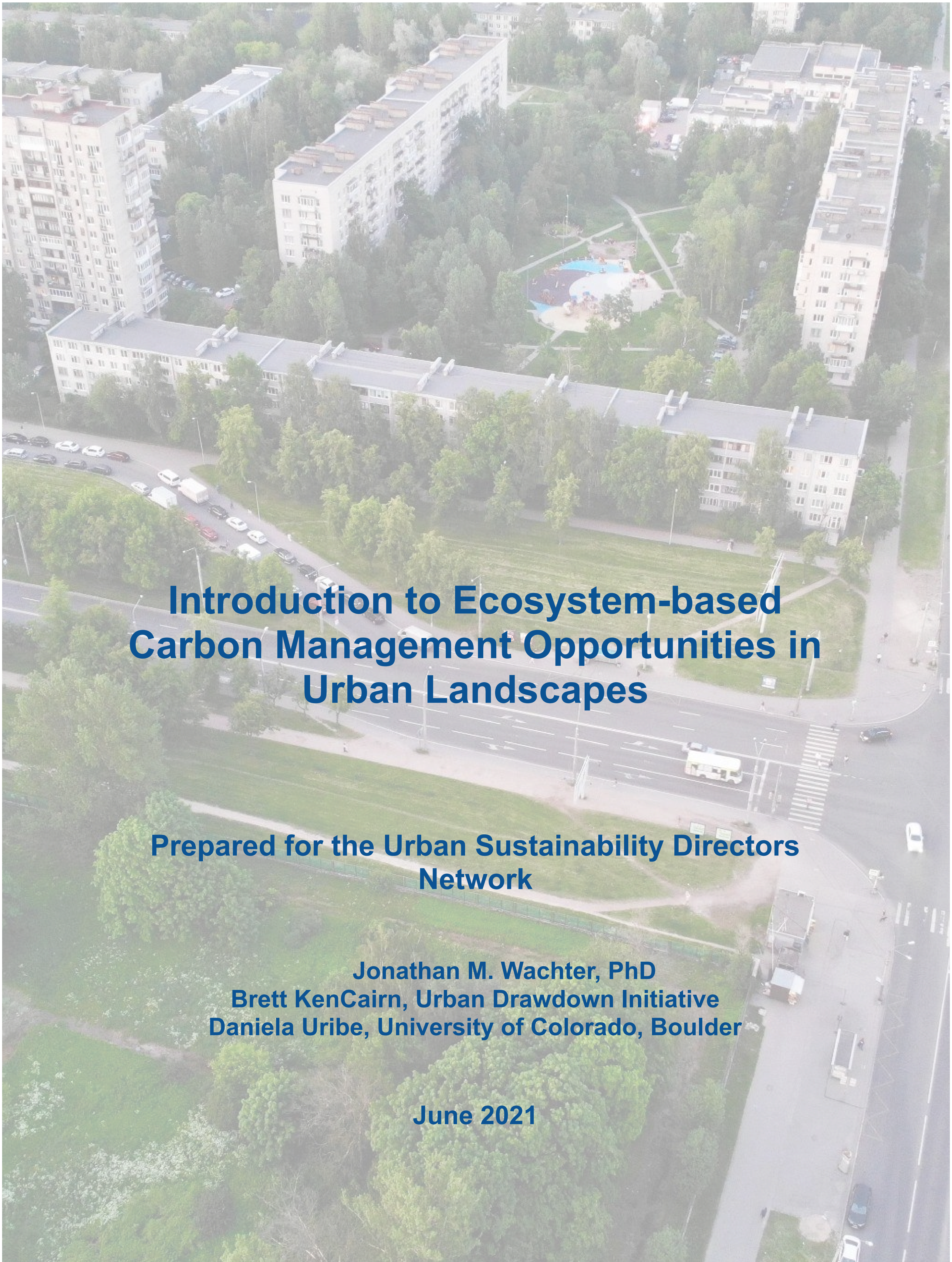

Introduction to Ecosystem-based Carbon Management Opportunities in Urban Landscapes

Prepared for the Urban Sustainability Directors Network

Jonathan M. Wachter, PhD
Brett KenCairn, Urban Drawdown Initiative
Daniela Uribe, University of Colorado, Boulder

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Introduction

Meeting climate change mitigation goals will require not only widespread reductions in annual greenhouse gas emissions but also the dramatic scaling up of carbon sequestration by ecosystems worldwide. Nature-based carbon sequestration is achieved through various processes in plants, healthy soils, and organic waste management, among others, capable of drawing down previously emitted carbon. The protection and stewardship of ecosystems for their climate benefits, such as healthy forests that sequester carbon, or the utilization of composting and biochar generation to both avoid and store carbon, often result in other benefits called ecosystem services. These services range from improving air quality to producing food.

Cities have a wealth of urban ecosystems that are currently delivering many climate and other benefits which, if managed with these outcomes in mind, could be further increased. For example, the urban trees and forests of Columbia, Missouri, Iowa City, Iowa, and Lincoln, Nebraska are sequestering thousands of metric tons of CO_2 every year in addition to the millions of tons of CO_2 they already store. These trees are simultaneously delivering pollution benefits valued at millions of dollars annually:

*Columbia's trees are estimated to be holding onto over **1.1 million metric tons of CO_2** and sequestering over **18 thousand metric tons of CO_2 per year** (i-Tree 2020). The air pollution removal by these trees is valued at **~$1.7 million per year**.*

*Iowa City's trees are estimated to be holding onto over **a quarter of a million metric tons of CO2** and sequestering over **six thousand metric tons of CO2 per year** (i-Tree 2020). The air pollution removal by these trees is valued at **~926,000 per year**. In total, Iowa City's publicly managed trees are estimated to be delivering **$4.2 million in value annually** (Iowa City 2018).*

*Lincoln's trees are estimated to be holding onto over **half a million metric tons of CO_2** and sequestering almost **15 thousand metric tons of CO_2 per year** (i-Tree 2020). The air pollution removal by these trees is valued at **~$712,000 per year.***

These cities' other urban ecosystems, from playfields to prairies, are likewise storing and sequestering significant quantities of carbon while providing a multitude of other benefits to their residents and environment. Critically, these benefits have as much to do with climate change as they do social equity and environmental justice. Trees, for example, can provide much-needed cooling during hot summer months. However, many of our cities have fewer trees in historically disadvantaged communities than in affluent neighborhoods. To address one of these challenges will necessitate addressing the others at the same time.

Assessing carbon management opportunities is a process intended to complement a city's Climate Action Plan by focusing on its urban ecosystems and the opportunities

they provide for sequestering carbon and utilizing the captured carbon to enhance critical ecosystem services they provide--enhanced shade, stormwater management, prevention of soil erosion, reduced pollution, biodiversity, food production, among many others.

Assessing these opportunities can be organized around eight major natural assets that can be found in cities: urban forests, dispersed trees, turfgrass, prairies, wetlands, urban agriculture, organic waste, and agricultural land outside of cities (Fig. 1) (Adaptive Circular Cities 2020).

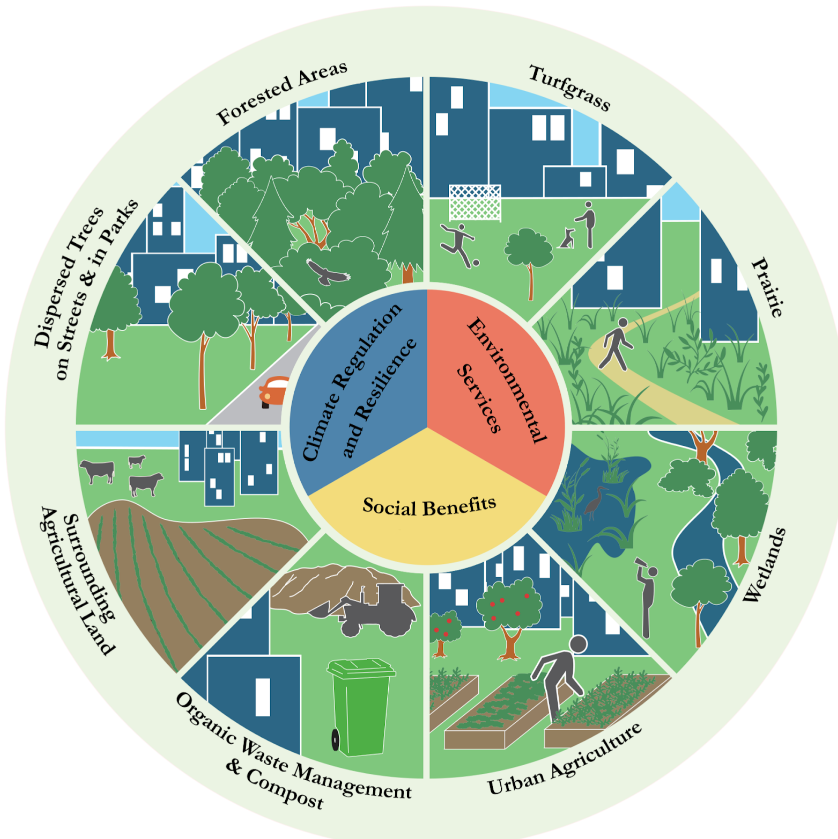

Figure 1: Illustration of eight primary natural assets that may be found in and around cities. By protecting and stewarding these natural assets, cities enable the delivery of numerous ecosystem services from climate regulation and resilience to environmental services to social benefits. Adapted from Adaptive Circular Cities 2020.

What is a carbon opportunity assessment?

Meeting climate change mitigation goals set by the Paris Climate Agreement will require not only dramatic reductions in annual greenhouse gas emissions but also the large-scale removal of greenhouse gases from the atmosphere. **There is growing recognition that ecosystems are one of our most valuable tools for massively scaling up rates of carbon sequestration across the globe** (Fargione et al. 2018; Griscom et al. 2017). Critically, the protection and stewardship of ecosystems for their climate benefits often results in a multitude of other benefits, also called **ecosystem services.** Ecosystem-based strategies are the only climate change mitigation strategies that deliver this multitude of co-benefits alongside their climate benefits.

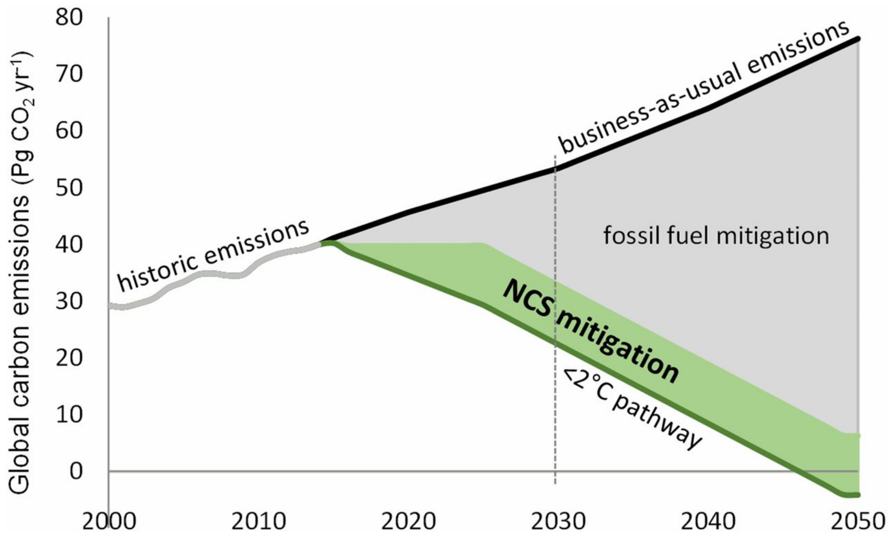

Figure 2: The role of ecosystem-based climate change mitigation strategies, or "natural climate solutions" (NCS) in achieving mitigation targets. From Griscom et al. 2017.

Cities are increasingly developing Climate Action Plans as guides for climate change mitigation and adaptation. Looking across sectors, the climate action planning process involves developing citywide greenhouse gas inventories, setting greenhouse gas reduction goals, carrying out vulnerability and adaptation assessments (UN-Habitat 2015).

Historically, Climate Actions Plans developed for cities have been **largely focused on emissions reductions with little focus on opportunities for carbon sequestration and other ecosystem services.** This has been in part due to the lack of data and protocols for quantifying the carbon sequestration potential of urban land use practices.

As more and more research focuses on the potential for urban ecosystems to sequester carbon, build climate resilience, and provide many other ecosystem services, the possibility arises of including these climate benefits in cities' greenhouse gas inventories. A book edited by Rattan Lal and Bruce Augustin entitled "Carbon Sequestration in Urban Ecosystems" reviewed the state of science at the time (Lal and Augustin 2012). David Nowak and others at the USDA Forest Service continue to study urban forests and their impacts on carbon cycling (e.g. Nowak and Greenfield 2018a). Multiple modeling teams are studying climate impacts and ecosystem services from urban ecosystems (e.g. Stanford University 2020). In 2019 ICLEI released its latest "U.S. Community Protocol for GHG Emissions Inventories" in which for the first time it lays out a protocol for including urban trees in a city's greenhouse gas inventory (Birdsey et al. 2019).

Carbon management opportunity assessments are therefore intended to complement a city's Climate Action Plan by focusing on the carbon sequestration and ecosystem service potentials of urban landscapes. These assessments are meant to serve as a starting point for **seeking alignment between carbon sequestration and ecosystem service opportunities and the needs of a city's communities.** As such, the opportunity assessments have four main aims:

1) To identify opportunities for carbon sequestration in urban landscape elements across the city;
2) Describe other ecosystem services that may be delivered by advancing these ecosystem-based carbon sequestration strategies;
3) Outline current methods and data requirements for quantifying these benefits; and
4) Discuss possible next steps for developing priority carbon sequestration projects.

What is an ecosystem services framework?

Ecosystem services are defined as the positive benefits that ecosystems provide to people. They are essential for human life and wellbeing, from the food produced by agricultural ecosystems to the oxygen produced by plants. While ecosystem services are often thought of as coming from wild or rural environments, the ecosystem services provided by urban ecosystems are equally important, and their proximity to high population densities make them uniquely influential (Woodruff and BenDor 2016).

At the cross-section of people, ecosystems, and climate change is the concept of ecosystem services (Fig. 5) (Morecroft et al. 2019). Successful ecosystem-based climate change mitigation will depend on integrating benefits to people (i.e. ecosystem services) with healthy functioning ecosystems. In urban areas, climate change is expected to increase risks for people, economies, and ecosystems. Looked at another way, **by enhancing ecosystem services and focusing on its social and ecological resilience, a city will be building its overall resilience to climate change.**

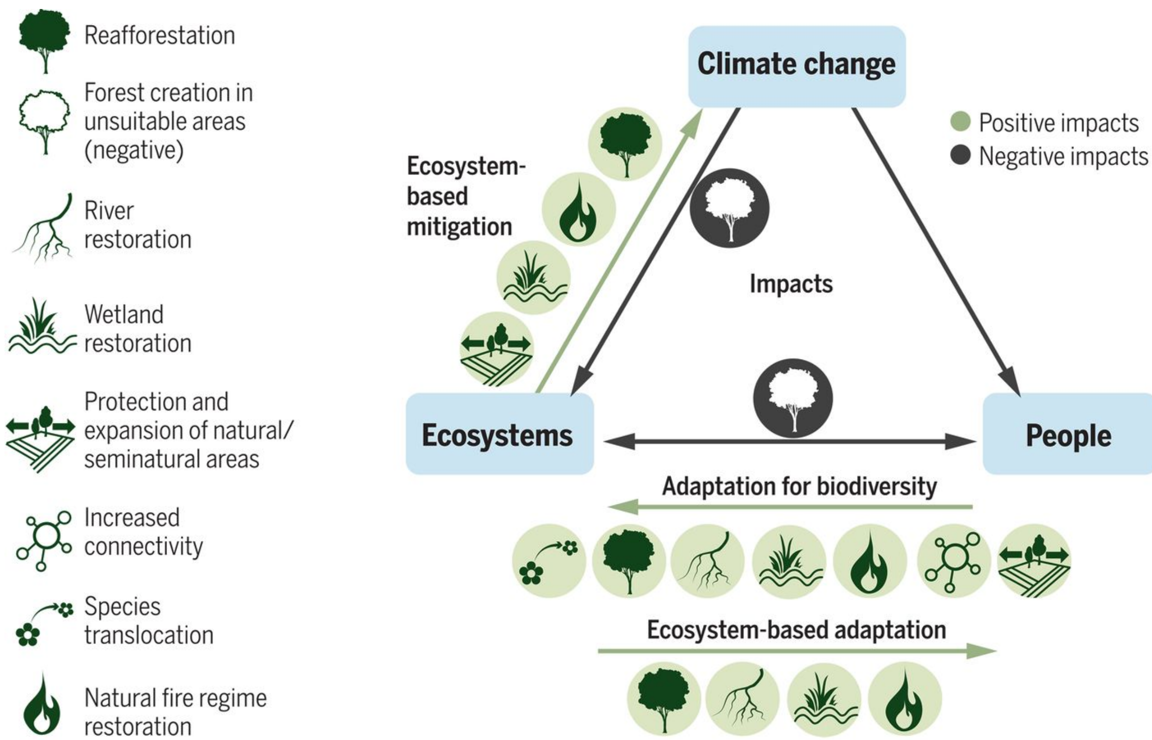

Figure 3: The relationship between people, ecosystems, and climate change. Successful ecosystem-based climate change mitigation will depend on integrating benefits to people (i.e. ecosystem services) with healthy functioning ecosystems. From Morecroft et al. 2019.

Ecosystem services can be difficult to quantify and, despite the clear and tangible services they provide, they are even more difficult to value economically. This is in part because society has largely taken these ecosystem services for granted, making it difficult to justify internalizing the cost of these services into the traditional marketplace. However, as the extent and health of ecosystems diminish, society is increasingly having to bear the costs of supplementing these ecosystem services with technological services with high social and economic costs. Carbon sequestration is one example of an ecosystem service that is receiving significant attention in the marketplace. Carbon credits representing the verifiable sequestration of a quantity of carbon can be bought and sold, giving this ecosystem service a real marketable economic value.

Because urban ecosystems deliver multiple ecosystem services at the same time, this raises the possibility of bundling multiple values together to more fully represent in the marketplace the services that an ecosystem is providing. With the current price of carbon on the voluntary market and with the relatively high cost of implementing ecosystem-based carbon sequestration measures in urban settings, it is unlikely that the market value of carbon sequestration alone would cover the costs of implementation. However, if the economic values of improved stormwater management and urban temperature regulation were realized in addition to the value of carbon sequestration, the bundled payment for these ecosystem services could make a significant contribution towards implementation. City Forest Credits is one example of an organization that is bundling the values of multiple ecosystem services this way for urban tree planting and preservation.

This section describes the major ecosystem services that can be provided by urban ecosystems. For the purposes of this document, ecosystem services are categorized broadly into three categories: **climate regulation and resilience, environmental services, and social benefits** (Fig. 4).

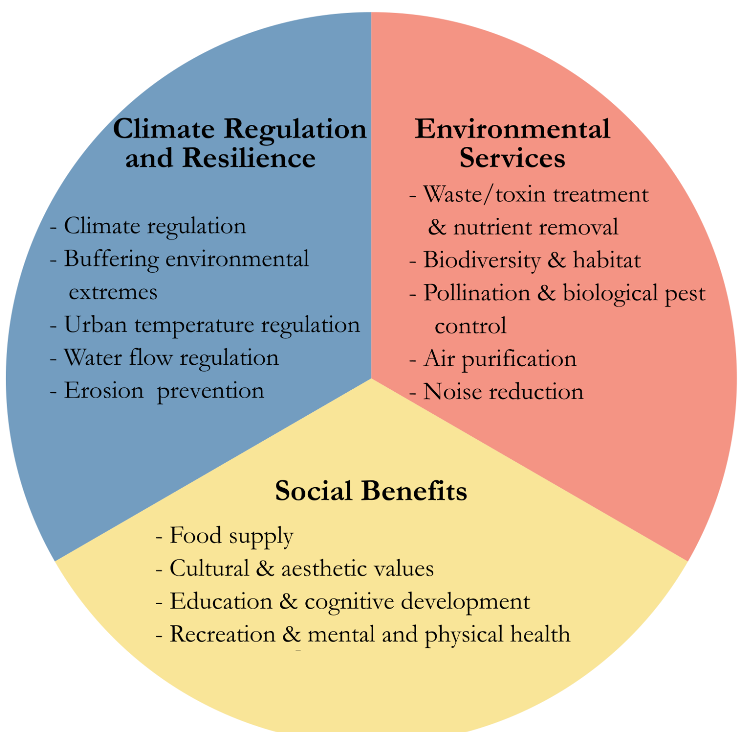

Figure 4: Ecosystem services provided by urban ecosystems organized into three broad categories. Critically, many of these ecosystem services are both interrelated and interdependent.

Climate Regulation and Resilience

Climate regulation. As plants in an ecosystem photosynthesize, they convert CO_2 from the atmosphere into plant matter, which is the process of carbon sequestration. This carbon can be stored in the form of woody biomass (trees) and soil organic matter.

Buffering environmental extremes. Ecosystems have the ability to moderate the effects of extreme weather from the buffering action of vegetative barriers on heavy winds and absorption of heat during heat waves.

Urban temperature regulation. Vegetated areas in cities absorb less heat than their surroundings and provide cooling via plant transpiration. Trees also provide direct shade during periods of heat, and block wind during periods of cold.

Water flow regulation. Vegetation slows down the flow of water during precipitation events, and well-structured soil soaks up and percolates water, in contrast to the surrounding hardened surfaces of a city. Wetlands can buffer and filter the flow of water throughout an urban watershed. By absorbing stormwater locally, the downstream load on water infrastructure is drastically reduced.

Erosion prevention. Soil is a valuable resource and its loss into waterways causes problems of sedimentation. The complex root systems of plants hold soil in place where otherwise the soil would be susceptible to erosion. Aboveground vegetation slows the flow of water during precipitation events, reducing the force of water flow on exposed soils.

Environmental Services

Waste/toxin treatment and nutrient removal. Through the microbial and plant activity of wetlands and other vegetated areas, excess nutrients are absorbed, toxins can be broken down, and pathogens can be removed, thereby filtering water runoff from urban spaces. A highly concentrated example of this ecosystem service is in compost production, wherein microbial activity is harnessed to transform organic waste materials into a stable and highly usable product.

Biodiversity & habitat. Urban ecosystems provide a living environment for plants, animals, and other organisms which otherwise would not have the resources to survive in an urban area.

Pollination & biological pest control. Urban ecosystems provide habitat to innumerable beneficial insects and other animals providing beneficial services throughout a city. Birds, bats, wasps, and others regulate populations of pests and diseases which otherwise would be unregulated.

Air purification. Trees and other vegetation play a significant role in removing pollutants from the air while producing oxygen from the process of photosynthesis. This is especially noticeable in urban areas where levels of polluting gases and particulate matter can be high.

Noise reduction. Thick vegetation can act as a barrier to block sound waves. Increased vegetative cover can soften the surfaces of urban surroundings, thereby absorbing and quieting sound waves. Noise in cities affects public health, animal life, and the ability of children to learn.

Social Benefits

Food supply. Urban ecosystems can be important sources of food for its communities. Whether in the form of community gardens or urban farms, these ecosystems can increase access to nutritious foods.

Cultural & aesthetic values. Urban ecosystems such as parks, trails, and street trees provide aesthetic enjoyment and contribute to a sense of place. Natural spaces can be culturally or spiritually significant. As an example of economic value, houses on tree-lined streets consistently have higher market value than similar houses on streets lacking trees.

Education & cognitive development. Urban parks and wild areas provide numerous opportunities for learning about nature and provide areas for quiet reflection in urban centers.

Recreation & mental and physical health. Outdoor play and other physical activities in city parks brings with it a multitude of public health benefits both mental and physical. They are essential for mental health and important for children's development.

Equity

Ecosystem services cannot be discussed outside the context of equity. **Disparities in environmental justice are rooted in not only the disproportionate exposure to environmental burdens but, in equal measure, the disproportionate distribution of access to natural ecosystems and the ecosystem services they provide**. This can be attributed at least in part to a lack of representation of some communities in the planning and decision-making processes (Jennings, Browning, and Rigolon 2019).

Research across many cities has found that low-income areas often have less access to and coverage of urban trees, vegetation, and recreational green spaces. Similar disparities are observed based on differences in race and ethnicity. Further, green space that does exist may be of poor quality, in disrepair, or close to pollution sources. Access to functional walkways and street trees has been framed as an issue of social equity and environmental justice. As one example, research has found that vegetation cover is associated with higher income and lower crime rates (Grove, Locke, and O'Neil-Dunne 2014).

Many of the same factors driving historic and current residential segregation are the same ones driving the disproportionate effects of environmental harms and the inequitable access to green spaces. In many cities across the United States, the uneven distribution of funding for parks and open space has perpetuated these discrepancies (Jennings and Gaither 2015).

One important result of disparities in access is a contribution to disparities in public health. The beneficial effects of ecosystem services from urban ecosystems have been linked to decreased heat-related illness and obesity, and improvements in cardiovascular health and mental health. Multiple stresses on public health in cities, such as heat and air quality, are expected to increase in magnitude with a changing climate. The challenges of addressing climate change, social equity, and environmental justice are sides of the same coin, and at their intersection is the important role of urban ecosystems and the ecosystem services they provide.

Managing for a changing climate

Ecosystem-based climate solutions are as much about building a community's resilience to a changing climate as they are building an adaptive solution that itself will be resilient to climate change stressors. Climate change is predicted to have widespread impacts at every scale, from global to local. In many cases, its effects are already beginning to be felt, with increased severity of weather events and record levels of heat.

Adapting to more extreme precipitation will require careful management of water resources by increasing infiltration and buffering flow through watersheds. Increasing heat will drive up energy demands for cooling and will increase risks to vulnerable populations. Adaptation will require green infrastructure to mitigate urban heat.

Natural and agricultural ecosystems will see shifting species dynamics and pest pressures. Higher temperatures and reduced snow cover is expected to affect wetlands and other aquatic systems most acutely in the near future. Adaptation will require a focus on conserving these ecosystems through protection and adaptive stewardship (Bathke et al. 2014).

Framework for Carbon Management Planning

Carbon Management Opportunity Assessment

There are four major steps in developing an initial carbon management opportunity analysis:

- Data needs analysis
- Stakeholder identification and mapping
- Data collection
- Initial carbon management analysis
    - Scale of carbon drawdown potentials analysis
    - Scale of benefits analysis

A detailed process guide for conducting a preliminary carbon drawdown opportunity assessment is being developed as a separate document and will be available soon at the "Resources" page of the Urban Drawdown Initiatives website.

As background to prepare for this more detailed process, the following sections provide information on the types of analysis that will be conducted in an opportunity assessment.

Quantification

Tracking changes in land use and land cover across the city is critical for informing planning and management decisions. However, green spaces and urban ecosystems are different and in many respects more complicated to track than other urban spaces. The type of vegetation and ecosystem making up a piece of land and how that land is managed will affect whether and to what extent it sequesters carbon, and the nature and magnitude of other ecosystem services it provides. Changes in an ecosystem are also opportunities for loss of carbon back into the atmosphere. For example, the conversion of a forest into a turf field would result in the loss of much of the carbon sequestered in those trees back into the atmosphere.

When accounting for the benefits of carbon sequestration by ecosystems, it is therefore necessary also to account for the emissions of carbon from ecosystem changes. These emissions typically occur either following a disturbance, such as tree mortality from a storm, or following the conversion of one land use into another land use.

Because these changes in land use are important events to account for in greenhouse gas emissions inventories, ICLEI recommends classifying land into six land use classes: forest land, Cropland, grassland, wetlands, settlements, and other land. These land use classifications can be used to track changes from one land use to another and the resulting carbon sequestration or emission of such a change (Birdsey et al. 2019).

Tracking land cover and land use changes is a necessary step in being able to quantify the carbon being sequestered in urban ecosystems and the carbon emissions resulting from changes to these ecosystems. In addition to identifying natural asset areas, models are needed to quantify the impacts of these areas. Different models are used for estimating forest carbon than for soil carbon and other ecosystem greenhouse gases (Fig. 5). The following sections describe several tools designed for these purposes.

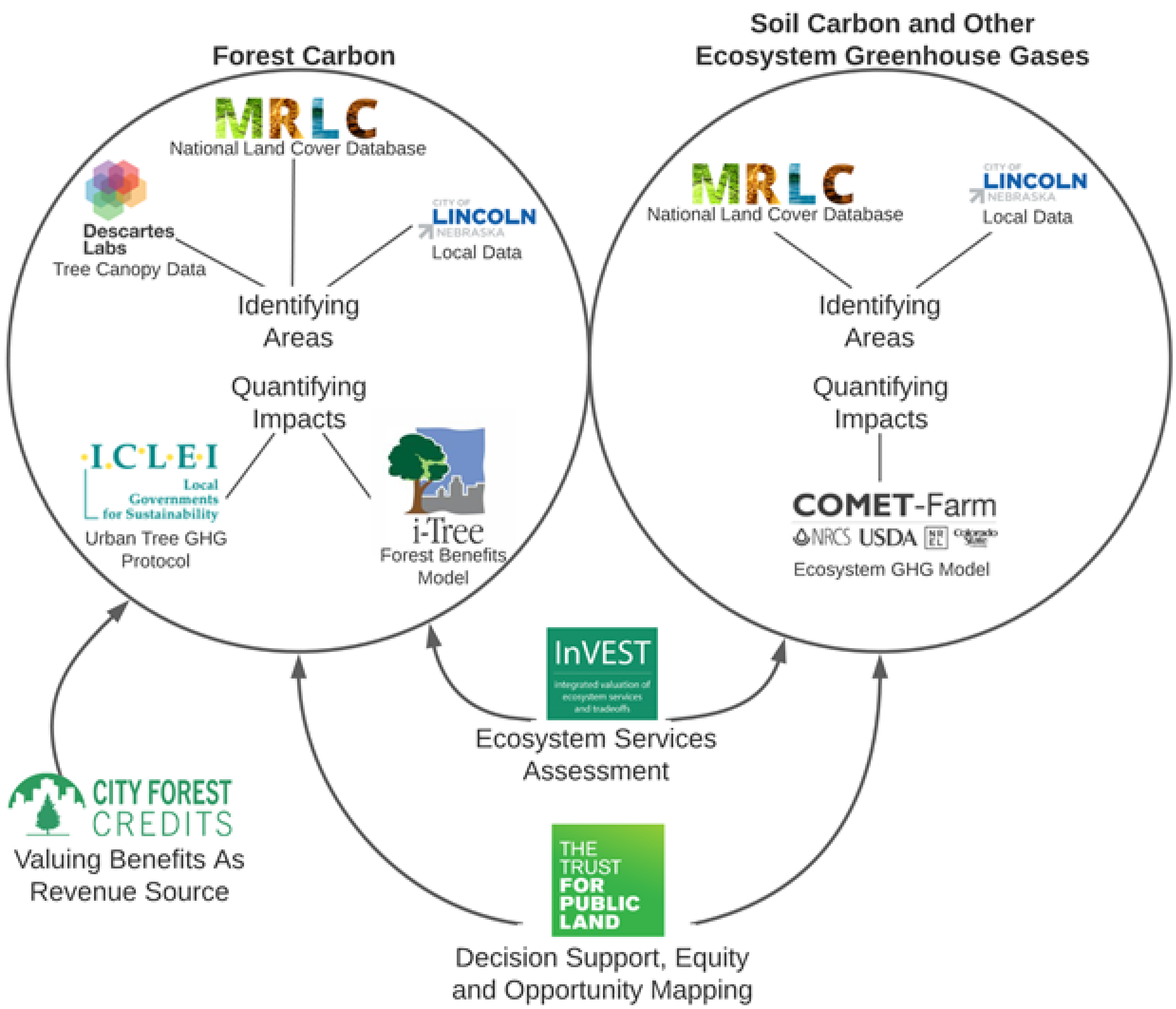

Figure 5: Diagram showing numerous tools and data sources that can be used for estimating forest carbon (left circle) and soil carbon and other greenhouse gases (right circle).

Project Identification: Trust for Public Lands Decision Support Tool

The Trust for Public Land is currently developing a decision support tool that pulls together multiple mapping resources and quantification models into a single platform (Fig. 6). This tool uses a combination of national datasets and local data sources to map the natural assets found across the city alongside social equity and site suitability data. The user can then apply different management scenarios to a natural assets area and be given an estimate of the carbon sequestration impact of that change.

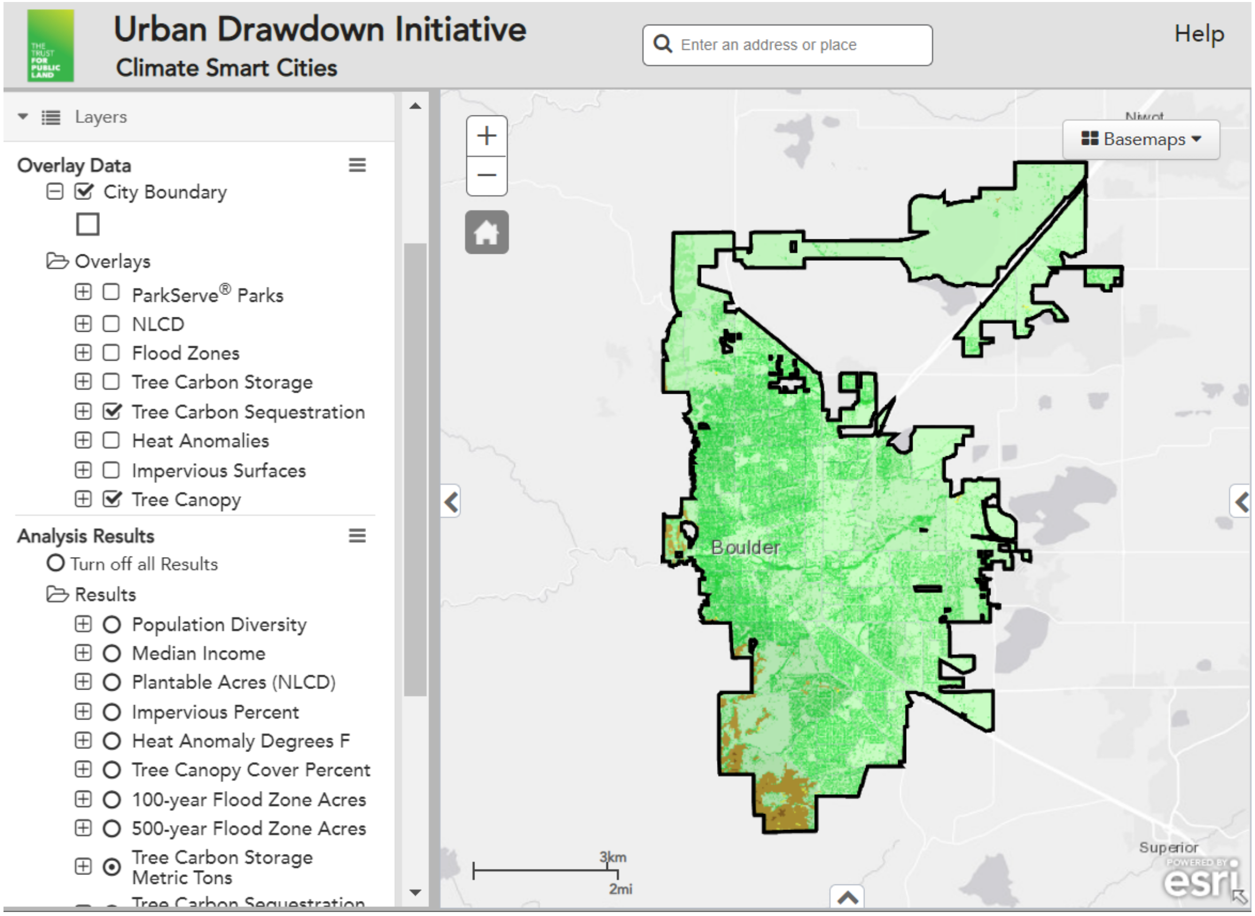

Figure 6: The Trust for Public Land's decision support tool. The screenshot shows the city of Boulder's layers for tree carbon sequestration, tree canopy cover, and tree carbon storage in metric tons.

The tool is intended to be user-friendly and to help guide the process of identifying opportunities for carbon sequestration through natural asset management. The tool has now been built for 8 U.S. cities. Access to the tool with associated information and support materials can be found at https://web.tplgis.org/udi/

UDI and TPL are working to make the tool available to a larger group of cities over the remainder of 2021. For more information on developing the tool for your location, contact Taj Schottland at TPL--taj.schottland@tpl.org.

An overview of the natural asset areas and the data layers and associated calculation tools used to assess carbon management opportunities is displayed in Figure 7.

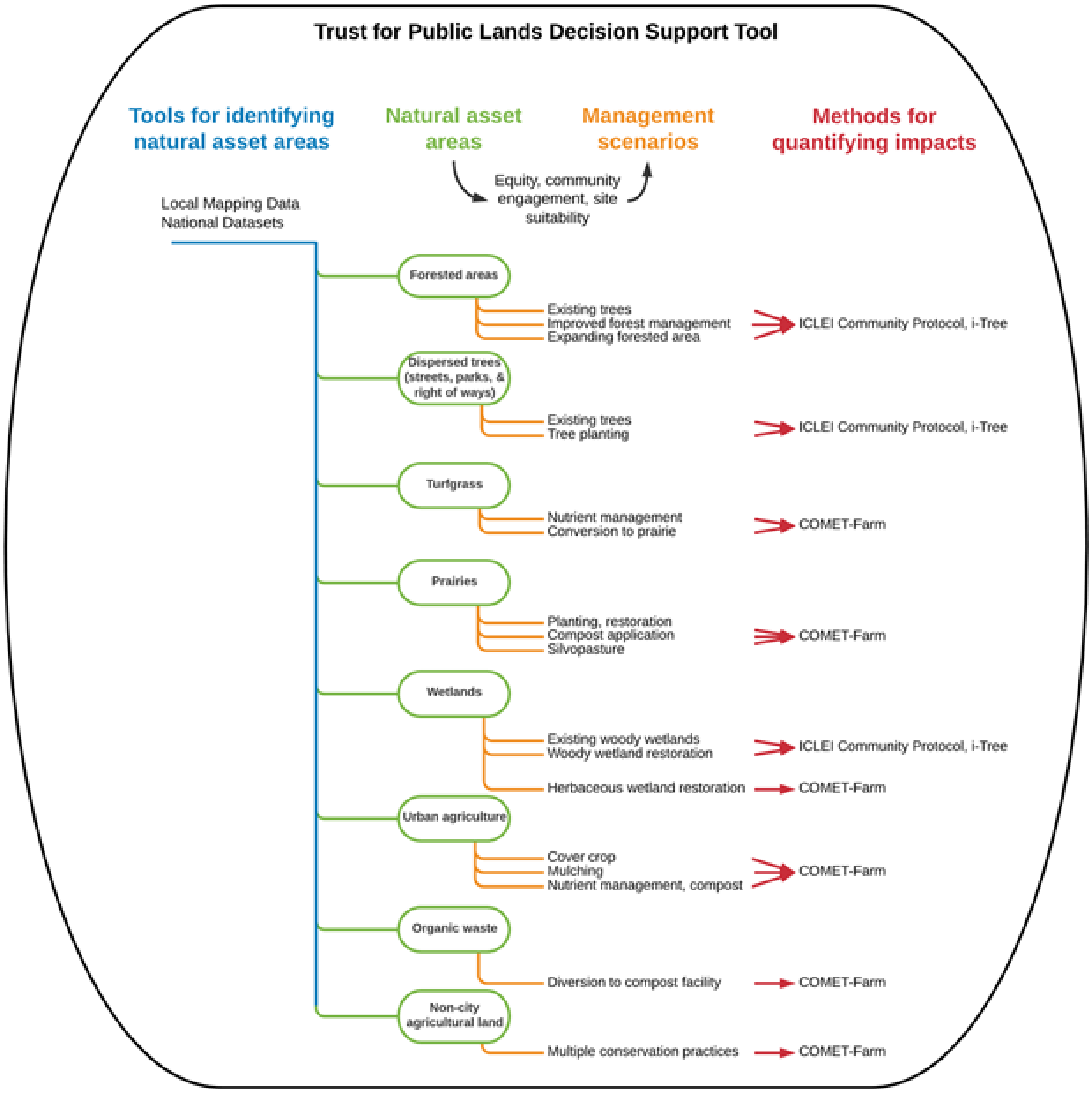

Figure 7: Conceptual depiction of the decision support tool currently being developed by the Trust for Public Lands.

Conclusion

This guide provides an initial introduction to the core concepts with which a natural systems-based carbon management and ecosystem services strategy can be developed. More detailed process guides are being developed to support carbon management opportunity assessment and strategy development. These process guides will be available at the Urban Drawdown Initiatives website under the “Resources” page found at this address: https://urbandrawdown.solutions/resources. For more information, please contact UDI at: Info@urbandrawdown.solutions.

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