AGRICULTURAL GREEN INFRASTRUCTURE: EXPLORING POTENTIAL NATURE-BASED SOLUTIONS IN THE ALBERTA CONTEXT

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1.0 Introduction

The global risks and opportunities presented by climate change are becoming increasingly observable in natural and built environments as anthropogenic emissions continue to rise. Climate adaptation and mitigation measures are needed to prepare communities and ecological systems for the impacts of climate change (Council of Canadian Academies [CCA], 2019). In Alberta, the effects of climate change are already being felt, and are expected to cause further warming and a shift in weather extremes (Alberta Climate Records, n.d.). These climatic changes will not only have environmental consequences but will create intersectional risks to human health, social welfare, physical infrastructure, and the economy (City of Edmonton, 2018). Thus, work needs to be done quickly to adapt to and mitigate these risks at the local, regional, and global scales.

Nature-based solutions (NBS) have emerged in both scholarly discourse and practice as a way to mitigate and adapt to the impacts of climate change. Given the implications of climate change on urban resilience, it is important to examine how NBS can be actualized in the urban environment. One emerging area of interest in the urban context is implementing urban agriculture as a NBS. We examine the concept of nature-based agricultural green infrastructure (AGI), which includes both roof and ground-based food production, and how it presents an alternative system for sustainable growth, development, and resilience-building within cities.

This report aims to examine the potential for Alberta municipalities to plan and implement AGI as a nature-based solution. This report will explore the benefits and challenges facing the implementation of AGI in the urban context, examine case studies from international jurisdictions, and investigate the future applicability of AGI as a NBS in the Albertan context. To explore these topics a literature review and document analysis were undertaken. Reviewing scholarly literature, policy, regulations, and case studies, our paper intends to showcase how implementing nature-based AGI can play a role in Alberta municipalities adapting to, and mitigating, climate change.

1.1 Nature-based Solutions

Nature-based solutions are a multi-dimensional approach to addressing the challenges facing rural and urban communities today. NBS are defined by the International Union for Conservation of Nature (IUNC) 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” (Cohen-Shacham et al., 2016). Table 1 lays out the general principles NBS should follow, as identified by Cohen-Shacham et al. (2016).

IUCN NBS PRINCIPLES	
1	Embrace natural conservation principles and norms.
2	Be implemented either alone or integrated with other technological or engineering (anthropogenic) solutions.
3	Be determined by place based natural and cultural contexts.
4	Include different knowledge systems.
5	Be applied at the landscape scale.
6	Maintain biological and cultural diversity.
7	Be designed and maintained in a way that promotes equity, fairness, and public participation.
8	Recognize the trade-offs that arise as a result of NBS implementation.
9	Ensure NBS is included as an integral part of policy design and actions.

Table 1. IUCN General Principles defining NBS.

If properly implemented, NBS offer an opportunity to create resilience in the natural, social, and built environments using "actions inspired by, supported by, or copied from nature" (Bourguignon, 2017). These actions can take many forms, including ecosystem restoration, green infrastructure development, ecosystem protection, and sustainable ecosystem management (Cohen-Shacham et al., 2016; Magdelenat et al., 2021; Miles et al., 2021; United Nations Environment Programme [UNEP], 2021). Furthermore, they can be implemented in both terrestrial and marine ecosystems, though there is a greater understanding of their applicability and effectiveness in terrestrial systems (Lowe et al., 2022; Miles et al., 2021). Commonly cited co-benefits of NBS developments include, but are not limited to: climate mitigation and adaptation, biodiversity protection, and disaster risk reduction (Cohen-Shacham et al., 2016). A major focus in the literature is on the potential NBS have to mitigate climate change, as studies suggest these solutions could "sequester enough carbon to get us more than a third of the way to the world's 2030 climate targets" (Task Force for a Resilient Recovery, 2020). Thus, NBS offer "huge potential to address both the causes and the consequences of climate change while supporting biodiversity and thereby securing the flow of ecosystem services on which human well being depends" (Seddon et al., 2020). In order to establish these benefits, it is imperative that NBS are context-specific and place-based; for the purposes of this report, we will therefore focus on the NBS that are well suited to the urban context (Magdelenat et al., 2021; Pérez-Cirera et al., 2021; Voskamp et al., 2021).

1.2 Nature-based Solutions in the Urban Context

Given that over half of the world's population lives in cities, and with projections showing that the proportion is expected to rise above 60% by 2030, it is vital to examine the implications of urban growth on climate change and urban resilience (Lal, 2012). Examining the impacts of continuous urban growth on land use and emissions, we find that urban centres are among the largest contributors to climate change; simultaneously, climate change will have a large impact on the urban microclimate (Specht et al., 2014). In the urban context, nature-based solutions present a way to address the cross-cutting challenges caused by urbanization and climate change, including the urban heat island effect and shifting urban hydrology (Artmann & Sartison, 2018; Kabisch et al., 2016; UNEP, 2021). Further, NBS provide adaptable solutions to reintegrate nature into our urban developments, and improve the livability and resilience of cities, resulting in better mental and physical health for urban residents (Bush & Doyon, 2019; CCA, 2022; Kabisch et al., 2016; Magdelenat et al., 2021). Thus, as argued by Kabisch et al. (2016), NBS not only work to mitigate the impacts of climate change but also provide an opportunity to limit these impacts through proactive adaptation. This means that cities that adopt NBS can work to solve the cause of their climate problems while also reaping numerous social, economic, and ecological benefits.

In the urban context, NBS can take multiple forms, including ecosystem restoration, urban forests, green or natural spaces, constructed wetlands, urban agriculture, and re-naturalized water bodies and wetlands (UNEP, 2021; World Bank, 2021). Literature shows NBS often takes the form of green infrastructure projects; the most commonly cited approaches to integrating NBS into infrastructure include green roofs, green walls, natural spaces, tree planting, and urban agriculture (Anderson & Gough, 2021; Frantzeskaki, 2019; Magdelenat et al., 2021; Russo et al., 2017; UNEP, 2021; World Bank, 2021). Specifically, these approaches are identified as invaluable solutions to redesigning our infrastructure and built environment within the context of urban climate change (Frantzeskaki, 2019). These projects, which focus on bringing vegetation into the urban environment, are designed to naturalize urban hydrology, reduce air pollution, and regulate temperatures (Anderson & Gough, 2021; Magdelenat et al., 2021; UNEP, 2021). The following section explores the opportunities and challenges facing NBS implementation generally, and in urban contexts more specifically.

1.3 Implementing Nature-based Solutions: Opportunities and Challenges

Many scholars and practitioners have begun advocating for the use, and mainstreaming, of NBS because “society does not stand isolated or apart from the natural environment” (CCA, 2022). Thus, moving forward, development must happen in a way that safeguards human well-being and natural ecosystems. Currently, there are both opportunities and challenges facing municipalities and urban governments hoping to implement NBS.

NBS can play a role in addressing multiple social-ecological challenges that face urban communities, including climate change, water and food security, human health, and socio-economic development (Cohen-Shacham et al., 2016; Magdelenat et al., 2021; UNEP, 2021; Voskamp et al., 2021). In order to implement these solutions, work needs to be done to mainstream NBS in the decision-making process. Mainstreaming cannot be done without ensuring that decision-makers, at any level, have access to the adequate tools, policies, and strategies that work in their jurisdictional and geographic contexts. Currently, opportunities exist for municipalities, as a variety of tools have already been developed and put into practice to facilitate the mainstreaming process, including methodologies, guidelines, software, and catalogues (Dupras et al., 2015; Frantzeskaki, 2019; Voskamp et al., 2021). Implementing NBS also provides an opportunity to empower local stakeholders and co-produce solutions and tools within communities; scholars have found that "co-creation is a way to cope with the complexity and uncertainty that sustainable solutions like nature-based solutions have in delivering on sustainability and resilience" and creating more public support for NBS (Frantzeskaki, 2019).

Despite the benefits, the implementation and mainstreaming of NBS face a variety of economic, institutional, and sociocultural barriers, even when tools and policies already exist. Economic barriers, defined as "barriers related to the effective funding and incentivising of nature-based solutions", commonly include the undervaluing of natural capital, the financial feasibility of NBS, and a lack of financial resources and incentives (Pérez-Cirera et al., 2021; Voskamp et al., 2021). Institutional barriers, which are "barriers related to the rules and conventions required for the effective governance of nature-based solutions", include conflicting, or unaligned, policy frameworks and siloed governance of NBS (Pérez-Cirera et al., 2021; Seddon et al., 2020; Kabisch et al., 2016; Voskamp et al., 2021). Sociocultural barriers include "barriers related to the behaviors of different actors required for scaling nature-based solutions" (Pérez-Cirera et al., 2021). Other barriers include limited data, insufficient practical knowledge, and uncertainty about how to plan and implement solutions (Bush & Doyon, 2019; CCA, 2022; Kabisch et al., 2016; Voskamp et al., 2021).

Scholars have suggested that in order to overcome these challenges, NBS must be mainstreamed through inter-sectional policy implementation, context-specific solutions, monitoring, and regulation (Kabisch et al., 2016; Magdelenat et al., 2021; Voskamp et al., 2021). Opportunities for mainstreaming NBS can also be actualized through integration into the urban planning practice (Bush & Doyon, 2019). Planning may be well-positioned to address these facets of NBS mainstreaming, garner support from the public, and work alongside other professionals to create visually and socially appealing NBS (Bush & Doyon, 2019; Frantzeskaki, 2019). Ultimately, relevant literature suggests that collaborative governance is needed to address the challenges faced in mainstreaming NBS (Frantzeskaki, 2019; Voskamp et al., 2021). If collaborative governance can be achieved, the benefits of NBS can be easily applied to various urban contexts; however, without proper discourse, knowledge sharing, community involvement, and policy support, NBS can be challenged before even basic implementation.

2.0 Nature-Based Agricultural Green Infrastructure in Cities

As urban populations grow, nature-based AGI presents a new option for cities to manage, and solve, a range of urban problems. AGI, when implemented using a NBS approach, can provide benefits to cities through the integration of natural ecosystem services into the urban context (Deelstra & Girardet, 2000; Lal, 2012). The agricultural aspect of these solutions is crucial as, currently, only 15-20% of food is grown in urban areas despite the fact that urban residents consume 80% of total food produced (Artmann & Sartison, 2018; Ellen MacArthur Foundation, 2019). This means that urban areas are massively reliant on rural agriculture, which in modern times has become ever more industrialized, globalized, and fossil-fuel dependent (Carolan, 2017; Moos et al., 2020). This reliance on industrialized agriculture has created major environmental, social, and economic problems for urban and rural areas (Carolan, 2017; Moos et al., 2020). The expansion of nature-based AGI systems, therefore, offers an important and potentially necessary mechanism for urban areas to enhance sustainability, resolve a range of socio-economic problems, and become increasingly resilient to our changing climate.

2.1 General Benefits of Nature-Based Agricultural Green Infrastructure

Nature-based AGI is defined in a plethora of ways by existing literature, and there is no clear consensus on what could or should count as nature-based AGI; these definitions are further complicated as they can translate into many different physical built forms in urban areas (Specht et al., 2013). In the context of this report, we will focus on the natural forms that AGI can take in urban areas, with a particular focus placed on urban agricultural systems. These forms include, but are not limited to, green roofs/walls, urban natural and protected areas, and various forms of urban gardening/agriculture. These forms line up with a definition provided by Russo et al. (2017), which states:

> Edible green infrastructure is a sustainable planned network of edible food components and structures within the urban ecosystem which are managed and designed to provide primarily provisioning – as opposed to highly studied urban “cultural” (e.g. recreation, increased property premiums, and aesthetics) and “regulating” (e.g. air and water pollution removal, temperature regulation, and flood regulation).

AGI can therefore include allotment or plot gardens, rooftop gardens, edible landscapes, urban beekeeping or chicken coops, and urban forests. Anthropogenic and futuristic approaches such as indoor-vertical farming or advanced hydroponic systems will not be included in this report. While these more anthropocentric forms of urban agriculture may play a major role in future urban food systems, they are beyond the scope of this report as they do not fit clearly within the definitions of a nature-based solution (Carolan, 2017; Russo et al., 2017; Specht et al., 2013).

Introducing nature-based agricultural green infrastructure can contribute greatly to reducing the environmental impacts of urban areas (De Zeeuw et al., 2011; Kabisch et al., 2017). Nature-based AGI can lower precipitation impacts and subsequent flood risks, absorb smog and other harmful pollutants, mitigate the urban heat island effect, reduce the impacts of high winds and urban wind tunnels, and help offset and even reverse biodiversity losses caused by urban expansion (Carolan, 2017; Kabisch et al., 2017; Snep et al., 2020). By expanding AGI, pressure is also removed from rural areas to continue developing new agricultural lands, potentially preserving natural forests and green spaces around the world and enhancing the ecosystem services that those natural areas provide (Carolan, 2017; Kabisch et al., 2017; Moos et al., 2020). Reducing reliance on rural agricultural systems, and replacing complex food supply chains with local sources, not only reduces the environmental impacts of agriculture but also builds up urban resilience to food supply crises, which are only predicted to get worse as our climate continues to change (De Zeeuw et al., 2011; Gulyas & Edmondson, 2021). Expanding green areas in cities can also restore natural ecosystem services within urban areas and increase biodiversity (Carolan, 2017; Moos et al., 2020). This increased access and visibility of nature and green spaces creates benefits, as they are directly linked to healthier emotional and mental states in urban residents (Carolan, 2017; Moos et al., 2020). In addition to the environmental benefits listed above, AGI also provides an impressive array of socio-economic and health benefits to cities (Carolan, 2017; Kabisch et al., 2017). These benefits differ slightly depending on what form AGI takes, but almost all forms contribute to building urban food resilience and security, adding economic development opportunities, and establishing or expanding community and social building aspects (Carolan, 2017; Kabisch et al., 2017). These benefits will be discussed in further detail in section 2.2.

2.2 Ground-based Agricultural Green Infrastructure

A common form of AGI is community urban gardens, which can be developed in several ways. The most basic community urban gardens are simple land-based gardens or farms, often developed from underused areas, such as parking lots, empty or abandoned properties, or repurposed park spaces (Carolan, 2017; Harrison, 2022; Moos et al., 2020). By making use of low-demand space, land-based community gardens can be developed and maintained easily and cheaply; they also generally require less technical knowledge and have fewer policy restrictions and barriers when compared to other forms of urban agriculture (Carolan, 2017; Snep et al., 2020).

These types of gardens do not need extensive technological support as compared to even simple greenhouses or more advanced horticulture or indoor farms. For example, land-based gardens can be kept almost entirely nature-based and can even be more productive in a natural environment if the principle and practice of agroecology is adopted (Carolan, 2017; Kabisch et al., 2017). Agroecology is a method of agriculture that is well suited for simultaneously enhancing the benefits and diminishing the challenges of nature-based urban agriculture

(Carolan, 2017). This form of agriculture uses only natural solutions, labour, and inputs, in highly biodiverse and intensively farmed small-scale systems known as polycultures (Carolan, 2017). Polycultures have been found to be more productive than other forms of agriculture and produce a higher quality and range of crops, which builds additional layers of resilience and food security (Carolan, 2017). They also increase urban biodiversity and create wildlife and natural corridors (Carolan, 2017). Further, these AGI systems, as most NBS do, reduce urban pollution, the urban heat island effect, drought, and flood risk (Carolan, 2017; Kabisch et al., 2017; Snep et al., 2020). Lastly, by adopting agroecology, and incorporating plants, animals, and all other natural aspects, urban gardens can avoid health and pollution concerns caused by fertilizers or pesticides, thereby making them easier to establish and cheaper to maintain as there is a lessened, or removed, need for these artificial inputs (Carolan, 2017).

2.3 Rooftop Developments

Another form of urban agriculture that has attracted much attention is rooftop gardening, either taking the form of simple planters placed on roofs like Toronto's Sky Garden or more advanced and expansive rooftop greenhouses such as Montreal's Lufa Farms (Carolan, 2017; Moos et al., 2020). These forms of urban agriculture can often stray away from being nature-based, as Lufa Farms shows, but agroecological rooftop gardens not only exist but also offer a major increase in the availability of land for nature-based green infrastructure in cities (Carolan, 2017; Snep et al., 2020; Whittinghill & Rowe, 2011). Rooftop developments not only have the potential for a similar range of benefits as land-based community gardens but can also eliminate some of the disadvantages that land-based AGI can suffer from; for example, rooftops currently have few uses but take up as much as 85% of urban areas (Lucertini & Di Giustino, 2021; Specht et al., 2013). By developing natural rooftop AGI, cities may be able to resolve some of the conflicting land uses, with affordable housing, for example, that would otherwise prevent these types of developments (Moos et al., 2020).

Rooftop AGI can also take a variety of forms. Low-intensity rooftop AGI can be as inexpensive and simple as planting grass on a minimal soil layer, while intensive rooftop AGI can involve much more advanced systems of production, including the development of fully agroecological polycultures (Carolan, 2017; Hugo et al., 2021; Snep et al., 2020). As expected, intensive rooftop developments such as rooftop polycultures are much more expensive and difficult to maintain than simple rooftop lawns, but they also provide all the benefits of urban agriculture atop the benefits of nature-based AGI within cities (Snep et al., 2020). All forms of rooftop AGI also reduce the effects of the "concrete jungle" by integrating nature into highly modified spaces. This integration provides social benefits and ecological supports by helping to establish natural areas in what are generally uninhabitable spaces for nature (Carolan, 2017; Moos et al., 2020). Rooftops are also an extremely valuable resource for urban livestock developments; not only is there the possibility of rooftop chicken coops, for example, but the expansion of natural green roofs or gardens also provide benefits for urban bees and other important pollinators (Carolan, 2017; Hugo et al., 2021; Snep et al., 2020). These developments can further diversify what products and food supplies agricultural green infrastructure can provide while simultaneously adding more natural elements to our urban environments.

Unused, or underused, building surfaces can also be host to green roofs or green walls, both of which are other forms of nature-based AGI. While similar to rooftop gardens, planter boxes, or greenhouses, natural green roofs differ in that they are designed to be a near replica of natural areas, with the requisite soil and biota composition (Snep et al., 2020; Specht et al., 2013; Whittinghill & Rowe, 2011). Creating a natural green roof generally requires a much greater amount of base material than a plot-garden would require but also allows for a more natural area that can mimic natural biodiversity even within a bustling urban centre (Snep et al., 2020; Whittinghill & Rowe, 2011). Furthermore, simple green roofs and walls may require much less maintenance over time, especially if they are not used to grow food. While limiting food production does take away some of the benefits that AGI provides, green roofs and walls can cheaply and effectively provide urban areas with natural, ecological, and social benefits. These AGI solutions may hold a stronger appeal for areas without the necessary capital or public support to fully retrofit buildings into rooftop gardens (Carolan, 2017; Hugo et al., 2021).

Rooftop green infrastructure developments also resolve some of the health and pollution concerns surrounding the production of food within cities; as the growth medium (soil) is fresh and uncontaminated, rooftop gardens do not face as many concerns over the quality of developable sites in the way land-based AGI might (Hugo et al., 2021; Snep et al., 2020; Specht et al., 2013). Rooftop developments can also provide direct bonuses to the buildings they are constructed on in addition to the overall area benefits (Hugo et al., 2021). By incorporating green roofs or gardens, buildings suffer less exposure damage from weather events such as storms, and these developments can even make use of rainwater for irrigation (Hugo et al., 2021; Snep et al., 2020). Green roofs also modulate the temperature of buildings, saving heating costs in the winter and reducing cooling costs in the summer, with potential savings of up to 40% of total building energy consumption (De Zeeuw et al., 2011; Hugo et al., 2021). Lastly, developing currently underutilized rooftops can help promote urban development and reduce suburban sprawl; this, in turn, reduces cities' impacts on the environment and helps to rebuild inner urban areas by providing new amenities using existing infrastructure (Moos et al., 2020; Lucertini & Di Giustino, 2021).

2.4 Challenges facing AGI Developments

Despite the wide array of benefits AGI can provide cities, it is important to recognise that these developments are not silver bullet solutions to all urban problems and that the success of AGI is highly context-specific. Scholars note that what may work in one city or region may not work in another, and vice versa (Gulyas & Edmondson, 2021; Moos et al., 2020). Furthermore, while there are credible and tangible benefits already being observed in cities that have invested in nature-based AGI, there are also extreme challenges that must be addressed; the magnitude of these challenges has frequently been found to make AGI unsustainable or unsuitable for numerous cities (Harrison, 2022; Kabisch et al., 2017).

An almost universal challenge facing AGI is the economic costs of establishing a new development. Cities already deal with an increasing number of expensive problems, and setting aside more money and more land for AGI is often seen as an extravagance or a waste (Moos et al., 2020). Competing priorities for city investment have been observed by scholars, as there has been pushback from current urban residents, planners, and leaders who may wish to utilize underused spaces in different ways (Moos et al., 2020; Kabisch et al., 2017). One of the most common competing land uses that challenges AGI is the lack of affordable housing that many cities currently face (Carolan, 2017; Moos et al., 2020). While proponents of affordable housing may not be against AGI, their support for developing underused urban land into housing or other structures is a powerful argument that can easily sway city officials away from AGI development. While AGI has significant benefits, cities may prefer to use the limited urban space to develop new, potentially more attractive sources of tax revenue, such as building new offices or commercial spaces, implementing affordable housing to reduce homelessness and/or easing housing prices, or even developing new transit options (Moos et al., 2020). All these developments have their own significant benefits and can be very positive for cities; this means that AGI is often pushed aside.

A solution generally offered for this challenge is to focus AGI on making use of non-competing spaces, particularly rooftops. While this is effective in many cases, it is also not a perfect fix, as even for the development of the simplest green roofs, reutilising space can be expensive (Gulyas & Edmondson, 2021; Hugo et al., 2021; Moos et al., 2020). Every single rooftop development faces the problem of retrofitting the building to be able to maintain rooftop AGI. This can mean retrofitting building supports to hold the weight of additional soil, rebuilding parts of the roof to maximize growing space, adding or altering runoff and waste-water systems, or replacing or shifting the location of other rooftop uses, such as moving air conditioning units to make room (Hugo et al., 2021; Snep et al., 2020). All of these processes take not only a lot of time, money, and effort, but, additionally, not every building will be able to be retrofitted for AGI; some buildings may not be able to withstand the additional load, or there may not be areas to move essential equipment (Snep et al., 2020; Specht et al., 2013).

Furthermore, while rooftop AGI has the benefit of not conflicting with other positive urban space developments, such as affordable housing or transit infrastructure, it does still conflict with existing rooftop uses (Carolan, 2017; Hugo et al., 2021). In our changing climate urban rooftops are seen as exceptional areas for photovoltaic installations to increase usage of renewable energy and reduce the urban heat island effect (Kabisch et al., 2017). While, in some cases, AGI and solar panels can work in tandem, generally these two emerging developments are in competition for rooftop property. The importance of renewable energy, and the prominence of solar in everyday discourse, is therefore a huge challenge for the further development of AGI. For example, most people can immediately imagine what rooftop solar looks like and what benefits building residents receive in the form of cheaper energy, but fewer know what AGI means or what benefits AGI can provide (Kabisch et al., 2017; Moos et al., 2020; Whittinghill & Rowe, 2011).

The lack of understanding of the benefits and challenges of developing AGI is another challenge facing AGI implementation and mainstreaming (Carolan, 2017; Kabisch et al., 2017). For developed nations such as South Korea or Japan, nature-based solutions are often seen as ineffective and inferior to technical or scientific solutions to urban climate problems (Han & Kuhlicke, 2021; Snep et al., 2020). This view that nature-based infrastructure developments are inferior is held not just by members of the public but also by many development experts, city planners, and engineers; many of these experts are also extremely influential in the push back against nature-based developments (Han & Kuhlicke, 2021). Furthermore, this challenge is complicated by the fact that even when the benefits of NBS over a more technical solution, such as reduced costs, improved biodiversity aspects, or reduced pollution, are explained, members of the public and expert community alike still favour technical solutions (Frantzeskaki et al., 2017; Han & Kuhlicke, 2021). Lastly, many of the benefits of nature-based infrastructure, especially the benefits of AGI, can be hard to fully explain or understand in the short term. For example, building a sea wall or dam is a highly visible flood mitigation measure, whereas developing green infrastructure throughout a city does not create the same immediate results that are visible to urban residents. These "hidden" aspects of NBS can therefore contribute to the general feeling that they are ineffective at solving urban problems (Han & Kuhlicke, 2021; Kabisch et al., 2017).

A similar challenge facing nature-based green infrastructure is the perception that natural farming options are inferior to more anthropogenic developments or that urban agriculture can only be viable if it is highly modified and technical (Snep et al., 2020; Specht et al., 2013). Nature-based polycultures are often seen as impossible to set up due to the lack of fertilizers, pesticides, and mechanical inputs. Therefore, these solutions are believed to be unsustainable in the long term. An example of this is the high level of focus placed upon futuristic farming systems, such as hydroponics, modular farming, and indoor vertical farming, also referred to as "Z farming," over NBS (Snep et al., 2020; Specht et al., 2013). While these "Z farm" types of urban agriculture have significant potential for expanding urban food production, they are currently hampered by high costs, low feasibility, and technological limitations (Carolan, 2017; Snep et al., 2020; Specht et al., 2013). This focus on "Z farming" only works to draw attention, resources, and support from nature-based AGI and is, therefore, a major challenge for supporters of nature-based developments.

Public support for agricultural green infrastructure has been found to be key to establishing these developments in cities. While AGI helps bring communities together and gets people involved in growing food and expanding natural spaces, AGI also needs people to work together in order to function effectively (Carolan, 2017; Frantzeskaki et al., 2017; Harrison, 2022). Therefore, if participation is lacking or if people become disinterested or leave, AGI initiatives can easily collapse. A key way this takes shape is the "aging out" of urban gardeners; many urban gardens rely on older, retired, and highly knowledgeable leaders to establish these developments, and this leads to a flourishing of the gardens under proper management and intense participation by these individuals (Frantzeskaki et al., 2017; Harrison, 2022). However, many gardens have trouble properly recruiting, training, or educating the next generation of urban gardeners, which means as senior gardeners leave, the gardens leave with them (Frantzeskaki et al., 2017; Harrison, 2022). Ensuring the next generation has the knowledge, skills, time, funding, and commitment to continue these gardens is, therefore, a key challenge in maintaining AGI in the long term (Gulyas & Edmondson, 2021). Without proper education support, training initiatives, or community building projects, AGI can easily collapse in a short time period; for example, around ⅓ of community gardens do not last for more than ten years (Frantzeskaki et al., 2017; Harrison, 2022).

Low public support and participation also have more wide-ranging effects, particularly as it relates to influencing planning, land use, and other city policy decisions (Frantzeskaki et al., 2017; Kabisch et al., 2017; Moos et al., 2020). Without popular support, activists, or committed individuals, AGI can be hampered by outdated public policy, negatory legislative frameworks, and opposition by better-funded private developers (Kabisch et al., 2017; Moos et al., 2020). AGI can also be disempowered by other residents who may have negative opinions about AGI (Kabisch et al., 2017; Moos et al., 2020). This is especially challenging for any AGI that involves animals, livestock, or bees; many developments have been found to deliberately not include livestock in order to avoid policy restrictions or public outcry (Gulyas & Edmondson, 2021; Kabisch et al., 2017). Further, AGI may be hampered by opposition from rural farmers and their supporters who see it as a threat to their livelihoods (Gulyas & Edmondson, 2021). Scholars observed that these factors ultimately create an environment where there is not only opposition to AGI development, but supporters are also disheartened or lack the energy or funding to continue the fight long term (Harrison, 2022). In short, the challenges can easily appear to overwhelm the benefits (Harrison, 2022). This can lead to a feedback loop of lower enthusiasm and support that makes it harder to maintain current AGI and even more challenging to establish additional nature-based solutions in cities.

While nature-based agricultural green infrastructure does present an opportunity for cities to mitigate and address climate change and climate events, it also faces challenges from climate change, and even just from the general climate of any particular city (Gulyas & Edmondson, 2021; Moos et al., 2020; Snep et al., 2020; Specht et al., 2013). The most obvious challenge is how northern or high-altitude cities, such as Edmonton, Canada, or La Paz, Bolivia, can sustain urban agriculture in harsh winter or cold conditions. While some cold cities have robust urban agricultural systems, they are still hampered during the winter months; even nature-based greenhouses can lose productivity due to reduced daylight hours (Gulyas & Edmondson, 2021; Moos et al., 2020). Together, the challenge of cold weather and low daylight means that urban agriculture is generally confined to summer months, leaving potentially half the year without usage. However, climatic challenges are not confined to cold cities or the wintertime. As our climate continues to warm, cities in warm climates, or even those with warm summers, also face the challenge of too much warmth and not enough precipitation; these problems are very obvious across much of the global south, with cities in South Africa already facing challenges in maintaining their urban gardens (De Zeeuw et al., 2011; Lucertini & Di Giustino, 2021; Specht et al., 2013). This problem is further exacerbated by the urban heat island effect, where large amounts of developed urban space creates more heat, absorbs more heat, and traps more heat, leading to between 2-4 degrees Celsius of additional warming within urban areas (Carolan, 2017; Hugo et al., 2021; Whittinghill & Rowe, 2011). While green infrastructure can help reduce the urban heat island effect, it can also be hampered, or even made unfeasible, by this increased warming (Hugo et al., 2021; Whittinghill & Rowe, 2011). This conundrum is especially hard to overcome as each city, and even each AGI development, may have unique circumstances that may not apply to other installations (Hugo et al., 2021; Whittinghill & Rowe, 2011). This challenge, therefore, raises further problems for AGI developers, as they may not be able to rely on lessons or ideas from other areas; this already has forced many cities to develop unique solutions that, while effective, are more time consuming and costly, and therefore a hindrance to future AGI development (Gulyas & Edmondson, 2021; Moos et al., 2020).

A final but crucial challenge that green infrastructure, and especially land-based urban farms, experience is the problem of pollution within cities. While a commonly listed benefit of AGI is the reduction of urban pollution, such as smog, GHGs, or dust, this benefit can also be a significant sticking point for the development of AGI due to health and safety concerns (Carolan, 2017; Specht et al., 2013). Many urban areas that are redeveloped for AGI have some form of prior pollution, whether it be from previous use, such as a redeveloped industrial site, or from nearby existing polluting land uses, such as major highways (Gulyas & Edmondson, 2021; Moos et al., 2020). As such, there a is significant, and valid, concern regarding the safety of these new developments; disturbing these areas may cause polluted dust to become aerosolized, risking the health of not only the construction workers but also any residents, as well as the urban gardeners themselves (Moos et al., 2020). Pollution is also notoriously difficult to fully remove, and concerns persist even after redevelopment that these natural areas may still be polluted and pose a health risk to users. This concern is further amplified for any agricultural use; if pollution is absorbed into the food being grown on these sites, it may make the food unusable due to the potential for poisonings (Carolan, 2017; Gulyas & Edmondson, 2021; Specht et al., 2013). As

AGI generally acts as a sink for urban pollutants, especially from wastewater or runoff, even if the initial site is clean, the food produced may become polluted over time, bringing with it all the same problems as an initially contaminated site (Moos et al., 2020; Specht et al., 2013). There have also been findings that runoff from AGI spaces can have increased wastes and pollutants due to fertilisation or soil erosion, and therefore act as a concentrator of pollution rather than a mitigator (Specht et al., 2013). All these problems make any approval of a new AGI development not only extremely costly but also contentious if any negative health impact is reported due to usage of these sites. Finally, pollution or contamination may make many urban areas unsuitable for AGI development, as plants and animals may not be able to successfully colonize or grow in these areas if they are too polluted (Moos et al., 2020). With urban space already being a general limitation to AGI development, the removal of any polluted areas further reduces the amount of land available for cities to redevelop into AGI, compounding the problems of urban land costs and the competition between AGI and other land uses (Moos et al., 2013).

3.0 Case Studies

Urban agriculture has long been a major part of many cities, dating back to urban gardens in Roman times, community farming in medieval towns, and even the “victory gardens" of World War Two London (Carolan, 2017; Moos et al., 2020). However, modern case-study literature on the benefits of nature-based agricultural green infrastructure, as described above, has been somewhat limited, especially in the global north and other developed countries. It has only been a recent area of study to investigate the benefits of AGI outside of the purely agricultural aspects. The scholarly literature that does exist on AGI implementation and benefits in cities does, however, offer insights into the role these developments can play in solving our cities' modern challenges.

3.1 Chicago, USA

A prime example of AGI, in the form of community gardening, comes from Chicago, USA. Similar to other cities in the American midwest, Chicago has an expansive imprint on the environment while simultaneously hosting a large number of underutilized urban spaces, including 32000 vacant lots (Harrison, 2022). While vacant lots are usually seen as wastes or eyesores, they offer an impressive opportunity for residents to develop AGI in their neighborhoods and build new skills, food security, and a sense of belonging between all community members (Harrison, 2022). Harambee Garden is just one example of a community banding together to develop urban agriculture. They have used the resources and capacity within their community to turn what had been an empty pit into a new, vibrant community centre (Harrison, 2022). The development of Harambee Garden required utilizing agricultural knowledge from senior residents, help and supplies from nearby libraries and fire stations, volunteers and workers from the area's schools, and funding in the form of garden plots rented to nearby wealthy residents (Harrison, 2022). Additionally, the establishment of Harambee also inspired other nearby communities to develop their own urban agricultural systems, which range from similar garden plots to a fully developed urban goat farm (Harrison, 2022). These urban agricultural developments have helped provide new knowledge to the area, increase food security, develop new community relationships and bonds between and within generations, and provide natural green space in an area historically known for being a concrete urban jungle (Harrison, 2022). Lastly, Harambee Garden has been a spawn point for uniting the community with other groups around the city of Chicago and has also been used as a model to set up an array of new gardens throughout the city (Harrison, 2022). These new farms and groups have begun networking together, expanding their knowledge through sharing experiences and tips, while also building up the public pressure and support for further development of urban gardens. By uniting and networking with other gardens, all communities involved have been able to better advertise their spaces, products, and offerings and have noticed a significant increase in participation from both their communities and surrounding areas (Harrison, 2022).

3.2 Warsaw, Poland

Warsaw, Poland, offers an example of how green infrastructure is being implemented in northern cities. After decades of degradation during and after the Cold War period, Warsaw has recently moved towards re-naturalising large parts of the city (Kabisch et al., 2017). It has become a hub for nature-based green infrastructure development, as many areas can easily be transformed from degraded land into natural areas. Scholars have found this surge in the development of AGI, with a particular boom in the installation of green roofs, is almost entirely due to pressure from leading scientists and NGOs who have implemented a range of policies that have proven to be extremely effective (Kabisch et al., 2017). However, outside of this niche group of scientists, almost no discussion occurs about green infrastructure or the benefits it provides; there is also limited discussion about how to properly maintain and grow these systems. This case study, therefore, depicts a paradox; green infrastructure has been successfully developed, but almost no one knows about it, and therefore it may be vulnerable to future redevelopment schemes that see nature as inherently opposed to human construction and urban design (Kabisch et al., 2017). This belief has also halted promotional efforts as organizers do not wish to call attention to such developments for fear of backlash. Overall, Warsaw depicts a potential trap for green infrastructure development: without public knowledge and support, green infrastructure may not be able to be constructed, but if there is widespread attention without sufficient knowledge sharing, there may be an even worse backlash against green infrastructure. This shows the importance of proper knowledge, education, and development transparency in implementing green infrastructure in urban areas.

3.3 Stockholm, Sweden

Recent developments in Stockholm, Sweden, also provide relevant information for nature-based AGI developments. Stockholm has been experiencing rapid growth, and despite a public desire for the maintenance and expansion of natural areas, economic and private development forces have put Stockholm's green areas at risk of being destroyed to address other priorities, such as affordable housing (Frantzeskaki et al., 2017). However, this increasing densification, reduction of natural space, and urban sprawl are also contributing to higher infrastructure costs and are negatively impacting the sustainability of the city (Frantzeskaki et al., 2017). To prevent this, nature-based solutions are now being placed front and centre in most new developments (Frantzeskaki et al., 2017). One solution to Stockholm's current challenges was to unify the existing agricultural green infrastructure that existed throughout the city under one banner so as to organize efforts and provide a platform for knowledge sharing and resource collaboration. This unifying organization had more resources, outreach, and support, which allowed for an increased voice in city development policies (Frantzeskaki et al., 2017). It also amplified the voices of nature-based solutions advocates and greatly expanded the public's awareness of the existence of the various farms, gardens, and other projects (Frantzeskaki et al., 2017). After years of hard work, the "green wedges collaboration" now has an impressively strong voice in urban development decisions throughout Stockholm, and urban agriculture projects have increased since the collaboration's founding (Frantzeskaki et al., 2017).

3.4 Dresden, Germany

Dresden, Germany, also provides an example of how collaboration between scientists, economic backers, gardeners, farmers, and developers is key in establishing AGI. In 2012 the leaders of several dozen existing green infrastructure projects united underneath the Urban Gardening Network, a collaborative organization designed to protect existing infrastructure and expand new projects across the city (Frantzeskaki et al., 2017). The network offers a wide range of support for AGI projects, including knowledge support, connections to developers and planners, tool-and-seed share programs, educational camps, public awareness seminars, and more (Frantzeskaki et al., 2017). Since establishing this network, nature-based green infrastructure has surged in Dresden, with particular success in establishing community gardens due to a program called "Seitentriebe," which is a mandatory educational program that requires participants to share their knowledge (Frantzeskaki et al., 2017). This knowledge sharing brings more attention to community gardening by bringing in new voices and perspectives. The Urban Gardening Network is also putting a specific focus on nature-based developments and has successfully fought the destruction of green spaces and the clearing of natural lands within and around Dresden (Frantzeskaki et al., 2017). With an already powerful and widespread network, the citizens of Dresden were able to prevent the private development of a large forest and meadow area, and are now investigating how to reintroduce natural farming methods and other sustainable uses to the area (Frantzeskaki et al., 2017). This area is currently slated to become a common green space and is being promoted as a NBS for wastewater management (Frantzeskaki et al., 2017). Further, the common green space will provide community gardening spaces, playgrounds, bee-friendly areas, multi-use parks and fields, and other urban green initiatives

(Frantzeskaki et al., 2017). The Dresden Urban Garden Network shows the great importance of collaboration when trying to establish and maintain AGI in urban areas. Research from Dresden suggests that it is likely that without this unified network of dedicated individuals, many AGI projects would not exist, and large green and natural areas would have been destroyed to make way for further urbanization. The network is also an example of how quickly AGI can be established with the proper support; within five years the network has already greatly expanded the number of projects within Dresden and has saved large areas of natural green space. Lastly, this case study is a prime example of how adequately funded and supported AGI networks can become unstoppable, as evidenced by the exponential growth of volunteers, workers, supporters, and new developments throughout the city (Frantzeskaki et al., 2017).

3.5 Venice, Italy

Finally, while not an example of successful implementation, advanced analyses of current land uses, climate patterns, social policies, and public support have been conducted in several major cities to determine if nature-based AGI is a viable solution to modern urban climate problems. This type of case study analysis was undertaken for the mainland portion of the city of Venice, Italy, also known as Mestre (Lucertini & Di Giustino, 2021). As Venice is a canal/lagoon city, it has limited room for any type of development whatsoever, making any implementation of AGI even more challenging than the average city (Lucertini & Di Giustino, 2021). However, the case study by Lucertini and Di Giustino (2021) analyzed the rooftops, empty lots, and other similar spaces within the city, to find which sites were feasible to be developed and compared these values to the average predicted crop output of AGI in similar climates. Their study found that, even with significant restrictions and adjustments to how many of these areas would be developed, supported, and funded, AGI had the ability to feed hundreds of thousands of Venetians, reduce the average temperature by over 2 degrees Celsius, mitigate the impact of high precipitation and storm events, and reduce building energy usage; altogether, implementing this level of AGI would also reduce or offset Venice's CO_2 emissions by over 750,000 kilograms per year (Lucertini & Di Giustino, 2021). While this study is based on modeling, assumptions, and simulated desktop analyses, it still shows the impressive potential AGI has for solving urban climate problems while simultaneously producing our cities' food supplies in areas that may have difficulty sustaining themselves (Lucertini & Di Giustino, 2021).

4.0 The Alberta Context

Current research and case study examples on NBS, and specifically on nature-based AGI, are limited in Alberta. Emerging work has suggested that "the largest opportunities for Alberta lie in climate-smart and economically efficient agricultural practices, followed by conserving and restoring grasslands, forests, and wetlands" (Rissling Wynn, 2022).

Examining the current state of policies, strategies, and tools in Alberta is imperative to understand the regulatory and governance context, as well as to identify any key actors and institutions that play a role in Albertan AGI. In Alberta, no strategies, policies, or bylaws currently exist that are solely focused on nature-based solutions. However, there are strategies that link AGI, biodiversity, and NBS principles, specifically for maintaining or restoring natural ecosystems.

4.1 Present State of AGI Governance in Alberta

AGI in Alberta is situated in a complex, multi-actor, and multi-institution framework, as federal, provincial, and municipal governments, citizen groups, and non-profit organizations all interact and influence policy (Mansfield & Mendes, 2012; Piso et al., 2019). Though all strategies that address food systems are essential, the ability for municipalities to govern access to food is imperative if local communities wish to address the challenges of urbanization and climate change (Mansfield & Mendes, 2012).

Alberta municipalities have begun to develop strategies that focus on developing AGI in multiple forms, including community gardens, greenhouses, and rooftop gardens. Municipalities also have begun to discuss urban agriculture in their Municipal Development Plans and bylaws. Further, groups of municipalities are also forming to work together on these projects. Municipalities that are a part of the Edmonton Metropolitan Region, for example, have been encouraged to develop urban agriculture plans under the guidelines from the Regional Agricultural Master Plan (Edmonton Metropolitan Region Board, 2021). Thus, more urban agriculture plans, that are region and context-specific, are expected to be developed and integrated into policy (Edmonton Metropolitan Region Board, 2021). Table 2 outlines the relevant municipal strategies, initiatives, and policies that are focused on urban agriculture and are currently being implemented throughout the province. It should be noted that this is not an exhaustive list, but rather an impressive sample of the various plan's municipalities are developing to support AGI in Alberta.

MUNICIPALITY	STRATEGY NAME	HIGHLIGHTS
AIRDRIE	Urban Agriculture Backyard Hens Bylaw	• Integrates, and sets out to define, urban agriculture as a concept for inclusion in the municipal Land Use Bylaw. • Sets out the guidelines for backyard hens, as an urban agriculture practice.
CALGARY	*CALGARY EATS! A Food System Assessment and Action Plan for Calgary*	• A key aspect of the plan is the implementation of urban agriculture, including community gardens, vertical gardens, rooftop gardens, household food production, and small-scale urban agriculture. • Goals include "improving soil health, air quality, reducing energy costs and greenhouse gas emissions by reducing the distance food travels and supporting biodiversity by providing habitat for insects and birds" (City of Calgary, 2021).
CITY OF BEAUMONT	*Environmental Master Plan*	• Aims to guide environmental stewardship and sustainability efforts, ranging from air and water quality to ecology and community design, in the municipality. • One key goal is to implement an urban agriculture pilot program in the community in order to "explore community interest, identify policy gaps, and understand the level of effort necessary to implement broader urban agriculture initiatives in Beaumont" (City of Beaumont, 2021).
CITY OF CAMROSE	*City of Camrose Municipal Sustainability Plan 2010*	• Sets out a goal to provide urban agriculture opportunities across the City through mixed-used zoning in the medium-term. • Sets out urban agriculture as a way to facilitate ecological sustainability, which they see including accessible green spaces, biodiversity protection, and availability of mixed use buildings, for the City of Camrose.
CITY OF COLD LAKE	*Urban Hen Keeping Bylaw*	• Urban hen keeping is allowed under Bylaw *704-AD-21*. • Bylaw sets out guidelines to regulate urban hen keeping at the property level.
EDMONTON	*fresh: Edmonton's Food & Urban Agriculture Strategy*	• Sets out a pathway for developing a sustainable food system. • The strategy sets out the ability of urban agriculture to create healthier ecosystems and support urban ecosystem services. • This strategy centres urban agriculture "as an opportunity to increase the sustainability and quality-of-life of their communities and as a critical lever for achieving many other civic goals and objectives" (City of Edmonton, 2012).
	Breathe Green Network Strategy	• "The Edmonton Green Network Strategy is a holistic approach to fostering a multi-functional, integrated network of open spaces within the city" (City of Edmonton, 2016). • Outlines benefits of open spaces, some relevant to this research include: Biodiversity, food production, and climate regulation.
FLAGSTAFF COUNTY	*Flagstaff Urban Farm Land Initiative*	• Initiative aims to establish urban agriculture on city-owned land. • Goals of the initiative include: increasing access to healthy food, improving environmental conditions of abandoned lands, providing improved employment opportunities, and rejuvenating area aesthetics.

LACOMBE	*Urban Hen Bylaw*	• This bylaw sets out to regulate and control the keeping of urban chickens in Lacombe.
RED DEER COUNTY	*Environmental Master Plan*	• Plan intends to empower stewardship and conservation actions. • Sets out intention to create an urban agriculture plan. • The document highlights citizens' interest in urban agriculture and notes that it reduces food miles, contributes to local economic systems, and builds community networks and resilience.
REGIONAL MUNICIPALITY OF WOOD BUFFALO	*Backyard Hen Bylaw*	• This bylaw sets out to regulate and control the keeping of backyard hens within the Regional Municipality of Wood Buffalo.
ST. ALBERT	*Urban Beekeeping Bylaw*	• This bylaw sets out to regulate and control the keeping of urban bees for personal use in St. Albert.
	Hen Bylaw	• This bylaw sets out to enable hen keeping as urban agriculture in St.Albert.
	Community Gardening on Environmental Reserve	• Aims to enable the St. Albert Community Garden Association to use specific municipal Environmental Reserve Lands to be used for the purposes of Community Gardening.
TOWN OF BLACKFALDS	*Environmental Stewardship Strategy*	• Sets out targets to increase land available for community gardens and urban agriculture in the area. • Sets out a goal to develop a Municipal Urban Agricultural Action Plan that identifies more opportunities including farmers markets, community edible fruit trees, and community gardens.
TOWN OF CALMAR	*Urban Agriculture Policy*	• Defines urban agriculture and articulates the goal of UA policy to create resilience in the built, natural, and social environments. • Policy sets out plans to foster community gardens, rooftop agriculture, urban farming education, the creation of a land database for urban agriculture, and integration of urban agriculture into land use planning.
TOWN OF COALHURST	*Urban Hen Bylaw*	• This bylaw sets out to regulate and control the keeping of backyard hens within the Town of Coalhurst.
TOWN OF DEVON	*Urban Hen Bylaw*	• This bylaw sets out to regulate and control the keeping of backyard hens within the Town of Devon.
TOWN OF HINTON	*Town of Hinton Community Sustainability Plan*	• Sets out a goal to develop community gardens and encourage the production of food locally.
TOWN OF INNISFAIL	*Urban Hen Bylaw*	• This bylaw sets out to regulate and control the keeping of backyard hens within the Town of Innisfail.
TOWN OF NANTON	*Urban Bees Bylaw*	• This bylaw sets out to regulate and control the keeping of urban bees for personal use in the Town of Nanton.
	Urban Chickens Bylaw	• This bylaw sets out to regulate and control the keeping of urban chickens for personal use in the Town of Nanton.
TOWN OF RIMBEY	*Urban Hens Bylaw*	• This bylaw sets out to regulate and control the keeping of backyard hens within the Town of Rimbey.

Table 2. Summary of select AGI Plans and Legislation in Alberta.

5.0 Future Applicability and Recommendations

Examining current and emerging policies and strategies, we see that urban agriculture is an area of interest in municipalities across Alberta. Municipalities, both large and small, are beginning to implement diverse urban agriculture strategies facilitating new AGI projects. The most commonly cited AGI solutions include community gardens, urban chickens and bees, and rooftop gardens. These new strategies are all very recent, with all identified strategies and bylaws being implemented within the last ten years. Given that those who are a part of the Edmonton Metropolitan Region have been directed to develop an urban agriculture plan, more of these types of strategies are expected to be developed, and this may also point to a greater level of cooperation between municipalities in developing AGI (Edmonton Metropolitan Region Board, 2021). Thus, we see the development of these plans as a key opportunity to expand the use of AGI and implement context-specific AGI solutions at multiple scales in the Alberta context.

Moving forward, implementing AGI requires that Alberta municipalities create policies that aim to foster biodiversity, integrate agroecology, build new working relationships and support networks, and take into consideration our specific geographic context. Strategic and innovative municipal policy can foster more resilient and biologically diverse landscapes in Alberta, and our research has shown that AGI can be a central aspect of these diverse landscapes. Currently, alongside integrating AGI into urban agricultural plans, we identify biodiversity policies as a space to govern and mainstream AGI. Biodiversity policies, strategies, and tools are imperative because "each [nature based] solution must either maintain or enhance biodiversity, without which an action cannot be classified as NBS;" given the current municipal powers under the Municipal Government Act, we see a space for biodiversity-enhancing AGI to be mainstreamed (Jefferies et al., 2019; UNEP, 2021). Previous work done by the Alberta Land Institute, focusing on biodiversity conservation in municipalities, argued that municipalities have a key role to play in protecting and enhancing local biodiversity; as such, Alberta municipalities have begun to integrate biodiversity considerations into their governance frameworks (Jefferies et al., 2019). Alberta municipalities have a clear mandate under the Municipal Government Act to foster the well-being of the environment and the legal authority to implement a wide variety of biodiversity measures using a variety of mechanisms, including statutory plans, land use bylaws, conservation easements, and environmental reserves (Jefferies et al., 2019). One particular area discussed in the report is green roofs:

> While municipalities in Alberta may have already possessed the authority to establish green roof programs and perhaps even bylaws, the new municipal purpose of fostering the wellbeing of the environment and the *City Charter Regulations'* powers allowing for

biodiversity conservation programs only solidifies this authority as valid municipal jurisdiction (Jefferies et al., 2019).

Thus, it appears that Alberta municipalities are well positioned, given their current powers, to implement AGI solutions that foster the wellbeing of their people, their communities, and their environments (Jefferies et al., 2019).

Future applicability is not only determined by the policy environment but also by external factors, including extreme weather and climate change. Given that Alberta's climate is warming faster than the global average, it is expected that extreme weather events and natural hazards may impact the feasibility of implementing AGI (Alberta Climate Records, n.d.). Scholars suggest through the mainstreaming of NBS, we can "equip communities to harness natural infrastructure and reduce the costs of extreme weather" (Task Force for a Resilient Recovery, 2020). As noted in the challenges section of this report, nature-based AGI is not a silver bullet solution, and the future development of AGI in Alberta faces plenty of challenges. Despite these barriers, it is important to recognize AGI can not only reduce the impacts of climate change but foster social connections, as seen in the Harambee Garden in Chicago, and limit the effects of food supply crises, creating resilience to future events in urban environments (De Zeeuw et al., 2011; Gulyas & Edmondson, 2021; Harrison, 2022; Lucertini & Di Giustino, 2021; UNEP, 2021). As climate change will continue to cause worse impacts to Alberta, any NBS that helps to mitigate, or adapt to, said impacts are applicable.

5.1 Recommendations

Based upon our literature analysis, international case studies, and the current governance context, we propose a series of recommendations that Albertan municipalities can take today. These recommendations are intended to facilitate the introduction and mainstreaming of nature-based AGI into Albertan municipal development schemata, with the understanding that these recommendations may vary in effectiveness based on the specific circumstances of each municipality.

First, there is great importance in promoting collaboration when trying to establish and maintain AGI in urban areas. AGI is situated within a unique environment as it operates at the intersection of biodiversity, agriculture, and planning; thus, proper integration and mainstreaming require constant collaboration, and the rejection of siloed work, in favour of an integrated approach to establishing AGI. As aforementioned, implementation of NBS should be a collaborative approach, with all relevant stakeholders, community groups, Indigenous communities, and government departments included to plan, co-create, and implement nature-based AGI solutions (IUCN, 2020; Mikulec et al., 2013; Voskamp et al., 2021; UNEP, 2021). As was shown by multiple case studies, including Dresden's Urban Garden Network, collaboration is imperative for establishing and maintaining AGI in urban spaces (Frantzeskaki et al., 2017). Thus, continued work should be done to facilitate "active, inclusive and transparent participation" and develop tools, such as handbooks, methods, catalogues, and platforms, that facilitate public participation and reduce departmental siloing (IUCN, 2020; Voskamp et al., 2021). This work may require that municipalities, who alone may not be fully equipped to undertake the co-creation of AGI solutions, bring in external "social innovators and other social actors to partner with and to facilitate co-creation processes together" (Frantzeskaki, 2019). This recommendation is imperative to overcoming institutional barriers related to developing and implementing effective NBS (Pérez-Cirera et al., 2021).

Second, we recommend focusing on the ecosystem and nature-based benefits of urban agriculture in Alberta's AGI plans. Currently, when urban agriculture is identified as an area for future development in strategies and policies, the discussed benefits are primarily limited to food provisioning and community building (van der Jagt et al., 2017). As more municipalities begin to develop new plans, we recommend the integration of biodiversity, environmental, and overall climate benefits as important points of discussion. Moving forward, municipalities in Alberta should also focus on the ability of AGI to lower climate disaster impacts, such as storm flood risks, absorb smog and other harmful pollutants, mitigate the urban heat island effect, reduce the impacts of high winds and urban wind tunnels, and offset or reverse biodiversity losses caused by urban expansion. As scholars have suggested, highlighting these benefits to a higher degree can bring about greater levels of public support and engagement and, therefore, facilitate an increased number of AGI projects (van der Jagt et al., 2017). Given that public support can be hampered by many factors, including outdated policy, development interest, and public perception, it is imperative to further emphasize all benefits provided by these solutions when planning and integrating AGI in our communities (Kabisch et al., 2017; Moos et al., 2020, Pérez-Cirera et al., 2021).

Third, knowledge sharing should be facilitated both within and between municipalities and communities. As was laid out in multiple case studies, including Chicago's Harambee Garden and Stockholm's "green wedges collaboration," sharing knowledge among different stakeholders within and outside the municipality can empower stronger AGI implementation (Frantzeskaki et al., 2017). Dresden's Urban Garden Network has been extremely effective at facilitating and encouraging participation in urban gardening and has led to the expansion of AGI projects within Dresden (Frantzeskaki et al., 2017). In Chicago, various independent AGI projects have begun sharing their experiences and mobilizing this knowledge to build public support for more urban agriculture (Harrison, 2022). These case studies enforce scholars' notion that knowledge transfer has been found to push NBS forward and enable the development of new projects (Frantzeskaki, 2019). Further, knowledge sharing is beneficial for overcoming both institutional challenges and knowledge gaps that arise when developing context-specific NBS and AGI solutions (Pérez-Cirera et al., 2021; Voskamp et al., 2021). By increasing knowledge sharing, Alberta municipalities can utilize each other's best practices and lessons to resolve challenges as they arise. We, therefore, recommend developing networks, platforms, and tools that facilitate knowledge sharing between stakeholders and encourage municipalities and communities to form networking groups with the express goal of using their collective knowledge to solve AGI challenges.

Fourth, we recommend utilizing existing, or developing new, tools that support the implementation and mainstreaming of nature-based AGI. Both human and financial resources are needed to develop these solutions, but as case studies have noted they are essential to maintaining AGI in the long-term and ensure benefits can be fully realized (Dupras et al., 2015; Frantzeskaki et al., 2017; Frantzeskaki, 2019; Harrison, 2022; van der Jagt et al., 2017; Voskamp et al., 2021). Challenges still exist as there are no site-specific examples of how to implement nature-based AGI in most areas of Alberta (Cohen-Shacham et al., 2016; Voskamp et al., 2021). Thus, the development of customizable AGI solutions could "provide cities with more knowledge on measures in general, and specific knowledge on NBS for particular challenges" (Voskamp et al., 2021). Context-specific capacity building is important both at the municipal and individual project level, and we suggest implementing or supporting the implementation of training initiatives, catalogues, and educational supports to further the process of mainstreaming NBS. For example, in Dresden, the Urban Garden Network's mandatory educational program has resulted in not only more public acceptance of AGI but increased uptake of AGI across the city; we, therefore, recommend similar programs be developed or integrated into the Albertan municipal context (Frantzeskaki et al., 2017). This work can be done by independent organizations, municipalities, community groups, or even individuals. However, if tools are developed at the municipal level, scholars emphasize that it is important that government actors communicate "directly in easy-to-understand language" (van der Jagt et al., 2017). Lastly, the development of these tools should also take into consideration stakeholders at all levels, regardless of who is the primary AGI developer, to ensure proper public engagement. Comprehensive stakeholder participation can also help to fill knowledge gaps and guarantee that all stakeholders feel included, useful, and understood in this complex but necessary process.

6.0 Conclusion

Given that the effects of climate change are becoming increasingly observable in the natural and built environments in Alberta, implementing solutions to create more sustainable and resilient municipalities is imperative. AGI, when implemented as a nature-based solution, presents an opportunity to create resilience in the social-ecological system at the municipal level by providing adaptation opportunities against the impacts of climate change, building community structures, mitigating municipalities' contributions to climate change, and increasing food security. We see an interest in AGI and a role for it to be implemented under municipal jurisdiction in Alberta, though our findings from case studies, policy, and scholarly literature emphasize the importance of focusing on collaboration, knowledge sharing, and tool development in the process of planning and mainstreaming AGI. Given that the food system is the "single strongest lever to optimize human health and environmental sustainability," ongoing and emerging work focused on AGI in Alberta is important to develop further (Willett et al., 2019). As climate change continues to pose an immense threat to all our systems, nature-based AGI is an asset for Alberta municipalities who are working to not only mitigate climate change but also adapt to climate impacts.

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