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Assessing the potential for urban trees to facilitate forest tree migration in the eastern United States

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ABSTRACT

Latitudinal shifts in tree species distributions are a potential impact of climate change on forest ecosystems. It has been hypothesized that some tree species may become extirpated as climate change effects may exceed their migration ability. The goal of this study was to compare tree species compositions in northern urban areas to tree compositions in forestland areas in the eastern U.S. as an indicator of the potential for urban trees to facilitate future forest tree species migration. Results indicated that a number of tree species native to eastern U.S. forests of southern latitudes are currently present in northern urban forests. The biomass density (Mg/ha) of urban tree species is typically less than half of forestland densities with the majority of urban tree species found in nearby (<100 km) forestland. Urban tree propagation is often facilitated by humans, whereas the necessary pollinators and agents of tree seed dispersal in forestlands may be lacking regardless of climate change. It is suggested that urban areas may serve divergent, dual roles as both a native tree seed source and refuge for a limited number of forestland tree species, but also a facilitator of non-native tree invasion.

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1. Introduction

Due to an increase in pre-industrial atmospheric carbon dioxide concentrations, the world's climate is forecasted to change significantly over the next century, resulting in an increase in mean surface temperatures of 2–4.5 °C, more episodic precipitation events, and a lengthening of growing seasons (IPCC, 2007). The combination of numerous climate change effects on forest ecosystems may ultimately lead to the migration of tree species (Opdam and Wascher, 2004; Walther et al., 2002). There is evidence of past forest migration rates exceeding 50 km per century during episodes of climate change (Schwartz, 1992; Noss, 2001; Parmesan and Yohe, 2003). An important question is whether predicted future climate change will be at a rate that exceeds a tree species' capacity to migrate, resulting in species extirpation/extinction or the conversion of forests to grasslands or other systems (Iverson and Prasad, 2002; Woodwell et al., 1998; Davis and Shaw, 2001). Forests may need to migrate one order of magnitude faster than in past migrations to adequately respond to current rates of warming (Schwartz, 1992). In addition, modern day fragmentation of forest ecosystems may inhibit the movement of tree species, potentially reducing tree migration capacity by one order of magnitude (Schwartz et al., 2001; Davis and Shaw, 2001; Walther et al., 2002; Opdam and Wascher, 2004). Monitoring current distributions of species is one of the best methods to assess climate change impacts (McLachlan et al., 2007).

Both projection models (Iverson et al., 2008) and empirical evidence (Woodall et al., 2009) have suggested that some tree populations in eastern North America may already be migrating northward. Tree species range maps from Woodall et al. (2009) display numerous examples of potential range outliers that could speed the process of tree migration. By some mechanism, tree species have been established far beyond their typical range limits. One hypothesis is that tree species non-native to certain ecosystems have been established by humans either unintentionally or deliberately to meet landowner objectives (e.g., shade tree, windbreaks, or ornamentals). The very same human actions that have allowed rapid migration of non-native invasive species (e.g., *Ailanthus altissima*) could also facilitate the relatively rapid movement of native tree species in the eastern U.S. Similar to past tree species migrations that have occurred at unexpected fast rates (Clark et al., 1998), future tree migration in the U.S. may overcome barriers to migration (e.g., forest fragmentation and rapid climate change) and shift at rapid rates due to the presence of numerous "outliers" possibly identified by forest inventories.

In urban areas, many tree species have been planted. The establishment of native eastern North American tree species

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outside of their natural range occurs as ornamental plantings by urban landowners (e.g., *Catalpa speciosa* (Warder) or *Pseudotsgua menziesii* (Mirb.) in Minneapolis, MN). These plantings at latitudes higher than their respective native forest ranges may serve as a seed source for future migration of native tree populations. Conversely, the establishment of non-native tree species in urban areas may enable rapid invasion of forestlands by non-natives if climate change provides competitive advantage to non-natives (for general invasive discussion see Dukes and Mooney, 1999). The facilitation of tree migration by humans may speed the process of migration as forests respond to climate change (Aitken et al., 2008). Van der Veken et al. (2008) recently found that plant species in nurseries and gardens far exceeded their northern native range thus possibly facilitating future migration. While conservation biologists currently debate assisted migration (McLachlan et al., 2007), many plant species may have already been established by humans at higher latitudes. To date, there has been no research to examine the role that urban forests could play in facilitating future native tree population migration.

The goal of this study is to compare the species compositions of selected northern urban areas of the eastern U.S. to that of forestland tree compositions to evaluate the role that urban tree populations might serve in future tree migration scenarios. Specific objectives were to:

(1) Determine the species composition of selected (above 40th parallel) eastern U.S. major cities (Syracuse, Boston, Hartford, New York City, and Minneapolis) and compare to forestland tree composition within 100 km of city center.
(2) Determine the difference in latitudes for each tree species in each urban area between two locations: (a) the latitude of urban area center and (b) the 99th percentile latitude for each urban tree species found in eastern U.S. forestland.
(3) Determine the latitude at which each forestland tree species has the same biomass density (biomass, Mg/ha) as the same species in the study's eastern U.S. urban areas.
(4) Discuss results in terms of implications regarding future urban tree species facilitated migration and future research directions.

2. Methods

2.1. Forestland inventory data

Forestland inventory data came from the USDA Forest Service Forest Inventory and Analysis (FIA) program. The FIA program is the primary source for information about the extent, condition, status and trends of forest resources across all ownerships in the United States (Smith, 2002). FIA applies a nationally consistent sampling protocol using a quasi-systematic design covering all ownerships in the entire nation (Bechtold and Patterson, 2005). FIA operates a multi-phase inventory based on an array of hexagons assigned to separate interpenetrating, non-overlapping annual sampling panels (Bechtold and Patterson, 2005). In Phase 1, land area is stratified

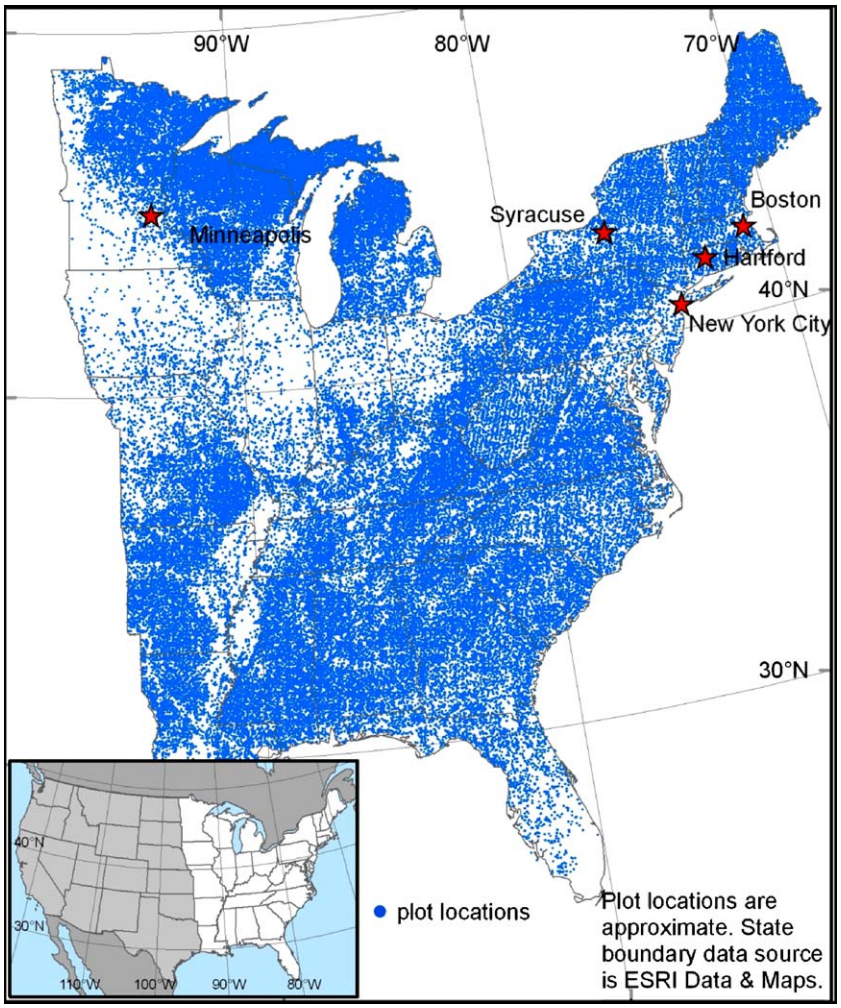

Fig. 1. Urban study areas and forestland study plots in eastern United States.