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Comparing climate-growth responses of urban and non-urban forests using *L. tulipifera* tree-rings in southern Indiana, USA

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ABSTRACT

Urban forests have many positive effects on human health and recreation. However, urban areas can create stressful environments for native trees, leading to increased mortality and an altered ecosystem. Here, we compare growth variability and the climate response from old (> 200 years) *L. tulipifera* growing in an urban forest in Bloomington, IN to surrounding non-urban sites in southern Indiana using dendrochronological techniques. We found that *L. tulipifera* growing in the urban forest responded similarly with small differences to climate compared to the non-urban sites. Radial growth from urban *L. tulipifera* had statistically similar correlation values with temperature, soil moisture, and precipitation compared to the trees in non-urban forests. Growth variability between the urban and non-urban *L. tulipifera* trees showed good agreement through time with the exception of the 20th century, where the urban forest experienced a stand-wide release from competition. Our results indicate that some urban forests may function similarly to non-urban forests from an ecological perspective. These findings suggest management practices from non-urban old-growth forest could be useful for management of rare urban old-growth forests.

1. Introduction

The benefits of urban forests and urban street trees have long been a topic of interest in ecological research. Urban forests provide a host of ecosystem services that translate not only into ecological benefits but also psychological and economic benefits for city-dwellers (Dwyer et al., 1991; Tyrväinen and Miettinen, 2000; Nowak and Dwyer, 2007; Moore, 2009; Greene and Millward, 2016). Examples of well-known ecological benefits provided by urban forests include moderating climate, air-quality improvement, and reduction in noise levels (Nowak and Dwyer, 2007). In particular, urban forest stands are known to help mitigate the urban heat island effect (Greene and Millward, 2016), an important benefit, as climate continues to change and populations increase and move into urban areas (United Nations, 2005). Urban trees, forests, and greenspaces also provide economic benefits, such as providing shade cover (thereby reducing energy costs) and increasing property values (Tyrväinen and Miettinen, 2000; Moore, 2009). In addition to ecological and economic benefits, urban forests have intrinsic psychological and emotional value in terms of opportunities for recreation, closeness to nature, and overall improvements in mood and wellbeing. In addition to simply viewing trees, the act of planting and maintaining urban trees can also foster a sense of emotional involvement within one's community (Dwyer et al., 1991).

While urban forests and trees have ecological, economic, and psychological benefits, urban landscapes can have both positive and negative impacts on urban trees. Trees planted near roadways or in medians are subjected to elevated abiotic stress conditions such as higher temperatures, increased soil salinity from de-icing salts, and increased runoff, which in turn can also lead to water stress and an increase in pest abundance (Bartens et al., 2009; Munck et al., 2010; Dale and Frank, 2014). However, the urban landscape can also benefit trees. For example, urban trees can be protected from stress by frequent watering during drought and added fertilizer to promote growth during unfavorable climate conditions (Gregg et al., 2003). The contradicting influences of urban landscape on tree growth and climate sensitivity complicate the understanding of the vulnerability of urban forests, creating the need for studies that compare urban and non-urban forests.

One way of examining the influence of climate on tree growth and comparing climate-growth response across sites is with the use of tree-rings (Fritts, 1976; Tardif and Bergeron 1997). Tree-rings have been long been used to represent past climate in the United States (Cook et al., 1999). The dominant growth factor of many mid-latitude trees (including the United States) is soil moisture. Because soil moisture is influenced by both temperature and precipitation, one can use tree-rings to examine the sensitivity to climate of a given species

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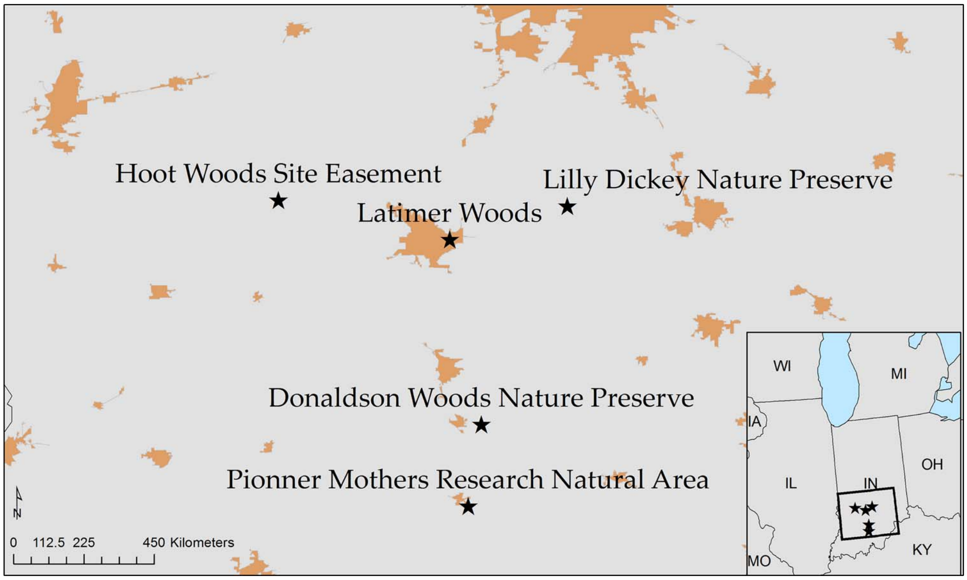

Fig 1. Map of study site (Latimer Woods) and non-urban comparison sites along with urban areas defined by the US Census Bureau (2010).

and how site differences influence the climate response of a species and thus determine the vulnerability of that species to climate variability.

Multiple studies have examined the suitability of examining tree-rings in urban trees to access the sensitivity of urban trees to climate (e.g., Cedro and Nowak 2006; Chen et al., 2006; Gillner et al., 2014). However, fewer studies have used tree-rings to compare urban to non-urban trees (Gillner et al., 2013; Finley et al., 2016). Similarly, fewer studies have examined climate-growth responses of urban trees over multiple decades (Gillner et al., 2014). Much of the previous urban forestry work has examined young trees or forest stands. Old-growth urban forests are rare and thus the climate-growth relationships are not well understood. Tree-rings are a particular good method for examining climate-growth response of older forests and this is a common practice in non-urban forests, especially for oak species (LeBlanc and Terrell 2009; LeBlanc and Stahle 2015). While oak species are generally more common in dendroclimatic studies in the eastern US, recent studies have shown that *Liriodendron tulipifera* (Tuliptree) are also sensitive to hydroclimate (Pederson et al., 2013; Maxwell et al., 2015; Maxwell and Harley, 2017). Old *L. tulipifera* have been found throughout the southern portion of Indiana, USA allowing for a comparison of climate sensitivity between differing site conditions (Maxwell and Harley, 2017).

The objective of this study is to compare the climate response of *L. tulipifera* within an old-growth urban forest site to that within non-urbanized sites. Specifically, we: (1) compare the climate signal of urban old-growth *L. tulipifera* with that of non- urban sites; (2) examine urban vs. non-urban site differences in the relationship between soil moisture and tree growth; and (3) identify historical periods where growth from the urban site differed from that of the non-urban sites.

2. Methods

2.1. Study site

Latimer Woods (LW) is a four-hectare plot of old-growth urban forest located in Bloomington, Indiana. Mr. Hugh Latimer and family dedicated the site to the Bloomington Community Foundation in 1999, and the management of LW was turned over to the City of Bloomington Parks and Recreation Department. The forest is located on the edge of the urban area of Bloomington. However, a shopping mall, an apartment complex, and major roads surround LW. The mall was constructed in 1965 and the area has become increasingly urbanized since that time. The site was passively managed until 2005, and has since been managed for conservation, allowing activities such as research, recreation, and education. LW is a Beech-Maple forest type with a mesic environment; observed species included *L. tulipifera*, *Acer saccharum* Marshall (Sugar Maple), *Fagus grandifolia* Ehrh. (American Beech), and *Prunus serotina* Ehrh. (Black Cherry). The forest is situated in a lower cove, and thus has little topography and contains a moderate amount of moisture (i.e. mesic). Similar to the broader region of southern Indiana, the site contains discontinuous loess over weathered limestone (Franzmeier et al., 2004).

We also examined *L. tulipifera* at four non-urbanized sites (Fig. 1). Tree-ring data from these non-urban sites have been published in dendroclimatic studies (Maxwell et al., 2016; Maxwell and Harley, 2017) and provide a good means to compare the climate response of *L. tulipifera* trees from LW. The non-urban sites include old growth forests of Pioneer Mothers (PM) and Donaldson Woods (DW), Hoot Woods (HW), which is a selectively logged forest, and Lilly-Dickey Woods (LD), a second-generation forest. The sites share similar soil types and species makeup. The ages of the trees and their corresponding size were similar between LW and the non-urban sites with the exception of LD, which had smaller and younger trees (Table 1).

2.2. Sample collection

Twelve *L. tulipifera* were sampled by targeting canopy dominant old-growth trees based on morphology (Pederson, 2010) with minimal evidence of anthropogenic influence. However, Latimer Woods is an urbanized site, and anthropogenic influences were prevalent throughout the site, including carvings in many trees as well as evidence of invasive plant management (e.g. vine removal). Thus, many sampled trees did have some anthropogenic influence. Two cores were taken from each tree using a 5.1 mm diameter increment borer, approximately one meter from the ground. Tree core samples were air dried, mounted, and ground with progressively finer sandpaper until growth rings and individual cell structure were visible. To ensure that each sample was properly dated, we visually crossdated (matching the growth pattern between trees) using the list method (Yamaguchi, 1991). To ensure visual crossdating was accurate we confirmed statistically using the program COFECHA (Holmes, 1983). COFECHA uses moving correlations of 50-year segments to compare growth patterns between individual samples with the remaining sampled trees. To