Prairie Climate Centre

Building a Climate-Resilient City:
Urban ecosystems

KEY MESSAGES:

- Ecosystems and green infrastructure provide human health benefits and critical environmental, social and economic services, and protect against climate shock.
- Healthy and well-managed ecosystems are economic assets that enhance a city's resilience to natural disturbances and extreme weather events.
- Investing in urban ecosystems and green infrastructure can provide lower-cost solutions to multiple challenges when compared to traditional infrastructure solutions.

Alberta's climate has changed and will continue to change in the coming decades. The province's mean annual temperature is expected to rise 2°C by the 2030s and 4°C by the 2060s (compared to the 1990s) should the current rate of global greenhouse gas emissions remain unchanged. This level of warming is greater than the projected increase for the globe as a whole. Precipitation levels and patterns will likewise change; total average annual precipitation is projected to increase, but with precipitation levels likely increasing in the winter and declining in the summer. Alberta's climate is also expected to become more variable, leading to greater risk of extreme weather such as flash floods, severe rain and hail storms, heat waves, lightning and tornados and long term stresses such as droughts, changes in seasonality and increase of pest, diseases & invasive species. These projected changes have significant implications for Alberta's economy, society and environment. Should global greenhouse gas emission rates decline, the change in Alberta's climate will be less severe but still significant.

These changes have a myriad of implications for Edmonton and Calgary and pose multiple threats to their urban natural spaces and the various ecosystems within them. The scale and sensitivity of these ecosystems will vary; some will be able to shift and expand their ranges and others will struggle to adapt. As damage in these ecosystems and their functions accumulates, their ability to supply ecosystem goods and services—the benefits humans derive from ecosystems—may be diminished. For example, urban ecosystems are particularly vulnerable to the arrival of a growing number of invasive species as changing climatic conditions make it possible for them to thrive in Alberta, including non-native plants and animals that have no natural predators. It is important to note that the magnitude, timing and location of these losses is difficult to predict, considering that the pace and nature of climate change itself is uncertain.

In response, there is a need to build the resilience of urban ecosystems and the cities that surround them so that they are better able to withstand anticipated and unanticipated shocks and stresses. A resilient city is one in which its institutions, communities, businesses and individuals have the capacity to function and are able to "survive, adapt and grow" in response to any kind of sudden short or long disruption that they may experience. Such cities integrate the qualities of flexibility, redundancy, robustness, resourcefulness, reflectiveness, inclusiveness and integration into all aspects of city functions (see Box 1). These qualities of resilience are considered to be essential to preventing the breakdown or failure of a system and enabling it to take action in a timely manner.[1]

With this in mind, the paper focuses on enhancing and using urban ecosystems to reduce exposure to natural hazards and enhance adaptive capacity in a changing climate, underpinning the qualities of a resilient city. It further explores the vast additional benefits that are gained

BOX 1. QUALITIES OF A RESILIENT CITY[2]

Reflective: People and institutions reflect and learn from past experiences and leverage this learning to inform future decision making.

Robustness: Urban physical assets are designed, constructed and maintained in anticipation of high-impact climate events.

Redundancy: Spare capacity is built into the system to account for disruptions and surges in demand. It also involves multiple ways of fulfilling a need or function.

Flexible: Refers to the willingness and ability to adopt alternative strategies in response to changing circumstances or sudden crises. This can be achieved through new knowledge and technologies.

Resourcefulness: Citizens and institutions are aware of climate risks, able to adapt to shocks and stresses and can quickly respond to a changing environment.

Inclusive: Inclusive processes emphasize the need for broad consultation and many views to create a sense of shared ownership or a joint vision to build city resilience.

Integrated: Integrated processes bring together and align city systems to promote consistency in decision making and investments. Exchange of information between components of the system enables them to function collectively and respond rapidly.

from using the multiple functions performed by urban ecosystems. It is one of a series of papers prepared by the Prairie Climate Centre to provide the public and government officials with an overview of the means by which to build cities that are resilient to the impacts of climate change, drawing on lived experience and best practices.

Understanding Resilient Urban Ecosystems

Ecosystems and their services are critical to human health and well-being and provide society with products that support biodiversity and economic development (e.g., food, clean water, flood mitigation and disease control). These products and services are often referred to as ecosystem goods and services.[3] A diverse array of urban ecosystems and habitats can provide ecosystem goods and services, including: green spaces (such as parks urban forests), cemeteries, vacant lots, gardens and yards, and campus areas; and blue spaces, including streams, lakes, ponds, artificial swales and stormwater retention ponds.[4] This list can be expanded to include green infrastructure (e.g., green roofs), which is defined as natural vegetative systems and green technologies that replicate the functions of ecosystems and provide society with a multitude of benefits.[5] Healthy and functional urban ecosystems are essential to building the resilience of cities as, through their ecosystems goods and services, they provide multiple environmental, social and economic benefits:

- **Environmental benefits.** Natural spaces such as urban parks, green walls, green roofs and street trees provide a number environmental benefits: they offset the urban heat island effect, improve air quality and reduce air temperatures through shade, thereby reducing energy use for cooling. Ecosystem services within and around cities can provide insurance by helping to buffer against many disturbances, such as flooding and storms.[6] For example, urban wetland ecosystems can act as filtration systems, treating stormwater to reduce pollution while simultaneously offering amenity value. Natural spaces and green infrastructure can reduce soil erosion and protect river banks[7] as well as help manage water quality and quantity by reducing total runoff, including untreated runoff, before it enters water

bodies. Moreover, ecosystems play a vital role in cycling and storing carbon for climate regulation. Soils store carbon while vegetation, particularly trees and forests, store carbon in biomass.

- **Social benefits**. Urban natural spaces provide mental and physical health benefits. Access to green space has been linked to reduced mortality and improved, perceived and actual general and mental health benefits.[8] In urban areas, vegetation helps to significantly reduce air and noise pollution, positively affecting health. In addition, natural spaces provide an excellent opportunity for education and citizen's involvement in their communities, which in turn can promote development of a stewardship culture and create opportunities for residents to be meaningfully engaged in planning processes.
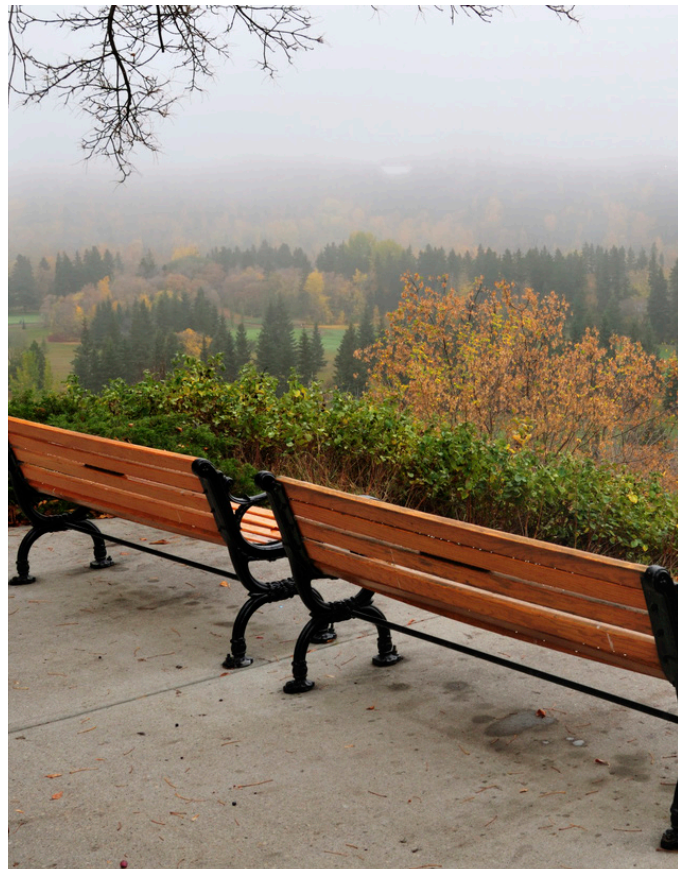
- **Economic benefits**. Urban ecosystems and green infrastructure, which can be combined with engineered infrastructure or other technological approaches, are often more cost-effective than grey infrastructure alone. To illustrate, Elmqvist et al. (2015) analyzed 25 studies done in urban regions that estimated the monetary value of benefits of ecosystem services based on quantification in biophysical units (e.g., carbon storage, stormwater reduction, pollution removal).[9] The data from the studied cities estimated that the ecosystems analyzed provided between USD 3,212 and USD 17,772 in benefits per hectare of urban green areas per year.[10] These calculations provide a useful economic rationale for investments in environmental protection and improvements. Green infrastructure can also simultaneously provide both climate change mitigating and adaptation benefits, which are particularly beneficial in the context of cities working within limited budgets.

Overall, urban ecosystems and green infrastructure provide a large roster of critical ecosystem services that can improve human health and well-being while also buffering against natural disturbances and extreme weather events. Maintaining a sustainable and vibrant supply of these services in the face of climate change and other threats is therefore essential toward fostering resilience.

However, only healthy, well-functioning ecosystems can provide these valuable services and make a positive contribution to building a city's resilience. Climate change is a threat to the future health of urban ecosystems. Therefore, not only do we need to ensure the continued existence of urban ecosystems and the services they provide to help build the resilience of cities, we also need to ensure that these ecosystems are themselves resilient in the face of climate change.

Building a resilient city therefore requires:

(1) Ensuring a resilient supply of urban natural spaces to maintain and increase their quality, quantity and diversity.

(2) Expanding and making active use of natural spaces and green infrastructure.

There are various ways in which the benefits of urban ecosystems can be maximized and contribute to building resilient cities, some of which are illustrated through interventions that enhance three of the qualities of resilient cities: robustness, redundancy and resourcefulness.

Building Robustness

Since urban ecosystems must thrive in a variable climate, it is important to integrate uncertainty and change into municipal management processes while ensuring sustainable delivery of ecosystem services. This can be translated into the practical techniques outlined below.

Assessments of the climate change vulnerability of urban ecosystems such as forests, the urban tree canopy, wetlands and other natural features in the city will be essential to understanding how ecosystem functioning might change over space and time and what factors contribute to this change.[11] The results of these assessments can be used to integrate climate adaptation into biodiversity conservation efforts by learning from monitoring outcomes and being proactive about managing urban ecosystems.[12] For example, in the case of planting trees, ensuring the continued presence of a riparian forest may mean adjusting its species and age mix so that the forest can withstand diseases or storms anticipated to become more common as the climate changes.[13]

Biodiversity is integral to healthy ecosystems. Thus, enhanced biodiversity increases the resilience of ecosystems. Protecting street trees and sites of ecological significance, such as mature forests and wetlands, and considering the connectivity of urban landscapes during city design and land-use planning are crucial to maintaining the resilience of ecosystems.[14]

With jurisdiction over parks, urban forests and conservation areas, cities are well positioned to integrate biodiversity into planning. Calgary's Biodiversity Strategy and Edmonton's municipal and environmental strategic plans contain measures to integrate biodiversity into the growth and development of these cities.

Preserving a city's natural infrastructure in good working condition will be critical to ensuring the resilient supply of ecosystem services and benefits. There are multiple ways through which cities can protect their natural spaces, such as through zoning, tradable development rights and support for land acquisition and securement. Included among these options is the use of asset management systems for urban ecosystems and natural landscapes in a similar way as for engineered infrastructure. An asset management system would recognize the services provided by urban ecosystems and the value of these services, and allow for them to be integrated into municipal operating budgets to ensure maintenance and regular support. Greenbelts, or land that is kept in reserve, are example of how zoning can be used to protect environmentally sensitive areas from urban development and sprawl. The urban population benefits from important ecosystem services such as clean air, water filtration, flood control and open spaces that offer opportunities for outdoor recreation. At the same time, the greenbelt can protect agricultural activities.[15]

Promoting Redundancy

Increasing green spaces and green infrastructure addresses multiple challenges and offers multiple benefits. They often turn out to be more economically viable, even under prevailing economic models, provided that the multiple services and associated benefits for the large number of recipients in cities are properly quantified and recognized.[16]

Increasing the uptake and incorporation of green infrastructure or low-impact development (small-

BOX 2. SUSTAINABLE URBAN INFRASTRUCTURE POLICIES AND GUIDELINES (CHICAGO)[17]

Chicago's Sustainable Urban Infrastructure Policies and Guidelines establish a city-wide approach for integrating environmental performance goals into infrastructure design. The document is specifically directed at Chicago Department of Transportation staff with the goal of integrating green infrastructure best practices and ecological services into all capital projects. The guidelines are organized into eight categories: water, energy, materials and waste, place-making, economics, commissioning, urban ecology and climate and air quality. Each category has three to six environmental objectives, which are implemented through over 60 specific requirements and 35 policies. The document is comprised of specific strategies, references and resources to help project managers, engineers and other professionals to accomplish the laid out set of sustainability goals and set of requirements. Through past pilot projects, the city's Department of Transportation has validated that the cost for green infrastructure can be lower than the cost for traditional grey infrastructure and achieve numerous economic and environmental benefits.

scale, on-site interventions) into city planning alongside existing or planned grey infrastructure can provide complementary benefits by retaining stormwater, shading surfaces such as asphalt and membranes, providing wind breaks and reducing energy demand. For example, green roofs retain rainwater and reduce runoff, create habitats, moderate the urban heat island effect, improve air quality and create new amenity spaces for community gardens or other recreational purposes.[18] In 2009, the City of Toronto passed a Green Roof Bylaw, which is complemented by the Eco-Roof Incentive Program.[19] Between 2009 and 2016, Toronto's green roof program saved the city CAD 135,462 per year in electricity, diverted 10.5 million litres of stormwater from sewers, avoided approximately 200 tonnes of greenhouse gas emissions, increased green spaces and generated new employment.[20] Bio swales and constructed wetlands present another good example of green infrastructure that has the potential of combining multiple urban functions in one measure. Apart from water retention, constructed wetlands could be used in cities for recreation, water purification, cooling and aesthetics.[21]

Mainstreaming green infrastructure elements into road planning, design and implementation represents an important tool for addressing multiple challenges and promoting various benefits. Traditional engineering practices are based on addressing economic inefficiencies and traffic congestions. Building a resilient city requires a more holistic approach to road design that addresses a broader range of problems and creates beneficial environmental outcomes. Design elements such as street trees, permeable surfaces and greening around main roads are specific opportunities that provide the additional benefits of managing surface water runoff, reducing the urban heat island effect and creating an improved environment—all elements that can contribute to a "smarter" and more sustainable city.[22]

BOX 3. PHALEN WETLAND RESTORATION PROJECT (ST. PAUL, MINNESOTA)[23]

The City of St. Paul in Minnesota replaced a crumbling shopping centre site with its original wetlands to create the Phalen Wetland Park. With the assistance of the City of St. Paul, Phalen neighbourhood residents explored a range of design alternatives for the deteriorating and financially bankrupt shopping centre. The residents embraced a plan to restore the original wetlands and redevelop the area, including a park to revitalize for the community. The shopping centre was demolished and a new urban ecosystem was constructed to mimic the original natural system.

TThis urban ecological restoration project resulted in multiple benefits for the City of St. Paul. The restored wetlands have become a cost-effective part of the area's stormwater retention system, as they serve as natural holding tanks for rainwater and prevent sewer overflow. In addition, they created an attractive natural landscape and studies have documented how the wetlands park has increased biodiversity and become a popular part of the cultural life of the community. In addition, the neighbourhood around the park has seen new investments in its immediate area in the form of new housing and commercial development in a previously low-income neighbourhood.

Urban ecological restoration and rehabilitation projects are approaches that are not only ecologically but also socially desirable. Successful examples of such restoration projects include sites of former landfills, previous industrial areas, vacant lots, and other "brown" areas. Restoring natural features and re-greening areas of the city provide an opportunity to connect ecological systems and urban spaces and contribute positively to the health and well-being of citizens.[24]

Encouraging Resourcefulness

Local governments can provide opportunities for active civic engagement through community gardens, residential gardening, greening programs, land acquisition and restoration, and advisory committee participation.[25] These initiatives can provide opportunities for educating young children and transmitting local ecological knowledge. They can also create a strong sense of place, which was found to be a major driver for environmental stewardship. For instance, residents engaged in community gardening can display strong emotional ties to their gardens and the surrounding areas.[26] Strong community programs that allow people to participate in and take ownership of the management of urban natural spaces promotes the development of a stewardship culture and has the potential to reduce centralized municipal efforts and resources.[27]

Recommendations

Protecting and enhancing urban ecosystems provide low-cost, health-alleviating and educational opportunities to address climate change and increase resiliency in urban areas. In light of these observations, consideration could be given to future actions that build on Calgary's and Edmonton's early achievements in this area:

Strategic

- Prepare and assess natural urban spaces to gain knowledge and a better understanding of the current distribution, abundance, trends and status of biodiversity and natural areas. Assessments and long-term monitoring are essential to the protection and resilience of natural spaces.

- Actively consider restoration and rehabilitation projects to assist in the recovery of natural spaces that have been degraded, damaged or destroyed, particularly along migration corridors, to encourage movement of species. Restoring degraded ecosystems has been an important tool that contributes to reducing vulnerability to natural hazards, enhancing ecological networks and improving the quality of life in many large urban centres.

- Due to the potential for significant environmental change in the future, adaptability is a key component that should be integrated into natural spaces management. This means that actions and initiatives should be taken in response to actual or projected climatic changes, thus reducing the effects of climate change on natural systems. This could include guidelines for planting and selecting vegetation that is adaptable to a changing climate.

- Consider capacity building and professional development for involved professionals, such as road authorities, to better enable them to take steps toward mainstreaming green infrastructure in city planning and investment decisions.

Regulatory/Administrative

- Consider ways to introduce or enhance assessments, approval processes, development limitations, surcharges, fees, incentives and rebates as well as by-law enforcement mechanisms within local regulatory regimes to ensure the sustainable management and protection of natural spaces.

- Integrate biodiversity and green infrastructure guidelines into city planning, streetscape design and design site plans to mimic natural habitat and functions. Integration is particularly encouraged when replacing aging infrastructure. Examples include bioswales, constructed wetlands, stormwater detention ponds, rain gardens, tree-lined streets, permeable pavement, green roofs and walls.

- Consider integrating urban ecosystem and natural infrastructure into asset management programs to help ensure ecosystems function properly and yield expected environmental services.

- Consider regulatory compliance for developers to ensure that new developments integrate natural features and capitalize on opportunities to create and enhance green infrastructure and natural landscape features.

Economic Instruments

- Explore and identify incentive or subsidy programs to encourage developers to integrate natural features (e.g., wetlands) and green infrastructure (e.g., green roofs) into new development. The benefits of such incentive programs have been demonstrated by initiatives such as Toronto's Eco-Roof Incentive Program.

Voluntary/Community Linkages

- Engage citizens in neighbourhood and city planning processes and promote learning opportunities. Connecting urban residents through public engagement with nature will build awareness and ecological literacy. Cities should advertise best management practices for naturalizing private property and consider homeowner grants to enable their implementation.

- Promote nature and biodiversity programming in schools and support programs that encourage students to learn about natural spaces and biodiversity in their cities.
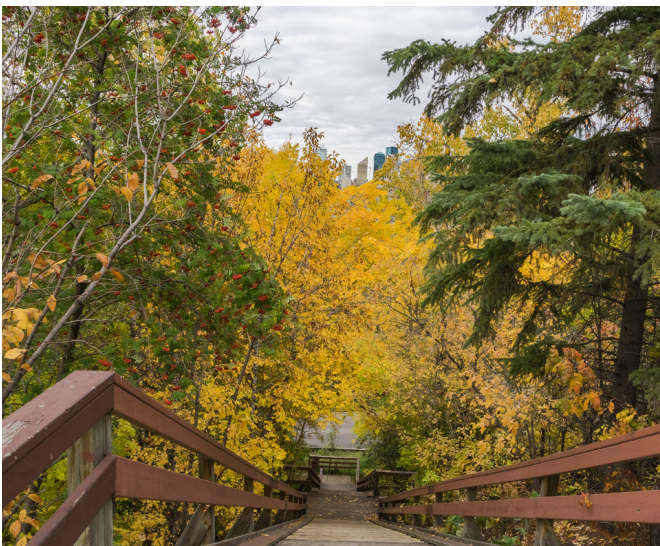
Further reading:

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The Prairie Climate Centre is a collaboration of the University of Winnipeg and the International Institute for Sustainable Development established to advance practical climate change solutions for the Canadian Prairies. The centre's mandate is to translate climate science into knowledge products, frameworks and decision-making tools that will help local governments, the private sector, civil society organizations and other practitioners implement adaptation measures.

For more information visit: http://prairieclimatecentre.ca/

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