
Article

Advancing Green Infrastructure Solutions in Rural Regions: Economic Impacts and Capacity Challenges in Southwest Ontario, Canada

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ABSTRACT: Green infrastructure (GI) is a growing topic in urban planning, asset management, and climate change adaptation. However, rural regions have been under-represented in the discourse. This paper explores the benefits and challenges associated with the implementation and management of GI through a regional study of rural communities in southwestern Ontario. Our focus concerns the inter-relationships between GI, economic resilience, and the development of rural places. Findings show rural communities benefit from GI initiatives like natural stormwater management, park naturalization, and natural heritage restoration, which provide low-cost municipal services, conserve agricultural soils, and contribute to the amenity appeal of rural places. Challenges surrounding awareness, organizational capacity, and environmental regulation have slowed the uptake of GI and led to inconsistencies across jurisdictions. A mix of supportive policies, funding of demonstration projects with economic monitoring, and training to build professional capacity will advance the use and efficacy of GI across rural regions.

Keywords: Green Infrastructure; Natural Assets; Rural Development, Economic Development; Land Use Planning; Ontario



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1. Introduction

Nature and its ecosystem services form the basis for all human societies and economies to function [1], with up to 55% of global GDP dependent on ecosystem services and biodiversity [2]. However, rapid land development and industrial economic growth have degraded natural ecosystems, harming the environment and the long-term economic resilience of communities and regions. Current development practices have been estimated to cost the global economy between \$4.3 and \$20 Trillion in lost ecosystem services annually [1]. To address the imbalance between land development and the decline of biodiversity and ecosystem services, a movement has been growing to value nature for its role in providing core infrastructure services to communities, like water purification and flood control, with added co-benefits that improve local quality of life [3,4]. When thought of and used in this way, natural features and their ecosystem services are often termed green infrastructure (GI) or nature-based solutions (NbS). For the remainder of this paper, GI will be used as the most relevant policy term for the study area of Ontario, Canada.

The purpose of this study is to investigate whether connections are being made regarding the role of GI in supporting and facilitating economic development and, if so, what the main economic motivators are for supporting GI initiatives in rural (settler) municipalities and regions. The connection between GI systems and economic development is an additional research gap with implications for framing the use of GI systems and mobilizing capacity and funding to expand their use. In the following sections, we provide an overview of GI and its connections to economic development in rural regions. We hope to contribute to the national and international discourse surrounding GI and NbS

as critical features for addressing both internal community dynamics of resilience related to the built environment and decisions about how the built environment is formed.

1.1. Green Infrastructure and Economic Development

Many definitions of GI exist depending on the intended use and field of study [5,6]. Within a wide body of literature, GI is defined as networks of natural and semi-natural features that can provide multiple ecological, social, and economic benefits. The term ‘green infrastructure’ was coined largely to change perceptions of green space among those who otherwise may have little interest in nature conservation (the term ‘blue-green infrastructure’ is also used to accentuate the role of water and water management). Because infrastructure has close associations with economic development [7,8], framing natural and enhanced natural systems as infrastructure has helped build the economic case for GI in the eyes of local and senior governments, developers, and economically minded organizations [9]. A growing body of literature has demonstrated that GI can have a diverse range of economic benefits that fit into four categories: (1) Direct benefits, (2) Indirect benefits and spinoffs, (3) cost savings, and (4) risk management (Table 1). While terminology and approaches may vary, GI is becoming an increasingly common development tool used to meet a variety of planning objectives. Regardless of the primary function, GI systems can be integrated with surrounding traditional or ‘grey’ infrastructure to provide a wide range of services and community benefits by using natural features and green space as adaptable community assets and amenities [4,10–12].

Table 1. The economic benefits of green infrastructure. Adapted from Caldwell et al., 2016 and Ecotec, 2008.

Types of Economic Benefits	Examples of Green Infrastructure Benefits
Direct Benefits	Growth of green industry to plan, build, and maintain GI
	Increased property values near green space
	Payments to landowners for providing ecological goods and services
	Leverage funding/resources from many organizations benefiting from GI
Indirect Benefits & Spinoffs	Attracting spending from visitors and residents accessing quality green space
	Reduced health care costs from pollution and inactivity
	Increased farm and timber productivity through sustainable management
	Educate children through hands-on learning
Cost Savings	Decreased infrastructure spending by using natural services
	Decreased energy and maintenance costs through passive design
	Reduce drought costs by retaining water on the land
Risk Management	Manage flooding risks by slowing runoff
	Moderate extreme heat events by increasing shade and evaporation
	Reduce disease by protecting biodiversity and native species

Most often, the base infrastructure function of GI relates to stormwater management in urban regions, with other outcomes considered to be co-benefits [6]. GI helps manage stormwater when green spaces like parks, boulevards, streams, wetlands, trees, and other vegetation are strategically used to retain rainwater where it lands and absorb runoff from nearby impervious surfaces. Green spaces surrounding communities (e.g., farmland, forests, and floodplains) can also offer important stormwater protection functions, storing rainfall and moderating stream flows to low-lying development [13]. However, GI can serve many functions beyond stormwater management. GI of all types can improve water quality and groundwater recharge [14]. Farmlands and forests offer provisioning services through crops and timber [15]. Public parks and greenways provide recreational opportunities and corridors for active transportation [16]. Parks, forests, and other vegetated areas moderate temperatures during summer heatwaves through shading and evaporative cooling [17]. These thermal benefits can reduce heat stress on vulnerable populations and even lower building energy use when trees, green roofs, and building façades are used effectively [4]. The full range of benefits GI provides will depend upon the type and scale of a particular system or frame of analysis, but planning for GI is most effective at a regional level and at the onset of development [18].

Some of the benefits of GI, like job creation, land prices, infrastructure cost savings, and resource values, are relatively easy to measure using standard economic procedures. However, approaches vary depending on objectives, resources, and other considerations [19,20]. Other benefits have more complicated ties to GI and can be difficult to account for accurately. This is especially true for indirect benefits or economic spinoffs (Table 1), which are some of the main ways GI can support economic development [21]. GI is a major contributor to community livability, which is critically important to how communities can attract and retain residents and investments in the local economy, especially with the current hypermobility of information, labour, and resources [22]. GI is also receiving substantial attention for

its ability to make infrastructure systems and communities more resilient to climate change, reducing risks and, ultimately, the costs of extreme events like floods, heatwaves, and droughts while providing additional co-benefits [23,24]. Despite challenges in accounting for complex benefits, GI's importance to community well-being is well demonstrated to date, and efforts continue to improve how ecosystem services are valued [25,26].

1.2. Rural Green Infrastructure

Applications of GI vary from the highly localized scale at the building or site level (e.g., green roofs, street trees, and rain gardens) to the landscape scale, which generally focuses on a watershed-level analysis of green space and natural areas [27]. Applications of GI also vary depending on local context, land use, and development pressures. Because of the relatively high population density and acute development pressures in urban areas, most research, policy, and program development surrounding GI has focussed on larger centres. Rural regions, with their seemingly abundant natural assets and small populations, have consequently been underrepresented in GI discourse. Definitions of rural vary considerably in the literature. Rural boundaries, however, matter from a political and administrative perspective. Population levels directly influence decisions and the allocation of resources regarding a wide variety of issues like service delivery and electoral boundaries. The Statistics Canada 'census rural' definition (individuals living in the countryside outside of centres of 1000 or more) produces a rural population figure of 22% of Canada's total population. However, if an OECD definition is used (individuals in communities with less than 150 persons per square kilometer), the Canadian rural population figure jumps to over a third of the total population [28].

Du Plessis et al. [28] present the concept of 'degrees of rurality', which nicely accommodates various interpretations of rural and allows for community identification as rural, even though certain communities may exceed population, distance, or density parameters. Du Plessis et al. [28] suggest that an appropriate definition of rural is contextually dependent, arguing that "Researchers, decision-makers, local leaders, and rural policy analysts often start with the question, 'what is the size of the rural population?' We suggest that an appropriate response is, 'the answer depends upon the issue you are addressing'".

There is a theme within some GI literature that presents rural areas as part of the GI assets that serve nearby cities, more so than communities that benefit from the local assets themselves (Horwood, 2011). An example of this type of urban-oriented yet rural-situated GI planning can be seen through the Greenbelt Initiative in the Greater Toronto region of Ontario [29]. Rural communities, however, experience many of the same benefits seen in cities, like cost-savings related to natural stormwater management [30], as well as unique benefits related to their proximity to and relationship with natural areas. Many components of the rural landscape, both within and surrounding communities, contribute to the overall stock of GI, including forests, farmland, conservation land, riparian areas, wetlands, public parks and trails, brownfield cleanup lands, private yards, windbreaks, street trees, and stormwater management systems [11]. These features provide a range of natural services and are often fundamental parts of a community's identity and character.

Not only do rural communities face their own unique set of infrastructure and development challenges, but many communities have also been challenged by decades of disinvestment and policy restructuring, leaving them with limited capacity to maintain and invest in infrastructure [31–33]. Further, investments by senior governments have been inadequate to keep pace with shifting service demands for a range of social and technological approaches to infrastructure, including renewable energy and transportation, digital infrastructure, green infrastructure, and social equity approaches to service provisioning [34,35]. This investment gap has left many communities with a large infrastructure deficit with disproportionate impacts on rural, remote, and Indigenous communities [7,36].

In response to these challenges, many rural communities are now searching for new place-based strategies, policies, and partnerships to improve rural services, renew critical infrastructure, and build community resilience [37,38]. GI is a rapidly growing topic area for both community resilience and place-based infrastructure development, though its application and impacts remain understudied in the rural context.

1.3. Study Objectives

As articulated above, this paper aims to explore the use and utility of GI in the rural context. We conducted a survey of municipal staff and elected officials from across Ontario, Canada, and a qualitative study of rural regions in the same province to study the rural dynamics of GI more intensively. The focus of this paper is on the rural study of GI but it is informed by the broader survey findings related to the state of infrastructure and infrastructure planning in Ontario. GI applications in rural regions represent a significant international research gap we seek to address. The study looks specifically at the relationship between GI and economic development. We also investigate how local awareness

and capacity, and the regulatory environment around land use and development processes support or constrain the use of GI in rural regions.

2. Case Context and Methods

While substantial progress has been made over the last 20 to 30 years, GI planning and practice are still in their infancy in rural Ontario. Additionally, the diversity of rural needs and infrastructure pressures mean that GI approaches vary depending on the local context. As a result, few communities demonstrate a comprehensive approach to GI. For these reasons, we conducted a province-wide survey investigating the state of rural infrastructure and infrastructure planning in Ontario as part of a larger research initiative, *Building for the Future: Rural Infrastructure and Regional Economic Development*. The survey was distributed to municipal staff and elected officials across the province of Ontario in the summer of 2020 and successfully engaged 303 people representing 238 municipalities. The questionnaire covered various topics aimed at understanding rural needs and capacity related to service delivery and economic development. One portion of the survey asked respondents to identify the degree to which they were prioritizing GI in their infrastructure planning and if their community has taken part in GI-related projects as either a lead or supporting organization. Responses to these questions helped contextualize the theme of rural GI which is the focus of this paper. The survey helped to identify the key themes related to GI, which were then explored through key informant interviews and a qualitative analysis of rural GI themes. The three research themes include (1) economic motivators for GI in rural communities, (2) rural capacity challenges, and (3) opportunities for collaborative governance.

2.1. Study Region

Building upon the survey findings using a positive deviance approach, we conducted a targeted regional study to investigate success stories and challenges associated with the breadth of GI's potential application. We selected the southwestern and northern portions of south-central Ontario as the most populated and developed region of the province outside the direct influence of major metropolitan centres. These regions can be predominantly characterized as a working agricultural landscape, with small settlements that support the agricultural, manufacturing, and tourism sectors. Manufacturing has declined in some areas, particularly primary agricultural processing, and has concentrated along major transportation routes. Tourism is most significant in lakeshore communities but is generally not considered to be a key sector regionally [37]). See Figure 1 for an overview of the study area.



Figure 1. Map of regional municipalities in southwestern Ontario. Shaded municipalities contained GI projects and initiatives discussed in the study.

In Ontario, responsibilities related to land use and environmental regulation are shared between the provincial government under the Planning Act, Provincial Policy Statement (PPS), and other ministry-specific acts; local and regional municipalities through Official Plans and local policies; and Conservation Authorities (CAs) under the Conservation Authorities Act. CAs are semi-governmental organizations in Ontario that have regulatory responsibilities to manage natural hazards and often run a variety of environmental programs at the discretion of their member

municipalities [39,40]. As such, GI initiatives can fall under the jurisdiction of CAs, local government policies, and/or provincial government policies. It should be noted the Ontario provincial government implemented new legislation in January 2023 (Ontario Bill 23) after data collection concluded, amending the role of CAs. The impact of this new legislation on CAs is still to be understood, particularly as it relates to GI and land use planning, as responsibilities currently held by CAs may be shifted to the provincial government.

As noted above, we selected study communities and GI-related initiatives using a positive deviance selection method [41] based on their engagement or leadership on GI issues and their position within the rural landscape (garnered from the province-wide survey and a web scan targeting leading GI initiatives in the study region). All examples are outside the influence of Ontario's major urban region of the Golden Horseshoe, and most are located more than half an hour's drive from smaller regional urban centres. For this study, a general definition of rural was used to select regional municipalities with low population density and no large urban settlements or cities with a population of less than 20,000 and a location distant from larger centres. We consider that this approach is sufficiently flexible to capture existing best practices in rural GI and to represent a spectrum (with rural on one side and urban on the other) of rurality as described by Bollman and Reimer (2018) [42].

2.2. Key Informant Interviews

We investigated the study's objectives identified via the survey using qualitative analysis of key informant interview data from 19 semi-structured interviews with professionals working on projects and policies related to environmental management, rural infrastructure delivery, and/or regional economic development. Sixteen out of nineteen interviewees reported having direct experience related to the implementation of GI projects and programs or experience related to GI policy development and advocacy. The other three were able to talk more generally about rural needs for infrastructure and economic development and identified key challenges and opportunities that may arise in GI planning. Interviewees were selected through a combination of internet research to identify exemplary GI projects and through interviewees' professional networks using a snowball sampling technique to connect with experts not easily identified through online resources. Three interviewees were also selected via their participation in our province-wide survey.

Interview questions for the study covered a range of topics emphasizing rural capacity, policy and program needs, and economic benefits associated with GI in rural regions. Interviewees were asked to share their experience working to implement GI projects or policies, identify benefits and challenges related to GI planning and development in rural communities, and brainstorm possible solutions to improve GI adoption locally and provincially. Interviewees from CAs and the planning profession tended to have a robust knowledge of and experience working with GI. Municipal elected officials and economic development professionals tended to be less familiar with specific applications of GI but could speak to broader ideas of natural capital, ecosystem services, and community well-being, as well as community priorities related to infrastructure, environmental, and development pressures that influence the adoption of GI. Table 2 shows the distribution of professionals engaged in the interview process. Interviews took place between October 2020 and March 2021 and were conducted via video calls lasting an average of 60 minutes. Before conducting the interviews, we reviewed relevant planning documents to establish a foundation of knowledge related to the cases.

Table 2. Key informant interviews by sector.

Role/Sector	Number of interviews
Municipal Planners	3
Municipal Elected Officials	3
Municipal Chief Administrative Officers	3
Economic Development Professionals	3
Conservation Authority Staff	3
Planning Consultants	2
Non-Governmental Organizations	2
Total	19

All interviews were recorded and transcribed to provide a text record. Text files were analyzed using a mixed inductive and deductive thematic analysis method to identify, code, and categorize themes that emerged through the interview process [43]. Interview transcriptions were coded and analyzed using NVivo 12 software. Initial themes for deductive analysis were developed by compiling a list of keywords from the literature review and discussions with team members regarding broad project objectives, including infrastructure needs, rural capacity, and regional economic development. These themes were used for the initial coding of the interview data. The data were then reviewed and coded a second time using inductive analysis to identify additional themes not captured in the original list of keywords.

Interview themes are presented in the findings section and were ultimately used to develop recommendations for improving the delivery of GI policy and programming in rural regions of Ontario and Canada, more generally.

2.3. Limitations

Our study is subject to certain limitations. First, the development of GI in the region is an ongoing process of considerable complexity. Such complexity requires a contained research focus that inevitably then leaves other related issues unexplored. Second, our interviewees represented key organizational actors who have experience with questions related to planning and GI. There are many other perspectives in the region, some of which are more marginalized or underrepresented, that would add value to the discourse through further research. Third, as a qualitative study, our interview data may be subject to interviewees self-censoring themselves or seeking to address a particular agenda. The scope of our complementary research and internal team review processes sought to sharpen our qualitative analysis, but limitations nevertheless exist [44]. Finally, Indigenous perspectives are gaining recognition and support in ecosystem management as demonstrated, for example, in recognition of the importance of “Indigenous and local knowledge” in the Intergovernmental Panel on Biodiversity and Ecosystem Services (2019) [45]. GI has been discussed specifically as a meaningful way to engage Indigenous communities in planning processes and improve development with traditional knowledge of land management [46]. However, Indigenous scholars also continue to question the validity of nature as capital and its position within settler colonial approaches to land management and reconciliation efforts [47,48]. Our study focuses on settler municipal and regional actors and agencies. We recognize this limitation in terms of the importance of Indigenous self-determination and territorial stewardship. More broadly, emerging research is advancing equity-based approaches and considerations related to GI and NbS that help to inform future studies [49].

3. Findings

The results of the province-wide survey revealed that the highest priority infrastructure and economic development themes reported by municipalities were related to roads, water infrastructure, housing, and broadband. While GI was not noted as a high-priority issue for most municipalities, 35% of respondents reported participating in GI initiatives as either a lead organization or supporting partner. The survey did not provide enough detail to identify specifics about these projects, but municipalities did report collaboration across local government related to source water protection, tourism and marketing, and climate change projects.

The background web search and planning document scan of GI initiatives and responses from the key informant interviews highlighted a variety of GI examples within the rural landscape. Many of these examples are related to land and shoreline restoration projects aimed at improving soil retention and water quality in agricultural areas and shoreline communities on the Great Lakes. Common initiatives include rain gardens, stream buffers, wetland restoration, tree-planting and woodlot retention, cover crops, and rural stormwater management systems that can slow runoff and erosion with features like berms and bioswales. While these examples illustrate site-specific initiatives to increase GI features on the rural landscape, other interviewees spoke of GI in a broader sense as the networks of green space that make up the fabric of the rural landscape itself. From this broad perspective, GI was discussed as landscape-level features that shaped the development and identity of rural communities.

For the remainder of this paper, examples of GI will primarily focus on site-specific projects and local to regional initiatives aimed at increasing or protecting natural environments or functional green spaces. The following subsections highlight themes from key informant interviews associated with the economic benefits of GI as well as challenges to implement and manage GI projects and initiatives effectively. Themes represent the most common views of interviewees with a focus on rural economic development.

3.1. Economic Motivators of GI In Rural Communities

GI projects and initiatives offer a wide range of benefits and may be pursued for a variety of environmental and social values. However, interviewees suggested that economic factors are often the primary motivator for communities and landowners to implement GI on the ground. While many GI features exist naturally on the landscape, deciding to actively protect, expand, or integrate these assets usually responds to a regulatory, environmental, or service delivery problem with economic consequences. Our interview data indicates that GI has a positive contribution to rural economic development in four key ways: supporting sustainable agricultural production; attracting tourism and recreation spending; providing low-cost and adaptable rural services; and direct employment in GI-related industries.

3.1.1. Agriculture

As the dominant economic sector in most rural communities in southwestern Ontario, agriculture presents challenges and opportunities for improving GI. Farmers have a vested interest in land stewardship, particularly as it relates to soil conservation as the base resource for agricultural production. GI initiatives like cover crops/no-till agriculture, windbreaks/tree-planting, bank stabilization/stream buffers, and rural stormwater management help farmers protect their soils and are used successfully throughout the study region. However, high agricultural land prices present a challenge for expanding GI as farmers are faced with tight profit margins and are incentivized to crop as much land as possible. This economic pressure has also contributed to the amalgamation of larger farms and reduced the variety of crops produced. Additionally, the high cost of land makes it increasingly difficult for new farmers to enter the market, further supporting the move to fewer, larger producers operating on larger, more homogeneous fields. These pressures make it difficult for farmers to choose to expand GI at the expense of highly valuable farmland:

“We’ve seen our farmland at least quadruple, if not go up five times in value. That has caused this sort of pressure on the farming community to farm every square inch they can. The other thing is that with bigger equipment, they’re kind of forced into having squarer fields, and they square them up by taking out natural heritage more often than adding to it.” ~ Municipal CAO and former CA staff.

While soil conservation benefits may be hard to quantify, preserving and restoring natural heritage features can also provide direct economic value to both private and public landowners. Woodlots provide an important source of income for both rural landowners and local governments, as timber can be harvested periodically on a sustainable basis. This can be a valuable way for landowners to offset the opportunity cost of keeping land out of agricultural production. This is supported by case studies of private woodlot owners in Southern Ontario by Schwan et al. [50]. Regional municipalities were also reported to use revenue from sustainable woodlot harvesting on municipally owned land to fund municipal services and programs. Several interviewees noted that farmers and municipalities are often looking for ways to diversify income. This is likely to be an increasingly important motivator for landowners to consider restoration and stewardship projects. The non-profit organization Alternative Land Use Services Canada (ALUS) has been an important group in accelerating the uptake of restoration projects on agricultural land. ALUS offers landowners payment for providing ecological services associated with restoring natural features like wetlands, woodlands, and meadows and keeping them in a natural state [51].

Our interviewees noted that GI initiatives on agricultural land are usually completed in partnership with the local CA, which provides technical and often financial support to landowners. CAs have a shared interest in soil conservation for the benefits of improved water quality and reduced sediment load in streams and lakes. Agricultural GI projects have been most effective and widely adopted in regional municipalities that deliver clean water projects, which provide 50% funding to landowners interested in reducing their contribution to water pollution. GI projects typically funded through clean water projects include activities like tree planting, bank stabilization, wetland restoration, and cover crops.

3.1.2. Tourism

Many communities in southwestern Ontario, particularly those near the Great Lakes, have substantial cottage development and tourism economies. Access to green spaces is a major appeal in rural communities both for tourists and residents. Amenities like beaches, nature parks, and trails were the most common features noted by interviewees as having a direct benefit for economic development as features that attract people to rural communities and contribute to the overall (potential) stock of GI within rural regions.

Interviewees identified that lakeshore communities and the larger recreation economy tied to the Great Lakes are the largest beneficiaries of GI initiatives within upstream conservation and restoration watershed initiatives that help improve water quality. Outdoor tourism demonstrates the connection between environmental quality and economic performance with high-quality environments and scenic spaces, potentially incorporated as intentional GI, attracting more visitors. Interviewees noted the Blue Flag beach program as a specific tourism initiative aimed at attracting visitors to certified beaches for their environmental quality. While natural features like beaches and forests can be considered part of a community’s overall stock of GI, several municipalities in the study region also reported engaging in specific GI projects to enhance the level of service and environmental quality at key community spaces. Projects like rain gardens along municipal roadways help to improve the streetscape; park naturalization and bioswales that help to protect water quality for communities and agriculture; and ecological restoration efforts to reduce erosion at community beaches, which protect and enhance tourism values and potentially costly infrastructure loss.

Several trail networks incorporated into GI connectivity planning were noted for their tourism traffic and value to local economies from accommodation and local spending. However, some interviewees also identified issues related to the capacity of other infrastructure like roads, campgrounds, public washrooms, and waste management to support the increasing interest in rural communities:

“We’ve been very successful at tourism promotion to the point where we now have capacity issues around some of the signature spots. In terms of infrastructure, we are really at this pivotal point where we have to start addressing specific issues around how we manage these natural resources and the impact of visitors to the area.” ~ Municipal Economic Development Manager

3.1.3. Infrastructure

The third most noted benefit of GI in rural communities is related to municipal services and risk reduction of other built infrastructure. The service most commonly associated with GI was stormwater management in small urban settlement areas, many of which have minimal and/or degraded stormwater infrastructure, to begin with and sufficient land to manage rainfall on-site. GI applications like rain gardens can also be visually appealing and contribute to the charm and aesthetic of small towns. Some communities have pursued GI actively for its low capital cost, adaptable scale, and aesthetic benefits that can generate economic spinoffs for local economies. These benefits were prominently noted in communities that have made core infrastructures like stormwater and wastewater treatment ponds key community assets that incorporate GI to provide wildlife and recreational values.

Several interviewees also noted the ability of GI to protect private property and public infrastructure from damage related to flooding and extreme weather events, particularly in lakeshore communities with development concentrated in flood-prone areas and near steep banks at risk of erosion. Initiatives aimed at addressing these risks were not commonly identified in the study area. However, risks associated with climate change were noted as an opportunity to advance GI as a means of protecting financial investments in property and infrastructure in high-risk communities. Local climate action planning initiatives are becoming more common and are the likely avenue to address these issues:

“Climate change adaptation is critical and if we're not planning for it, we are planning for failure, and green infrastructure permits a more responsive infrastructure. For example, if the bioswale isn't working, you can make it a little bit bigger for minimal cost, but if an oil grit separator isn't working or is overwhelmed by the volume of stormwater you need to buy another bigger oil grit separator.” ~ Municipal CAO

Windbreaks or living snow fences and natural heritage conservation/restoration projects aimed at improving water quality were noted for their ability to save on infrastructure maintenance and operation costs like snow removal and water treatment. While infrastructure cost savings were widely believed to be a benefit of GI, monitoring and quantifying benefits were noted as a challenge. All examples given had only anecdotal evidence, with no funding directed to pre-and post-project monitoring.

3.1.4. Direct Employment

Finally, a significant yet often under-recognized benefit of GI is its contribution to the labour market both directly through jobs in the planning, construction, and maintenance of GI features and indirectly through employment and economic activity in supporting and spinoff industries like nurseries, parks, recreation programming, and tourism-related retail and service industries. Interviewees identified a substantial need to improve GI on the rural landscape and recognized this as a valuable opportunity to support stable, decent employment in essentially all communities.

“I think it's part of this whole green economy that we need to be developing around the world. Maintaining, restoring, and protecting nature needs to be a part of that, and there is a huge economic benefit to restoration that requires employing people. You need contractors, you need people with expertise around things like wetland construction, you need people to do the work, and I think it's a way to provide quality jobs in rural Canada.” ~ ALUS representative

This statement is supported by a recent study commissioned by the Green Infrastructure Ontario Coalition (GIO), which demonstrated the significant contribution of the GI sector to the provincial economy and projected significant growth potential for the coming decades [26].

3.2. Recognizing Rural Capacity Challenges

Despite the realized and potential benefits of GI articulated by our interviewees and evident in the region, capacity challenges are a real limitation for rural municipalities and other organizations working on infrastructure, development,

and environmental issues. Interviewees identified awareness, human resources, and finances as the biggest challenges limiting the uptake of GI practices in rural areas, particularly for municipalities and CAs.

A general lack of awareness was consistently mentioned as a barrier to the widespread adoption of GI. With most GI research and development efforts focused on urban communities, it can take time for the learnings from these projects to be disseminated to smaller municipalities and presented in a way that applies to a diversity of rural contexts. The small staff sizes and limited financial resources of rural municipalities and CAs further limit their ability to pursue innovative infrastructure solutions compared to their urban counterparts. Staff in rural organizations are generally responsible for many priorities, limiting the time available to seek out new solutions for any one topic. While interviewees expressed confidence in the ability of CAs to provide the technical knowledge and expertise to promote, manage, and implement GI effectively, concerns remain about the capacity of CAs to drive widespread action, given their limited resources and a lack of support from senior government policies. Several interviewees also noted that while CAs have relatively strong expertise in implementing GI projects, outcomes can be limited due to a lack of municipal expertise to maintain GI features after implementation:

“Our biggest challenge has been that small rural communities don’t have the staff with the expertise and know-how to look after trees and shrubs and plants. Because parks staff are part-time, they’re shifting from arenas and recreation complexes to outdoor parks, and they favour the skills associated with those other facilities. What we have had to do since we finished the park naturalization is to have a volunteer group help the community look after the park and the trail because the municipality doesn’t have the expertise to do it. That’s a huge weakness in rural Ontario.” ~ CA Manager

To overcome the capacity challenges limiting the uptake of GI, interviewees stress the importance of good information and demonstration projects that show the benefits of GI at local and regional scales. This includes increased funding for pre and post-project monitoring to support the development of the rural business case for GI. However, several interviewees noted that current government mandates and funding structures pose barriers to implementing GI when municipalities face many demands to renew aging infrastructure and often have access to a limited amount of funding:

“The sewer main on Main Street is always going to take priority over something that’s maybe green and new. So, I think it would be good if there was a separate category designated by the government that only directed funding to green infrastructure projects and I don’t even think the pool would have to be that big to have huge impacts on communities.” ~ Municipal CAO

While funding for GI projects is expanding through environmental and infrastructure programs, funding acquisition and delivery continue to prove challenging in rural regions. Projects may have access to a broad range of funding sources, but coordinating multiple applications can be onerous and raise questions of shared accountability. In rural communities, GI work is often coordinated through environmental programs funded by the federal government, donor organizations, or CA programs. Infrastructure funding has also been increasing for GI through programs like the Disaster Mitigation and Adaptation Fund (DMAF) and FCM’s Municipalities for Climate Innovation Program (MCIP). Interviewees noted that this type of infrastructure funding has limitations for funding GI projects, which may not meet funding thresholds for large infrastructure grants. The multifunctional benefits of GI are also not well captured in infrastructure funding applications, which tend to prioritize singular benefits/functions and measure their impact based on human use, further disadvantaging rural communities.

3.3. Opportunities for Collaborative Governance

The many forms, small-scale distributed nature, and multifunctional benefits of GI may make it more complicated to manage than traditional forms of infrastructure. It certainly requires new skill sets and monitoring systems. Regulation, funding, and guidance of GI practices involve collaboration among many different stakeholders on local and national scales, and their relationships can be nuanced. Interviewees identified a variety of opportunities and constraints for improving rural GI policy and programming within the current regulatory environment in southern Ontario.

Because of the intense land use and development pressures in southern Ontario, natural features are heavily regulated through both provincial legislation and municipal policy documents or plans [52]. While regulatory approaches to conservation and land use have proven to be contentious at times, interviewees expressed that regulation is often the fastest mechanism for senior and local levels of government to drive changes in development practices. Regional municipalities were noted as having some power to set regional priorities and standards to influence GI, most notably through land use policy and planning. Still, interviewees also noted the importance for the provincial government to set a level playing field and ensure consistency across regions:

“The counties (A county government is a federation of municipalities within its boundaries.) as broader planning areas have a role. I also think the Conservation Authorities rolling it up by watershed is a great idea. I think the watershed level analysis is a very technically sound way of doing it, but the difficulty is that the watershed boundaries don’t line up with the boundaries of municipalities and you end up with complex relationships of different watersheds doing it different ways and different municipalities ending up in different watersheds. So, I think that brings it back to the importance of the province setting the standard of how things should be mapped and managed. The other scale to get down to is the community scale. There is still a place in my view for a local municipality or even a dedicated group of individuals, not the County, to provide services at a very local level because if they know what the big picture plan is, all they need to do is implement it.” ~ Municipal CAO and former CA staff

Interviewees noted positive progress over the years on regulation relating to natural heritage, urban development, stormwater management, and asset management to support the consideration and use of GI, though most have focused on urban development. GI has also been defined as a priority within Ontario’s Provincial Policy Statement. The largest regulatory opportunity noted to improve GI practices in rural areas was through updating the Drainage Act, which was recently reviewed for administrative purposes but not for improvements to the purpose and outcome of the Act. Interviewees noted the agricultural landscape is the largest contributor to stormwater quantity and quality issues in rural communities in the study area, and drainage practices have seen little improvement from a regulatory standpoint. The recent inclusion of GI in Ontario’s asset management regulation (O. Reg. 588/17) was also noted as an opportunity to expand the scope of natural heritage reporting and align multiple objectives between CAs and municipalities related to natural service provisioning.

Interviewees generally agreed that GI is most effectively managed using a systems approach at a regional scale. CAs were again identified for their strategic position to deliver GI programs in Ontario, as they are the only organization of their kind to operate within the natural boundaries of a watershed with the mandate and expertise to improve natural systems. However, challenges do arise with the overlap in boundaries between CAs and multiple municipalities. Municipalities and CAs generally have strong partnerships to deliver programs and services, but many of the most successful GI-related programs are funded based on the discretion of municipal councils, such as stormwater management and erosion control projects funded through municipal clean water programs. While this is largely a reflection of local choice and political priority, interviewees note that the lack of consistency among regions has likely limited the progress and, ultimately, the benefits received from GI throughout the province.

Beyond regulatory changes, changes to GI funding, as described in the previous section, were thought by interviewees to be the most effective mechanism for improving GI implementation in rural regions. To effectively mobilize funding, interviewees stressed the importance of aligning the priorities of multiple stakeholders and funding organizations to coordinate GI projects around common objectives. Directing more funding toward GI research and knowledge mobilization in rural areas will also help bolster efforts already being made by organizations like the Green Infrastructure Ontario Coalition, the Municipal Natural Assets Initiative, and the Federation of Canadian Municipalities who, also advocate for improved policy and offer webinars and educational resources to promote GI. Several interviewees also noted the value of promoting GI through professional development training for engineers, drainage and landscaping contractors, and municipal staff, who are often the stakeholders most responsible for the design, implementation, and maintenance of GI assets.

4. Discussion

Following decades of disinvestment and piecemeal approaches to economic development [33,52], rural communities need new strategies to manage an ever-growing infrastructure deficit and numerous economic, social, and environmental challenges. Interviewees in our study identified intense agricultural land pressure from high land values, a lack of affordable housing, limited social services and employment opportunities, demographic challenges associated with an aging population, and the accelerating impacts of climate change as common, complex problems facing non-metropolitan communities in southwestern Ontario. These are all important issues, but limited human and financial capacity leaves many communities in a difficult position to proactively prepare for a future that will look very different from their past. While there is no single solution to these challenges, our case illustrates that GI is an overlooked tool with the potential to ease many overlapping pressures facing rural regions.

GI and its diverse applications offer flexible and often low-cost solutions to address the pressure of infrastructure deficits and support the development of communities that are rich in natural amenities and resilient to a changing climate [10,53]. Rural communities are generally well-positioned to take advantage of the benefits of GI, given their low

population density and position relative to natural spaces [55,56]. Further, GI approaches are place-based, using the unique geography and natural assets of a region, allowing communities to pursue the GI strategies that are best suited to their local strengths and needs [18]. Many of the GI examples noted throughout this paper reflect the adaptability of GI to meet community needs, whether expanding the capacity of existing built infrastructure in small urban settlements (e.g., bioswales, stormwater wetlands, and rain gardens), or improving soil retention and productivity of agricultural land (e.g., cover crops, windbreaks, and stream buffers), or restoring floodplain and forests to support biodiversity, natural hydrology, and recreation amenities. All these examples have been implemented in Ontario communities and have demonstrated value to a diverse group of rural stakeholders.

GI will not replace the need for built systems like roads, water treatment and distribution, sewers, and other core community services. However, GI can reduce environmental and economic pressures and boost the capacity of these systems while providing a broad range of co-benefits [4,57]. The many distributed components of GI can provide both site-specific and cumulative benefits at a regional scale. The planning and management of diverse GI assets require system thinking to assess how specific elements will interact with one another and with other forms of built infrastructure to provide broad-scale environmental, social, and economic benefits. Accounting for the total value of GI remains a challenge everywhere, yet the lack of discourse surrounding GI in rural regions and the limited capacity of rural actors to pursue new approaches has likely slowed the uptake of GI relative to urban areas.

Further, the lack of a unified approach to GI in rural areas makes it difficult for communities to value and invest in GI properly. This is also complicated by inconsistent terminology, overlapping jurisdictions, and competing political and service priorities. We hope that by identifying the varied economic development impacts associated with GI, municipal councils (and other levels of government) may look upon GI solutions with new interest and confidence.

The complex regulatory and stakeholder relations governing GI present barriers that have largely been overcome through collaboration among interested stakeholder groups. Collaboration depends on the social capital of a region, which ensures rural communities have the human, technical, and financial capacity to manage and strategically invest in natural and built assets [53]. The rural extension model [58] has effectively mobilized stewardship-minded landowners, developers, and municipalities to undertake pilot projects and build local knowledge and capacity on GI through collaborative partnerships [59]. While good examples of GI exist, intense agricultural land use and urban development pressures remain dominant throughout the study area, and implementation of GI is uneven in distribution and approach depending on local priority and capacity [11]. Recently adopted provincial legislation further compounds the situation.

Making GI a priority within land use and development processes requires a broader recognition of the many benefits it provides. This relies on a fundamental reshaping of what we consider to be infrastructure, as it tends to have a narrow association with built structures like roads and bridges. Broadening perceptions of what constitutes infrastructure will help reframe nature as a core element contributing to the well-being of all communities, but with particular benefits for rural communities where the land serves as a foundation for agricultural, resource, and amenity economies [60].

With the introduction of natural asset accounting in municipal asset management regulation, Ontario has taken a large step towards recognizing and valuing the services provided by GI. However, municipal asset registries typically consider only those assets directly owned by a municipality. Unlike traditional forms of infrastructure, GI assets exist on both public and private land, making system-level management complex. Effectively integrating GI within municipal asset management may require specific land use and financial policies to ensure both public and private assets are managed effectively to support cumulative efforts toward natural service provisioning [61].

Beyond asset management, the study findings suggest that GI should continue to be prioritized through land use planning and development processes, and conservation programs. The collaborative and multi-jurisdictional nature of GI management presents opportunities for action and leadership at local, regional, and provincial/federal scales to improve GI policy, funding, and knowledge mobilization. It is important to consider similarities and differences in the mandates and capacity of different government agencies and stakeholder groups to leverage resources and align action on GI effectively. For instance, infrastructure, environmental, and agricultural agencies are interested in particular aspects of GI and should work together to ensure funding is coordinated for projects that meet multiple objectives. This may require resources to be pooled and administered by different agencies or organizations that are strategically positioned to deliver small, distributed projects across the rural landscape.

Recognizing the variability of GI implementation, interviewees called for a more standardized approach to GI backed by clear, enforceable policy and regulation at the provincial level. However, interviewees also cautioned against overly prescriptive approaches that might limit creativity and choice in addressing local priorities and conditions. Regulation of rural stormwater management was one notable area that could be standardized to prioritize GI approaches

through funding applications and approval processes for drainage works. Public opposition toward increased land use regulation was noted as a likely barrier to this type of regulatory change. Other GI priorities, like GI's lifestyle and biodiversity benefits, were thought to be better pursued through information and incentive-based programs.

There was wide agreement among interviewees that the success of GI is determined at a regional, ideally watershed, scale. Management and monitoring efforts should also be directed at this scale. Ontario's CAs provide a unique advantage in this regard due to their mandate to manage land use, natural heritage, and water resources with multiple partners, though we recognize the future effectiveness of CAs is uncertain as their authority may be limited by recent changes to provincial legislation. Regional analysis was also believed to be an effective scale to draw attention to the economic benefits of GI. While efforts to quantify specific benefits of GI, like reducing agricultural sediment and nutrient runoff, have improved [62,63], co-benefit accounting has proven to be challenging, and there is a need for more studies dedicated to quantifying the diverse benefits of GI in rural regions.

5. Conclusions and Recommendations

The results of this study suggest a wide array of benefits and challenges related to expanding the use of green infrastructure in rural regions. These benefits and challenges were explored through the perspective of interviewees with firsthand experience in the field of natural resource management and municipal planning and governance. Interviewees generally presented an optimistic view regarding the service provisioning and development potential of GI when aligned with effective regional partnerships, planning, and management. Interviewees emphasized the foundational role a healthy environment plays in supporting vibrant rural communities and economies. This optimism was tempered by a recognition that a complex regulatory landscape and numerous competing development priorities have resulted in a slow uptake of GI and nature-based solutions.

The following recommendations are intended to be considered in order to improve GI policy and programming in the context of the study area of Ontario, Canada. While the environmental and governance context is highly contextualized to our case region, many of the themes identified in our study resonate with the international literature. First, all levels of government should prioritize GI as part of efforts to address infrastructure deficits, with standards that clarify how communities and stakeholders should prioritize action. The introduction of GI into provincial policy, guidelines, and asset management regulation is an important step toward making GI a mainstream practice. Setting GI as a policy priority ensures all communities consider GI as an option when making investment decisions. This requires improving and clarifying regulations so that municipalities conduct regular inventories and quality assessments of GI assets and have the tools available to understand key stakeholder responsibilities and coordinate planning at a regional level. Looking for further opportunities to prioritize GI in provincial and municipal policies and regulations will also help mobilize action and funding resources.

Second, senior governments should provide targeted GI funding to support diverse projects in terms of size and timescale. Dedicated funding should be targeted at GI projects that make use of natural services to avoid competing priorities with other necessary built systems like water and sanitary sewers, and clean technologies like renewable energy and electric vehicle infrastructure. Importantly, our findings suggest that funding programs must be designed to support long-term processes that build regional capacity and provide stakeholders access to resources when they are ready to undertake work rather than when grants are available. Project funding should also be prioritized to cover baseline studies and post-project monitoring to help quantify the many benefits of GI.

Third, there is a need for further research—and in different settings—to advance awareness and understanding of the benefits of GI in rural communities through regional studies. Our survey and key informant interviews note a lack of awareness and understanding of GI, particularly in rural regions. This can be addressed through collaborative research partnerships with universities/colleges, municipalities, CAs, NGOs, and private landowners. Studies should focus on the cumulative regional benefits of many distributed GI projects.

Finally, as more research and information become available, it needs to be targeted to and integrated with training for GI stakeholders to build local capacity. Information should be tailored directly to the different audiences of planners, council members, engineers, financial organizations, municipal staff, and landowners. Targeting GI training through professional development, guidance documents, and peer-to-peer networks will help make GI a mainstream practice in all communities.

As the discourse surrounding GI evolves, rural communities must continue sharing their experiences. The recommendations presented above provide actionable steps that rural researchers, planners, practitioners, and policymakers can take to improve the uptake and realize the benefits of GI in any jurisdiction.

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Author Contributions

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Ethics Statement

The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Research Ethics Review Board of Simone Fraser University (protocol code 2020s0055, March 2021).

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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