-being: Synthesis*. Island Press. https://www.millenniumassessment.org/documents/document.356.aspx.pdf

Millennium Ecosystem Assessment. (n.d.). *Overview of the Millennium Ecosystem Assessment.* https://www.millenniumassessment.org/en/About.html#1

Morpurgo, J., Remme, R. P., & Van Bodegom, P. M. (2023). CUGIC: The consolidated urban green infrastructure classification for assessing ecosystem services and biodiversity. *Landscape and Urban Planning, 234*, 104726. https://doi.org/10.1016/j.landurbplan.2023.104726

Oviedo, M., Drescher, M., & Dean, J. (2022). Urban Greenspace Access, uses, and values: A case study of user perceptions in Metropolitan Ravine parks. *Urban Forestry & Urban Greening*, *70*, 127522. https://doi.org/10.1016/j.ufug.2022.127522

Regier, K., & Conway, T. (2022). Where to expand green infrastructure to support equitable climate change adaptation in the City of Toronto? *Cities and the Environment, 15*(1). https://doi.org/10.15365/cate.2022.150101

Rodrigues, B. N., Favoreti, A. L., Molina Júnior, V. E., Silva, C. M., & Canteras, F. B. (2025). Green infrastructure for urban climate mitigation and adaptation: Methods, strategies, and typology selection based on Ecosystem Services. *International Journal of Environmental Science and Technology, 22*(16), 17383–17404. https://doi.org/10.1007/s13762-025-06754-1

Seiwert, A., & Rößler, S. (2020). Understanding the term green infrastructure: Origins, rationales, semantic content and purposes as well as its relevance for application in Spatial Planning. *Land Use Policy, 97*, 104785. https://doi.org/10.1016/j.landusepol.2020.104785

Statistics Canada. (2026, January 14). *Canada's population estimates: Subprovincial areas, 2025*. https://www150.statcan.gc.ca/n1/daily-quotidien/260114/dq260114a-eng.htm

Toronto and Region Conservation Authority (TRCA). (2014). *The Living City Policies for planning and of the Toronto and Region Conservation Authority*. https://trcaca.s3.ca-central-1.amazonaws.com/app/uploads/2021/10/20155211/2329_TheLivingCityPolicies_rev19_forWeb.pdf

Toronto and Region Conservation Authority (TRCA). (2021). *Green stormwater infrastructure asset management resources toolkit.* https://giexchange.org/wp-content/uploads/2021/12/GSI-AM-Resources-Toolkit-Final-Dec-17.pdf

Toronto and Region Conservation Authority (TRCA). (2024). *Toronto's current and future climate.* https://www.toronto.ca/wp-content/uploads/2024/12/949f-TorontosCurrentandFutureClimate-REPORT-Final.pdf

Toronto and Region Conservation Authority (TRCA). (n.d.a). *Disaster mitigation adaptation fund (DMAF) projects.* https://trca.ca/conservation/erosion-risk-management/dmaf-projects/

Toronto and Region Conservation Authority (TRCA). (n.d.b). *Ecosystem services and valuation.* https://trca.ca/conservation/creating-green-infrastructure/ecosystem-services-valuation/

Toronto and Region Conservation Authority (TRCA). (n.d.c). *Green infrastructure.* https://trca.ca/conservation/creating-green-infrastructure/

Toronto and Region Conservation Authority (TRCA). (n.d.d). *Green infrastructure asset management planning.* https://trca.ca/conservation/creating-green-infrastructure/asset-management-planning/

Toronto and Region Conservation Authority (TRCA). (n.d.e). *Green infrastructure solutions.* https://trca.ca/conservation/creating-green-infrastructure/asset-management-planning/

Toronto and Region Conservation Authority (TRCA). (n.d.f). *The Living City Policies.* https://trca.ca/planning-permits/living-city-policies/

United Nations Department of Economic and Social Affairs, Population Division (UN DESA) (2025). *World urbanization prospects 2025: Summary of results.* https://population.un.org/wup/assets/Publications/undesa_pd_2025_wup2025_summary_of_results_final.pdf

Wang, Y., Berardi, U., & Akbari, H. (2016). Comparing the effects of urban heat island mitigation strategies for Toronto, Canada. *Energy and Buildings, 114*, 2–19. https://doi.org/10.1016/j.enbuild.2015.06.046

Waterfront Toronto. (2025). *Largest Park in a Generation Opens on City of Toronto's New Island through Transformative Port Lands Flood Protection Project.* https://www.waterfrontoronto.ca/news/largest-park--in-a-generation-opens-on-torontos-new-island-through-transformative-port-lands-flood-protection-project

Waterfront Toronto. (n.d.). *About Us.* https://www.waterfrontoronto.ca/about-us

Zarei, M., & Shahab, S. (2025). Nature-based solutions in urban green infrastructure: A systematic review of success factors and implementation challenges. *Land, 14*(4). https://doi.org/10.3390/land14040818

Zimmer, A. (2010). Urban political ecology. theoretical concepts, challenges, and suggested Future Directions. *ERDKUNDE*, *64*(4), 343–354. https://doi.org/10.3112/erdkunde.2010.04.04

APPENDIX A

The classification system draws primarily from the Assessment Matrix in Jones et al. (2022), which evaluates 47 typologies across one provisioning service, seven regulating services, three cultural services, and one biodiversity category. Nine of these eleven categories were adopted for this study, with "Food provision" and "Noise mitigation" excluded due to their limited relevance. The typology categories from Jones et al. (2022) were supplemented with the green–blue–grey classification in Figure 2 of the same article, which distinguishes typologies as "Blue," "Combined," "Green (few trees)," "Green (with trees)," and "Unvegetated."

To incorporate spatial considerations, only typologies that overlapped with the 25 found in Figure 8 of Rodrigues et al. (2025) were retained, allowing each typology to be associated with an application scale. The five scales of green infrastructure are outlined in Table A1 of Rodrigues et al. (2025), but ultimately only three (Particular, Local, and City) were carried forward because they were shared across both studies. Table A1 below summarizes the original groupings from Jones et al. (2022) and Rodrigues et al. (2025), and the decision-making process used to narrow the list to the final 12 typologies.

Table A1

Decision-Making Process for Selecting Classification System Typologies

Classification System Typology	Jones et al. (2022)	Rodrigues et al. (2025)	Notes on Decision-Making
Park	Park	Parks	Substantially similar; identical typology.
Private garden	Private garden	Private Green Spaces (Gardens)	Substantially similar; both refer to privately owned vegetated residential spaces.
Allotment	Allotment	Urban Agriculture	Conceptually aligned; both involve community-based food production.
City farm	City farm	Urban Agriculture	Conceptually aligned; both involve community-based food production.
Green roof	Green roof	Green Roofs	Substantially similar; identical typology.
Green wall	Green wall	Vertical Gardens	Substantially similar; both refer to vegetated vertical surfaces.
Street/urban tree	Street tree	Urban Tree Canopy	Substantially similar; both refer to trees in public urban streetscapes.
Rain garden	Rain garden	Rain Gardens	Substantially similar; identical typology.
Bioswale	Bioswale	Bioswales	Substantially similar; identical typology.
Permeable pavement	Permeable paving	Permeable Pavements	Substantially similar; identical typology.
Retention/detention pond	Attenuation pond	Retention/Detention Ponds	Substantially similar; terminology differs by region but refers to the same infrastructure.
Wetland	Wetland	Wetlands	Substantially similar; identical typology.

Note. Table created by the author showing the comparison of typology groupings from Jones et al. (2022) and Rodrigues et al. (2025), and the decision-making process used to narrow the combined list to the final set of 12 typologies.

These typologies are broadly representative: 10 of the 12 also appear in Elliott et al.'s (2019) Table 2 list of 14 typologies, which similarly compares ecosystem service performance across green infrastructure types. Although Rodrigues et al. (2025) provide a normalized matrix of ecosystem service associations, only the results from Jones et al. (2022) were used in the classification system due to methodological incompatibilities between the studies. The Jones et al. (2022) matrix is methodologically robust, drawing on multidisciplinary evidence synthesis and expert consultation to produce a standardized scale ranging

from negligible (0) to very high (4), with ecosystem service delivery assessed on a per-unit-area basis to allow for fair performance comparison regardless of a typology's typical physical size. Table A2 presents the adapted classification system used to assess Canadian government publications, and Figure A1 visualizes the typologies on a scatterplot based on the average of their regulating and cultural ecosystem service scores, symbolized by both category and scale.

Table A2

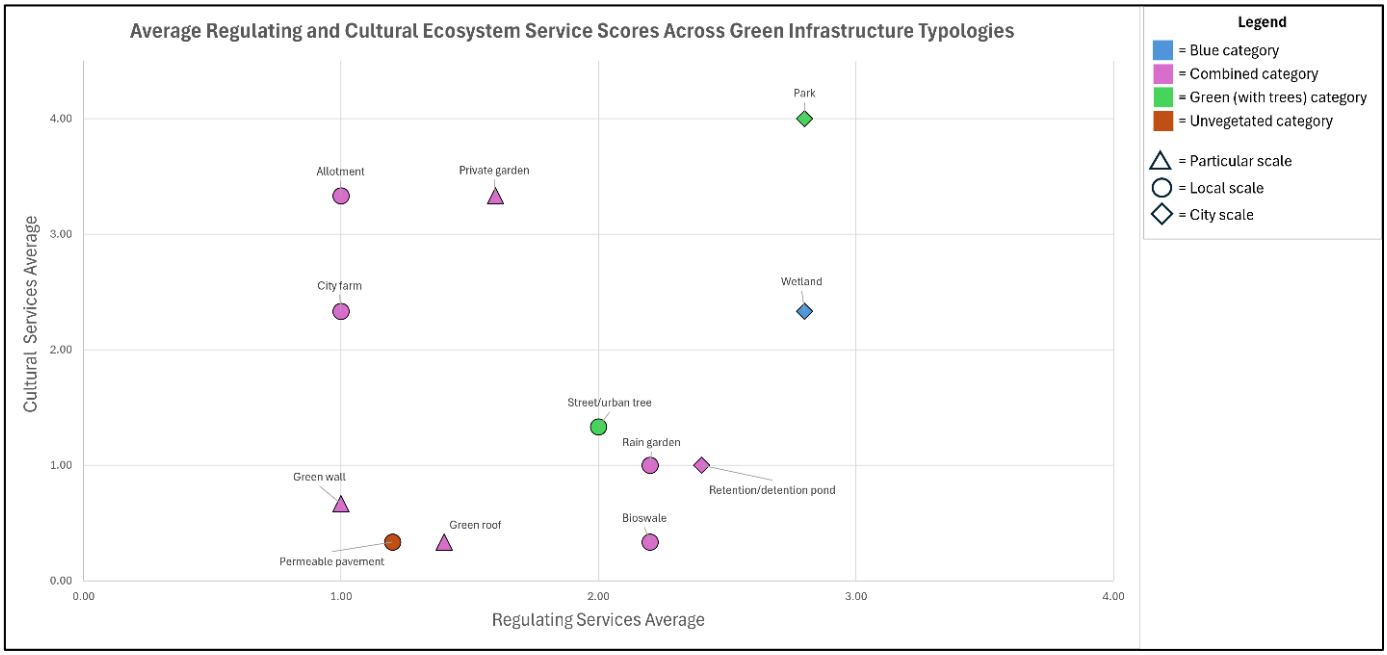
Classification System of Green Infrastructure Publications

Typology	Category	Scale	Air pollution removal	Heat mitigation	Water quality mitigation	Water Flow management	Maintaining carbon stocks	Supporting physical activity	Supporting social interactions	Restoring capacities - stress reduction and cognitive restoration	Supporting biodiversity
Park	Green (with trees)	City	High	High	High	Medium	High	Very high	Very high	Very high	High
Private garden	Green (with trees)	Particular	Low	Medium	Medium	Medium	Low	Very high	Medium	Very high	High
Allotment	Combined	Local	Medium	Low	Negligible	Medium	Negligible	High	High	Very high	High
City farm	Combined	Local	Medium	Low	Negligible	Medium	Negligible	Medium	Medium	High	Medium
Green roof	Combined	Particular	Low	Low	Low	High	Low	Negligible	Negligible	Low	Low
Green wall	Combined	Particular	Medium	Low	Negligible	Low	Low	Negligible	Negligible	Medium	Low
Street/urban tree	Green (with trees)	Local	High	High	Low	Low	Medium	Negligible	Low	High	Medium
Rain garden	Combined	Local	Medium	Low	High	High	Medium	Negligible	Negligible	High	Medium
Bioswale	Combined	Local	Medium	Low	Medium	Very high	Medium	Negligible	Negligible	Low	Medium
Permeable pavement	Unvegetated	Local	Negligible	Negligible	High	High	Negligible	Low	Negligible	Negligible	Negligible
Retention/detention pond	Combined	City	Low	Low	Very high	Very high	Medium	Negligible	Low	Medium	High
Wetland	Blue	City	Medium	Medium	Very high	Very high	Medium	Low	Medium	Very high	High

Note. Adapted classification system created by the author, with data from Jones et al. (2022) and Rodrigues et al. (2025).

Figure A1

Green Infrastructure Typologies by Average Regulating and Cultural Service Scores



Note. Scatterplot created by the author, with each point symbolized by its application scale (particular, local, or city) and category (Blue, Combined, Green (with trees), or Unvegetated).

External figures and tables referenced to create the classification system from Jones et al. (2022), Rodrigues et al. (2025), and Elliott et al. (2019) are included in Appendix B.

APPENDIX B

Appendix B contains the external figures and tables used to create the classification system found in Appendix A. This includes Figure B1, which is Figure 1 from Jones et al. (2022), Figure B2, which is Figure 2 from Jones et al. (2022), Figure B3, which is Figure 8 from Rodrigues et al. (2025), Figure B4, which is Figure 9 from Rodrigues et al. (2025), and Table B1, which is Table 2 from Elliott et al. (2019).

Figure B1

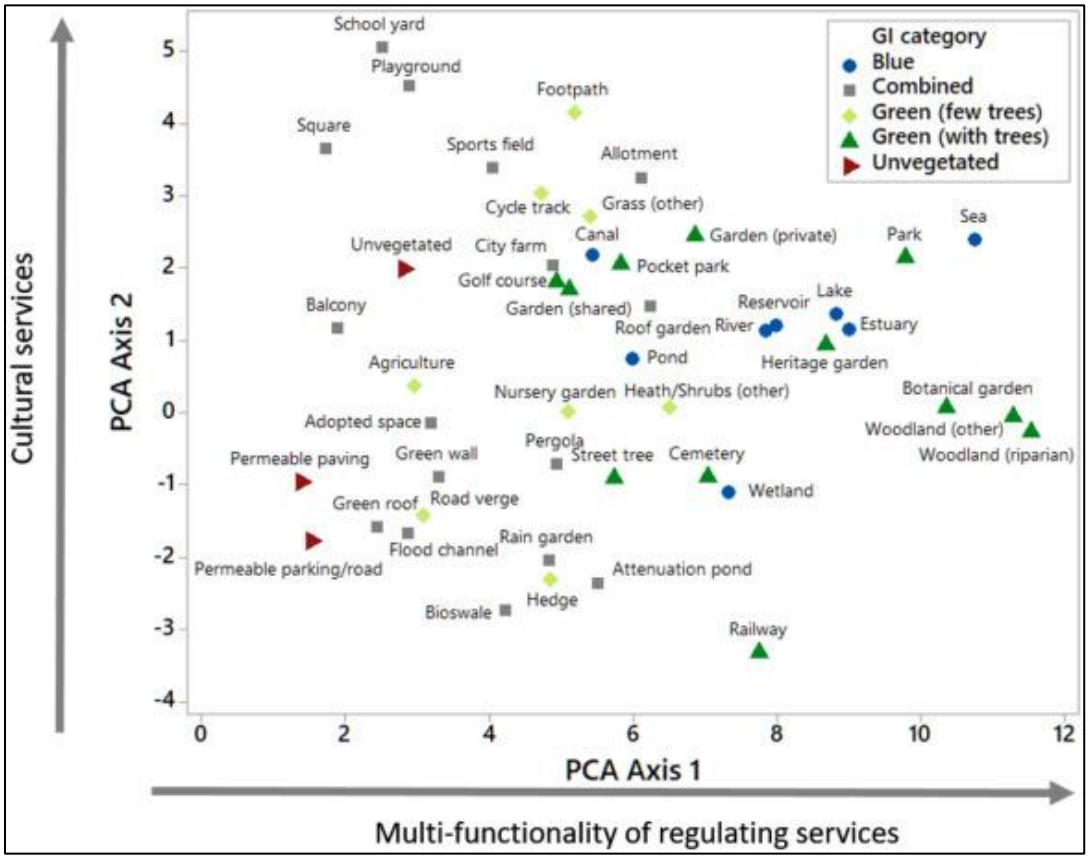
Assessment Matrix Used to Create the Classification System.

Brief description	Object type	Object category	Food provision	Air pollution removal	Noise mitigation	Heat mitigation	Water quality mitigation	Water flow management	Maintaining carbon stocks	Supporting physical activity	Supporting social interactions	Restoring capacities - stress reduction and cognitive restoration	Supporting biodiversity
Mainly private space linked to dwellings	Gardens	Balcony	Low	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Low	High	Low
		Private garden	Medium	Low	Low	Medium	Medium	Medium	Low	Very high	Medium	Very high	High
		Shared common garden area	Medium	Low	Low	Medium	Medium	Medium	Low	Medium	High	Medium	Low
Mainly public space, but some access restrictions may apply	Parks	Pocket park	Low	Low	Low	Low	High	Medium	Low	Medium	Very high	High	Medium
		Park	Low	High	High	High	High	Medium	High	Very high	Very high	Very high	High
		Botanical garden	Low	High	Very high	Very high	High	Medium	High	Medium	High	Very high	Very high
		Heritage garden	Medium	Medium	High	High	High	Medium	Medium	Medium	High	Very high	High
		Nursery garden	Medium	Medium	Low	Low	High	Medium	Medium	Low	Medium	Medium	Low
Areas designed primarily for specific amenity uses	Amenity areas	Sports field	Negligible	Low	Low	Low	Low	Low	Low	Very high	High	Medium	Negligible
		School yard	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Very high	Very high	Medium	Negligible
		Playground	Negligible	Negligible	Negligible	Negligible	Low	Low	Negligible	Very high	Very high	Medium	Negligible
		Golf course	Negligible	Medium	Low	Low	Negligible	Medium	Low	Medium	High	High	Medium
		Shared open space (e.g. square)	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Medium	Very high	Low	Negligible
Areas designed primarily for specific uses (not leisure); some access restrictions may	Other public space	Cemetery	Negligible	Medium	Medium	Medium	Medium	Medium	High	Low	Low	Very high	High
		Allotment/other growing space	Very high	Medium	Low	Low	Negligible	Medium	Negligible	High	High	Very high	High
		City farm	Very high	Medium	Low	Low	Negligible	Medium	Negligible	Medium	Medium	High	Medium
		Adopted public space	Low	Medium	Low	Low	Low	Low	Negligible	Negligible	Low	Medium	Low
Linked to routeways, geographical features and boundaries	Linear features/routes	Street tree	Low	High	Low	High	Low	Low	Medium	Negligible	Low	High	Medium
		Cycle track (as green/blue corridor)	Low	Low	Low	Low	Low	Low	Low	Very high	Medium	High	Low
		Footpath (as green/blue corridor)	Low	Low	Low	Low	Low	Low	Low	Very high	Very high	High	Low
		Road verge	Low	Low	Low	Low	Medium	Medium	Low	Negligible	Negligible	Low	Low
		Railway corridor	Negligible	Very high	Very high	Very high	Low	Medium	High	Negligible	Negligible	Low	Very high
		Riparian woodland	Low	Very high	Very high	Very high	Very high	High	Very high	High	High	Very high	Very high
		Hedge	Low	Medium	Low	Low	High	High	Medium	Negligible	Negligible	Medium	Medium
Constructed green and blue space, added to infrastructure	Constructed GI on infrastructure	Green roof	Negligible	Low	Negligible	Low	Low	High	Low	Negligible	Negligible	Low	Low
		Green wall	Negligible	Medium	Medium	Low	Negligible	Low	Low	Negligible	Negligible	Medium	Low
		Roof garden	Medium	Medium	Low	Medium	Low	Low	Medium	Low	High	Very high	Medium
		Pergola (with vegetation)	Negligible	Medium	Low	High	Low	Low	Medium	Negligible	Low	High	Low
Infrastructure designed to incorporate some GBS components	Hybrid GI (for water)	Permeable paving	Negligible	Negligible	Negligible	Negligible	High	High	Negligible	Low	Negligible	Negligible	Negligible
		Permeable parking/roadway	Negligible	Negligible	Negligible	Negligible	High	High	Low	Negligible	Negligible	Negligible	Negligible
		Attenuation pond	Negligible	Low	Low	Low	Very high	Very high	Medium	Negligible	Low	Medium	High
		Flood control channel	Negligible	Low	Negligible	Low	Low	Very high	Low	Negligible	Low	Negligible	Medium
		Rain garden	Low	Medium	Negligible	Low	High	High	Medium	Negligible	Negligible	High	Medium
		Bioswale	Negligible	Medium	Low	Low	Medium	Very high	Medium	Negligible	Negligible	Low	Medium
Bluespace features	Waterbodies	Wetland	Negligible	Medium	Low	Medium	Very high	Very high	Medium	Low	Medium	Very high	High
		River/stream	Low	Low	High	High	Medium	High	Low	Medium	High	Very high	High
		Canal	Low	Low	Low	Medium	Low	Medium	Low	Medium	High	Very high	Low
		Pond	Negligible	Low	Low	Low	Low	High	Medium	Low	High	Very high	High
		Lake	Medium	Low	Medium	High	High	High	Medium	High	High	Very high	Very high
		Reservoir	Low	Low	Medium	High	High	Very high	Medium	High	High	Very high	Medium
		Estuary/tidal river	High	Low	High	High	High	N/A	Medium	Medium	High	Very high	Very high
		Sea (incl. coast)	High	Low	High	Very high	High	N/A	Very high	Very high	Very high	Very high	Very high
Other un-sealed features without specified use, often on private land	Other non-sealed urban areas	Woodland (other)	Low	Very high	Very high	Very high	High	High	Very high	High	High	Very high	Very high
		Grass (other)	Low	Low	Low	Low	Medium	Medium	Low	Very high	High	Medium	Medium
		Shrubland (other)	Low	Medium	Low	Low	High	High	Medium	Medium	Medium	High	High
		Arable agriculture	Very high	Medium	Low	Low	Negligible	Low	Negligible	Low	Negligible	Low	Low
		Sparsely vegetated land	Negligible	Negligible	Low	Negligible	Low	Low	Negligible	Medium	Medium	Medium	Low

Note. Image from Jones et al. (2022).

Figure B2

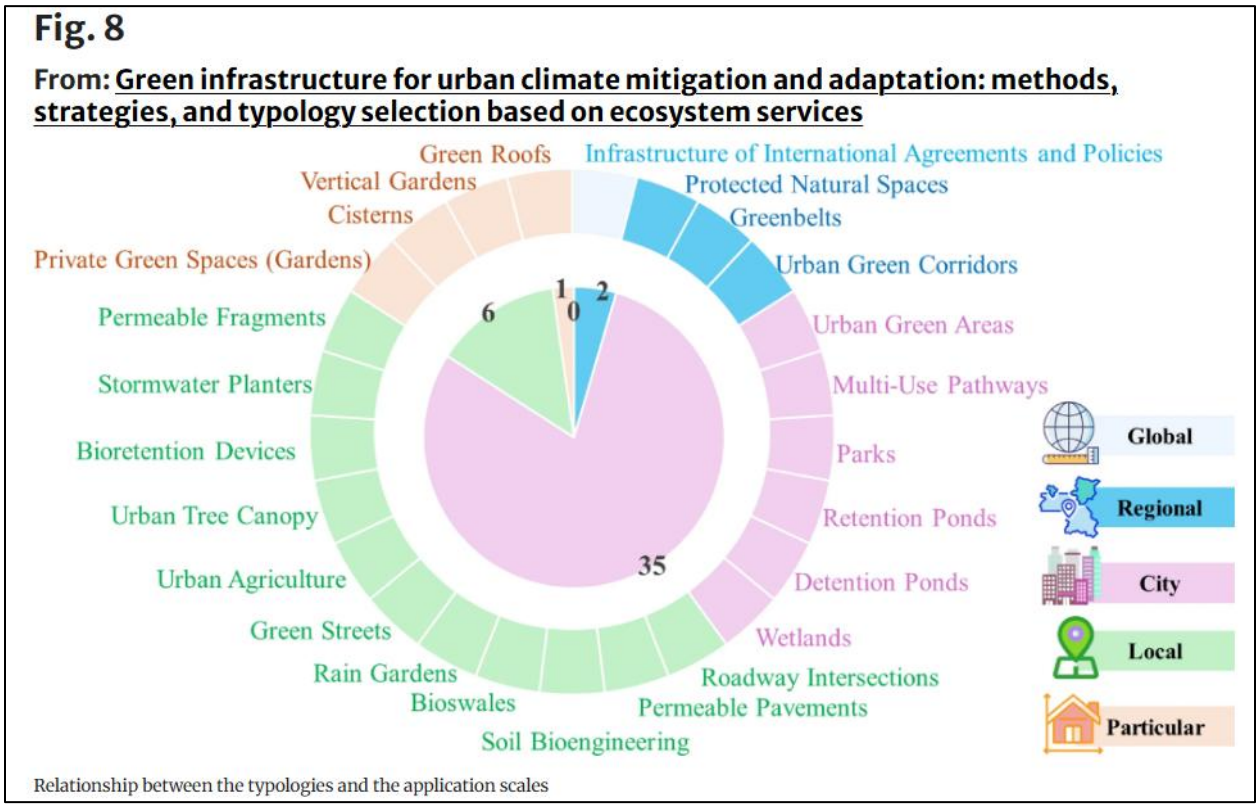
Principal Component Analysis of Green Infrastructure Typologies



Note. Image from Jones et al. (2022) depicting green infrastructure typologies used to create the classification system's categories.

Figure B3

Relationship Between Green Infrastructure Typologies and Application Scales



Note. Image from Rodrigues et al. (2025), which was used to create scale component of the classification system.

Figure B4

Normalized Matrix Used for Classification System

Typologies	Serviços de Regulação	Global Climate Regulation	Local Climate Regulation	Air Quality Regulation	Water Flow Regulation	Water Purification	Nutrient Regulation	Erosion Regulation	Natural Disaster Regulation	Pollination	Pest and Disease Control	Waste Regulation
Urban Green Areas		1,00	1,00	1,00	1,00	1,00	0,00	0,00	1,00	0,00	0,00	0,00
Parks		0,29	0,48	0,50	0,63	1,00	0,00	0,00	0,25	0,00	0,00	0,00
Private Green Spaces (gardens)		0,29	0,29	0,25	0,38	0,33	0,00	0,00	0,17	0,00	0,00	0,00
Green Roofs		0,14	0,33	0,33	0,50	0,67	0,00	0,00	0,25	0,00	0,00	0,00
Wetlands		0,57	0,29	0,33	0,50	0,67	0,00	0,00	0,25	0,00	0,00	0,00
Permeable Pavements		0,00	0,19	0,25	0,44	1,00	1,00	1,00	0,42	0,00	0,00	0,00
Rain Gardens		0,00	0,19	0,33	0,38	0,67	1,00	1,00	0,33	0,00	0,00	0,00
Urban Green Corridors		0,29	0,19	0,17	0,31	0,33	0,00	0,00	0,00	0,00	0,00	0,00
Urban Trees		0,29	0,19	0,42	0,31	0,00	0,00	0,00	0,17	0,00	0,00	0,00
Permeable Fragments		0,29	0,19	0,42	0,31	0,00	0,00	0,00	0,17	0,00	0,00	0,00
Urban Agriculture		0,43	0,24	0,33	0,31	0,00	0,00	0,00	0,17	0,00	0,00	0,00
Vertical Gardens		0,29	0,14	0,33	0,25	0,33	0,00	0,00	0,08	0,00	0,00	0,00
Protected Natural Spaces		0,29	0,14	0,17	0,25	0,00	0,00	0,00	0,17	0,00	0,00	0,00
Bioswales		0,29	0,10	0,17	0,19	0,33	0,00	0,00	0,00	0,00	0,00	0,00
Green Streets		0,14	0,05	0,17	0,13	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Cisterns		0,00	0,10	0,08	0,13	0,67	0,00	0,00	0,17	0,00	0,00	0,00
Roadway Intersections		0,00	0,05	0,08	0,06	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Retention Ponds		0,00	0,10	0,17	0,13	0,33	0,00	0,00	0,17	0,00	0,00	0,00
Detention Ponds		0,00	0,10	0,08	0,13	0,67	0,00	0,00	0,17	0,00	0,00	0,00
Bioretention Devices		0,00	0,05	0,08	0,06	0,33	0,00	0,00	0,08	0,00	0,00	0,00
Multi-Use Paths		0,00	0,05	0,00	0,06	0,00	1,00	1,00	0,08	0,00	0,00	0,00
Soil Bioengineering		0,00	0,05	0,00	0,06	0,00	1,00	1,00	0,08	0,00	0,00	0,00
Stormwater Planters		0,00	0,05	0,08	0,06	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Greenbelts		0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

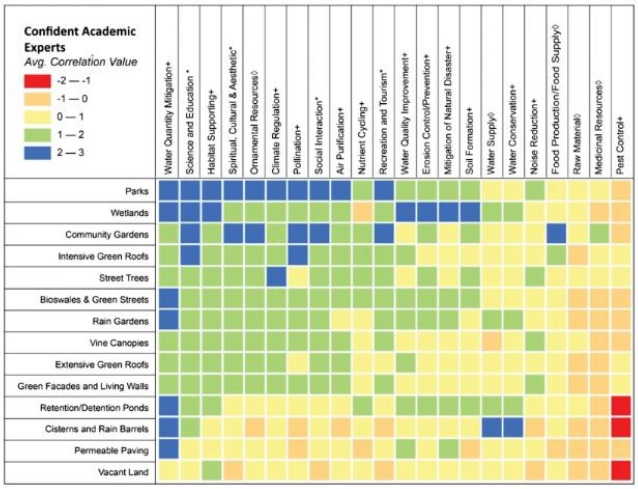
Note. Image from Rodrigues et al. (2025).

Table B1

AGEL Scores for 14 Green Infrastructure Types and 22 Ecosystem Services

Table 2 The participant AGEL scores between 14 Green Infrastructure types and 22 Ecosystem Services. Green infrastructure typologies are presented in descending order (from top to bottom) of how positively expert judgement linked them to ecosystem services. Similarly, ecosystem services, and their overarching categories, are presented in descending order (right to left) of how well expert judgement linked them to GI. *Cultural ES, +RSM ES, ◊ Provisioning ES

From: Identifying linkages between urban green infrastructure and ecosystem services using an expert opinion methodology



Note. Image from Elliot et al. (2019) which was used to compare typologies found in the classification system.