Adapting Urban Forests to Climate Change in the Chicago Region

By Leslie A. Brandt, Abigail Derby Lewis, Lydia Scott, Robert T. Fahey, Lindsay Darling, and Christopher W. Swanston

The urban forest is a key component in building community resilience to a changing climate. Many municipal climate action plans include increasing tree canopy as part of their overall adaptation or mitigation strategies, as they can help reduce the urban heat-island effect, control stormwater, and store carbon. Despite this, few urban areas have examined the vulnerability of their trees to current and future climate conditions or developed specific adaptation plans to ensure that their urban forests continue to provide benefits into the future.

The Northern Institute of Applied Climate Science (NIACS), a multi-institutional partnership supported by the U.S. Forest Service that focuses on incorporating climate-change considerations into forest management, teamed up with partners in the Chicago, Illinois, U.S., region to develop a framework for climate-change adaptation in urban forests (Brandt et al. 2016a). NIACS and its partners at The Morton Arboretum, The Field Museum, the Chicago Botanic Garden, and the Chicago Region Trees Initiative used the Chicago region as a test case for urban forest vulnerability assessments and adaptation with the hopes that lessons learned can be applied to other urban areas (Brandt et al. 2016b).

Vulnerability of the Region's Trees

Which tree species are the most at risk to current and projected climate changes in the Chicago region? To find out, we assessed the vulnerability of the trees most commonly found in the Chicago region (Brandt et al. 2017) based on a recent sample inventory (Nowak et al. 2013).

We sought to understand how vulnerable different trees were by first examining how changes in temperature and precipitation may affect habitat suitability. For native trees, we relied on modeled projections of habitat suitability developed by the U.S. Forest Service Landscape Change Research Group (Landscape Change Research Group 2014). These projections incorporate changes in temperature, precipitation, and factors such as soil type in natural habitats.

For non-native trees and cultivars, we compared known heat and hardiness zone ranges of each species to current and projected heat and hardiness zone ranges for the region (Table 1). For example, a tree species with a maximum Heat Zone tolerance of 7 would be considered to be negatively impacted by climate change because the area may reach Heat Zone 8 within a tree's lifespan (Figure 1).

Habitat suitability models and changes in Heat and Hardiness Zones only tell part of the story, however. Warmer temperatures and changes in precipitation may make conditions more favorable for some pests and diseases, and more extreme storms increase risk for species intolerant of wind, ice, or flooding. In addition, some species may be more or less adaptable to a range of site conditions found in urban environments. We addressed these factors by developing adaptability scores for each species based

Table 1. Current and projected USDA Hardiness Zones and AHS Heat Zones for the Chicago region under low and high greenhouse gas emissions scenarios (Brandt et al. 2017).

	Low emissions				High emissions			
	1980–2009	**2010–2039**	**2040–2069**	**2070–2099**	**1980–2009**	**2010–2039**	**2040–2069**	**2070–2099**
Hardiness Zone	5b–6a	5b–6a	6a–6b	6a–6b	5b–6a	6a–6b	6b–7a	7a–7b
Heat Zone	4–5	5–6	5–6	5–6	4–5	6–7	7–8	8

on their tolerance of disturbances and capacity to adapt to a variety of environments (Matthews et al. 2011).

Adaptability scores were then combined with modeled changes in habitat suitability to give an overall rating of vulnerability. Species with *low vulnerability* are adapted to current and future climates and have a variety of traits that make them tolerant of disturbances and a wide range of site conditions. Species with *high vulnerability* are those that are not adapted to current or future conditions, are less tolerant of disturbances, or have very specific site requirements. These species may have reduced health or productivity, and may eventually experience more mortality than species that are less vulnerable.

Our assessment revealed that the majority of trees in the region had low or low-moderate vulnerability (Figure 2). However, many of those trees were invasive species, such as European buckthorn (*Rhamnus cathartica*) or Amur honeysuckle (*Lonicera maackii*) (Table 2). Many of the region's native species were vulnerable, especially those at the southern end of their range, such as balsam fir (*Abies balsamea*), paper birch (*Betula papyrifera*), white pine (*Pinus strobus*), and white spruce (*Picea glauca*).

Community-Level Vulnerability

Getting a sense of what's vulnerable at a regional scale is helpful, but how does this translate to management of specific areas? We answered this question by developing a process for municipalities, park districts, and forest preserve districts to assess their own vulnerability to climate change based on the composition of their urban forest, physical factors, and human dimensions, such as organizational capacity, funding, and community support.

Ten case studies were developed in the Chicago region using this approach. We found that most communities expected a similar degree of negative impacts on their urban forests, but had a greater variation in their perceived adaptive capacity (Figure 3). In general, communities that had urban forests with high species, genetic, and age class diversity and had sufficient organizational, technical, social, and economic resources were less vulnerable to climate-change impacts.

Adapting to Change

Once we understand how vulnerable our urban forests are to climate change, how can we adapt our management? Adaptation actions are designed to specifically address climate-change impacts and vulnerabilities in order to meet climate-informed goals or objectives (Figure 4). Adaptation actions can include resisting change, such as watering during drought periods or installing gray or green infrastructure to control flooding. They can also include building resilience through enhanced age, species, and genetic diversity. Finally, there may be some cases where managers may want to facilitate transitions through activities, such as incorporating new species that are not currently found in their area or converting from one ecosystem type to another.

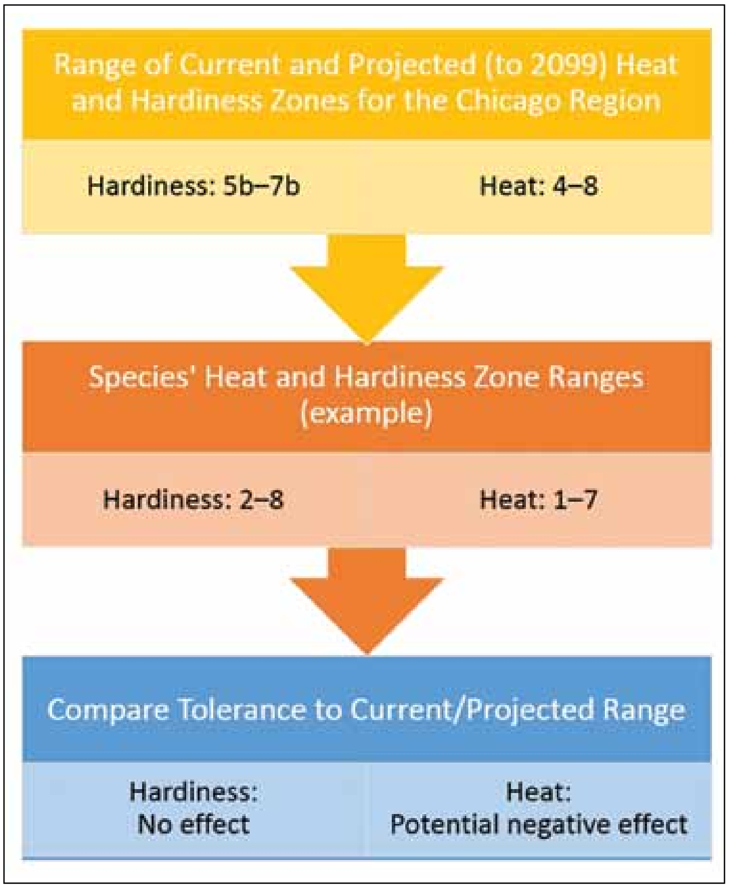

Figure 1. Schematic for determining habitat suitability for a species using current and projected USDA Hardiness Zones and AHS Heat Zones. This example species may be negatively affected because the species is only tolerant to Heat Zone 7, but the area may reach Heat Zone 8 by the end of the century.

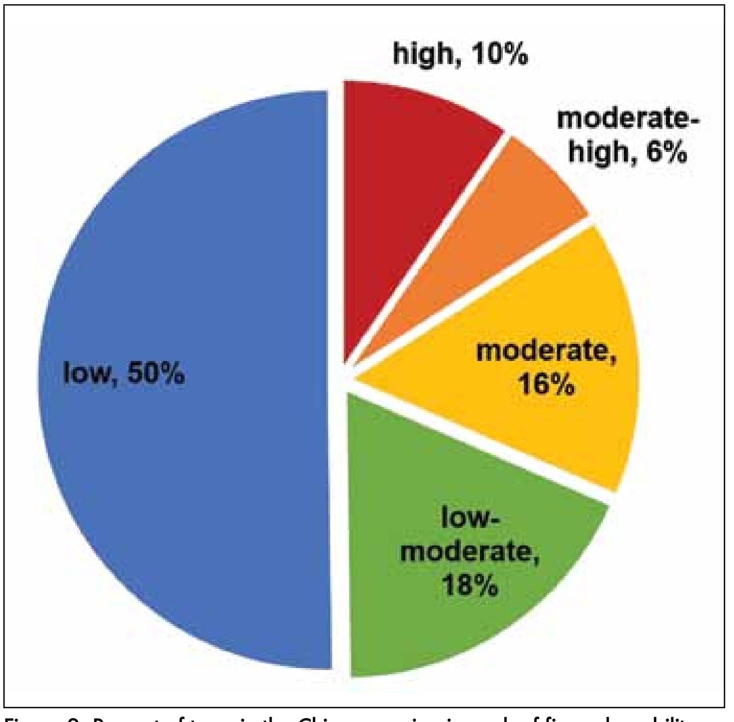

Figure 2. Percent of trees in the Chicago region in each of five vulnerability categories (Brandt et al. 2017).

Table 2. List of top 10 most common species in the low- and high-vulnerability categories, and a list of 10 species native to North America not commonly found in the area that may potentially gain suitable habitat (Brandt et al. 2017).

Common species with high vulnerability	Common species with low vulnerability	Potential new species
Balsam fir (*Abies balsamea*)	Amur honeysuckle[z] (*Lonicera maackii*)	Black gum (*Nyssa sylvatica*)
Black cherry (*Prunus serotina*)	Black locust (*Robinia pseudoacacia*)	Chestnut oak (*Quercus montana*)
Douglas-fir (*Pseudotsuga menziesii*)	Black oak (*Quercus velutina*)	Chinkapin oak (*Quercus muehlenbergii*)
Eastern hemlock (*Tsuga canadensis*)	Boxelder (*Acer negundo*)	Common persimmon (*Diospyros virginiana*)
Gray birch (*Betula populifolia*)	Bur oak (*Quercus macrocarpa*)	Cucumbertree (*Magnolia acuminata*)
Jack pine (*Pinus banksiana*)	European glossy buckthorn[z] (*Rhamnus cathartica, R. frangula*)	Mockernut hickory (*Carya tomentosa*)
Paper birch (*Betula papyrifera*)	Freeman maple (*Acer saccharinum*)	Pignut hickory (*Carya glabra*)
Quaking aspen (*Populus tremuloides*)	Gingko (*Ginkgo biloba*)	Shumard oak (*Quercus shumardii*)
White pine (*Pinus strobus*)	Littleleaf linden (*Tilia cordata*)	Sugarberry (*Celtis laevigata*)
White spruce (*Picea glauca*)	Northern hackberry (*Celtis occidentalis*)	Yellowwood (*Cladrastis kentukea*)

[z] Non-native invasive species: typically considered harmful to native ecosystems.

Tools are available to assist with the process of developing adaptation strategies for a specific site. NIACS designed the *Adaptation Workbook* as a flexible, logical process to consider climate-change information and to design customized management actions that can help managers achieve their objectives (Swanston et al. 2016; Figure 5). The workbook integrates a menu of adaptation strategies specific to urban forests that was developed by NIACS and its partners in the Chicago region and is applicable to urban forests in most temperate areas. An online version of the workbook is available that incorporates location-specific climate impacts (https://adaptationworkbook.org).

Dozens of managers working in urban areas have used the *Adaptation Workbook* to develop their own adaptation plans. In the Chicago region, the villages of Hazel Crest and Riverside are incorporating species that are projected to do well under current and future climates into their planting. Hennepin County, the Mississippi Park Connection, and the National Park Service in the Twin Cities area (Minnesota, U.S.) are using gravel-bed nurseries to grow future-adapted trees in a cost-effective manner that ensures a strong, more resilient root system. Our work with local urban forestry professionals has shown that adaptation does not require dramatic changes to management and can potentially save money over the long run by reducing risks. These adaptation actions can be made while considering other important factors, such as providing habitat for urban wildlife or restoring native ecosystems. More examples of adaptation projects can be found online (http://forestadaptation.org/demos).

Moving Forward

Our work in the Chicago region provides a framework for how we can consider the vulnerability of urban forests and adapt to anticipated changes. We have built on lessons learned from this effort and expanded our reach to other urban areas, working with partners in the Twin Cities (Minnesota, U.S.), Cleveland (Ohio, U.S.), Philadelphia (Pennsylvania, U.S.), New York City (New York, U.S.), and Boston (Massachusetts, U.S.) regions. Each place has its unique climate-change challenges and brings new sets of expertise and perspectives. We hope that by learning from each other, we can collectively reduce the vulnerability of our urban forests to a rapidly changing climate.

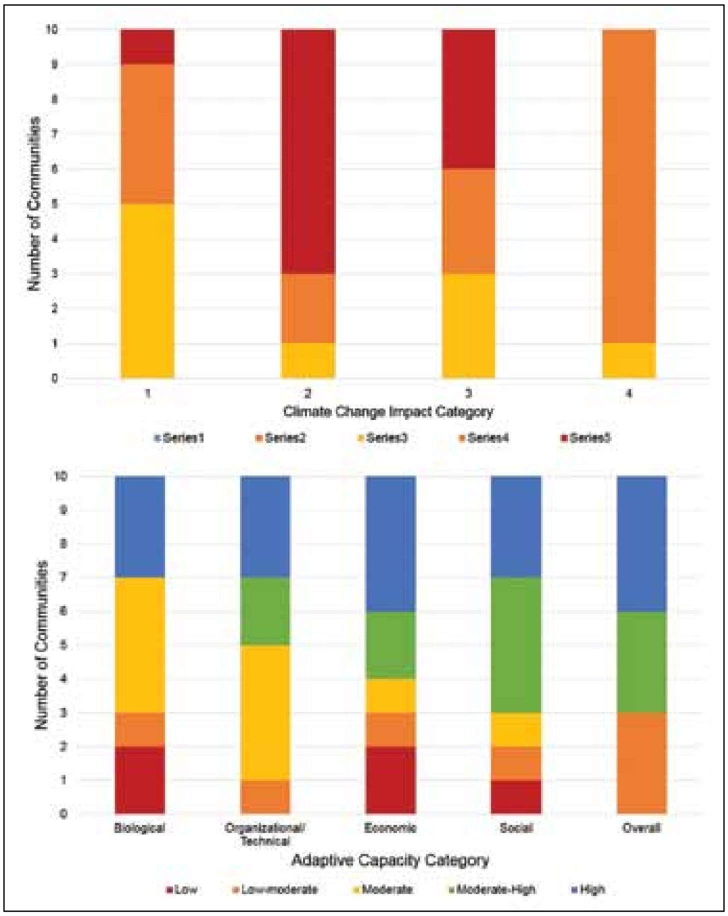

Figure 3. Variation in impacts (top) and adaptive capacity factors (bottom) among 10 case study communities.

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MICHAEL COLLINS, VILLAGE OF RIVERSIDE

Figure 4. The Village of Riverside, Illinois, U.S., is incorporating future-adapted trees into its ash replacement program, such as pecan and Ohio buckeye.

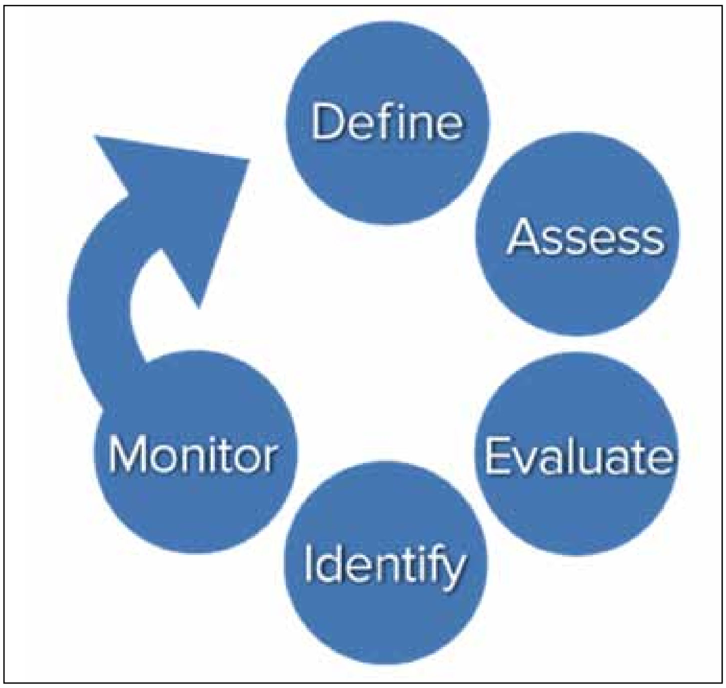

Figure 5. The *Adaptation Workbook* is a structured process to consider the potential effects of climate change and design land management and conservation actions that can help prepare for changing conditions. The process is completely flexible to accommodate a wide variety of geographic locations, ownership types, ecosystems and land uses, management goals, and project sizes.

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