Forest Ecology and Management 341 (2015) 110–120

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Forest change in the Driftless Area of the Midwest: From a preferred to undesirable future

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ARTICLE INFO

Article history:
Received 5 October 2014
Received in revised form 13 December 2014
Accepted 16 December 2014
Available online 30 January 2015

Keywords:
Forest Inventory and Analysis
Mesophication
Oak forest
U.S. Public Land Survey

ABSTRACT

In the midwestern and eastern U.S., oaks (*Quercus* spp.) have been a dominant component of forests for at least the last 10,000 years, providing vital habitat for numerous wildlife and plant species that have adapted to oak forest conditions. However, the current state of these oak systems, in which there has been a general lack of successful oak regeneration and recruitment and an increase in the relative dominance of mesophytic species, may be nearing critical thresholds. If reached, restoring oak systems through natural regeneration and other methods, such as prescribed fire, may become especially challenging if not impossible. An understanding of spatial variation in oak dominance over time can inform and potentially improve the efficacy of intervention strategies. Using Public Land Survey and Forest Inventory and Analysis (FIA) inventories, we evaluated changes in the composition of timberland across ecoregional subsections in the Driftless Area of the Midwest at three time periods (pre-settlement 1800s, 1990s, and 2000s). We identified an overall decrease in oak dominance, and particularly dominance of the white oak (*Quercus alba* L., *Q. macrocarpa* Michx., and *Q. bicolor* Willd.) species group since the pre-settlement era, and an increase in other eastern soft hardwoods. Within the last 20 years, both the red oak (*Q. rubra* L., *Q. ellipsoidalis* E.J. Hill and *Q. velutina* Lam.) and white oak species groups decreased in dominance, with an increase in hard maple-basswood (*A. saccharum* Marsh., *A. nigra* L., and *Tilia americana* L.) species group dominance, indicating further mesophication of forests in the region. However, we found a notable decrease in hard maple-basswood relative dominance within the small diameter class across most of the regions within the last 10–20 years, with an increase in dominance of other, non-oak, species. Our findings complement qualitative evidence from interviews with natural resource professionals from the region and offer further information on the potential for forest conversion to "undesirable" forest conditions, as identified as a source of concern by some professionals. There was spatial variation in these trends, however, with some pronounced differences across adjacent state boundaries. The variation in forest change across state boundaries suggests the role of state-level socioeconomic and policy factors in affecting forest conditions, and thus the potential for a targeted and timely approach to promoting preferred pathways of change.

1. Introduction

Oak-dominated forests (*Quercus* spp.) of the midwestern and eastern United States are experiencing substantial changes, as the combination of natural succession and human-related factors have created conditions that typically favor more mesic, shade-tolerant, broad-leaved forest types (termed the "mesophication" of the forests; Nowacki and Abrams, 2008). The consequences of this conversion may have profound impacts on ecosystem services. For instance, oaks provide important resources for a variety of plants and animals (McShea and Healy, 2002; Rodewald and Abrams, 2002; Fralish, 2004) and are highly valued by society for economic and cultural reasons (Starrs, 2002). Yet, management to promote and retain oak as a dominant forest component is fraught with difficulties, including the need for adequate forest disturbance. For example, prior to Euro-American settlement, the disturbance of oak forests by periodic fire was common (Abrams, 1992), and

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http://dx.doi.org/10.1016/j.foreco.2014.12.013
0378-1127/

early- to mid-successional, fire-adapted oak forests maintained a competitive advantage over later-successional forest types. Spatial variation in fire disturbance maintained landscape-level heterogeneity of ecosystem types (Nowacki and Abrams, 2008). Changing land ownership patterns and management decisions since settlement have contributed to altered fire regimes, particularly fire exclusion, and consequently early- to mid-successional communities have subsequently dwindled in extent (Williams, 1989; Askins, 2001; Hanberry et al., 2012). Presently, fire suppression and widespread selective harvesting (often high-grading) of oak forests have led to within-stand and landscape-level forest homogeneity, favoring later-successional forest types (Kittredge et al., 2003; Nowacki and Abrams, 2008; Rhemtulla et al., 2009).

Forest managers seeking to promote oak regeneration face combined ecological, economic, and social issues that inhibit the efficacy of typical oak management prescriptions, such as overstory removal and prescribed fire (Knoot et al., 2009), especially since the majority of forestland in the U.S. is privately owned (Butler and Leatherberry, 2004). Periodic disturbance is crucial to the persistence of oak (Johnson et al., 2009), but management aimed at maintaining or restoring early- to mid-successional types may appear counterintuitive to conservation-minded small private landowners (Askins, 2001). In addition, trends in forest parcelization and land tenure in the U.S. (Best and Wayburn, 2001; Zhang et al., 2009) reduce the likelihood that landowners will embrace the long-term land management perspectives that are required for perpetuating oak (Knoot et al., 2010).

The current state of oak forests in the midwestern and eastern U.S., in which there has been a general lack of successful oak regeneration and recruitment and an increase in the relative dominance of mesophytic species, may be nearing critical thresholds. If reached, restoration through natural regeneration and other methods, such as prescribed fire, may become especially challenging, if not impossible (Nowacki and Abrams, 2008). Yet, changes in forest composition can be highly variable across the landscape, likely due to complex and interacting driving factors (Fei et al., 2011). For example, social forces, including but not limited to forest parcelization and short land tenure, constrain landowner decision making regarding oak at multiple spatial scales (Knoot et al., 2010). Ecological drivers of forest change (e.g., availability of oak regeneration, soil moisture availability) also occur at multiple scales and vary over space and time (Iverson et al., 1997; Nowacki and Abrams, 2008; McEwan et al., 2011). There are a variety of policy mechanisms, including economic incentives, which could be used to encourage landowners to conserve oak (Fischer and Bliss, 2008). But spatially informed approaches—those which identify regions where forest change is most rapid and pronounced or where forest composition appears stable—could help increase the effectiveness of the limited funding devoted to landowners assistance.

The purpose of our research was to evaluate the magnitude and direction of forest change among three time periods—1832–1857, 1990–1996, and 2006–2010—across the Midwest Driftless Area, particularly focusing on change in the dominance of oaks. This region of the Midwest has experienced an overall decrease in the total spatial extent and dominance of oak-hickory forests over the last century and half (Rhemtulla et al., 2009). Yet, questions remain concerning how different species groups of oaks have changed over time relative to other dominant tree species and whether trends in oak forest composition follow similar trajectories in other regions (Abrams, 2003). We address three main questions in this study: (1) To what extent has the dominance of different oak species groups, relative to other tree species groups, changed over time? (2) Are changes in forest composition consistent across the region or, alternatively, do trajectories vary depending on location? (3) What is the likely future trajectory of change? We expect this quantitative assessment of the spatial variation in forest change across the region can promote dialogue on preferred alternative futures for the forest resources, how to attain them, and the development of targeted policies to achieve such visions.

2. Methods

2.1. Study area

The Driftless Area, also known as the Paleozoic Plateau or Blufflands, is roughly 50,000 km^2 in size, is dissected by the Mississippi River flood plain, and includes portions of Minnesota, Wisconsin, Iowa, and Illinois (Fig. 1). This geologically unique region was circumvented by ice during the most recent glaciation (Hobbs, 1999) and is characterized by a loess-capped plateau and steep ravines formed by several large rivers that flow through the region. Prairie soils can be found on the ridges, with thick silt loams (loess) covering cherty residuum, with an underlying dolomite bedrock, and silt loam over sandstone on valley walls found in some parts of the region (Albert, 1995). Soils are typically considered Udalfs, with Udolls on the valley floors (Albert, 1995). The Driftless Area is considered part of the humid, hot continental climate division (mean annual precipitation = 82 cm, mean January temperature = −9.7 °C, mean July temperature = 22.3 °C; Wendland et al., 1992), and is contained within the eastern deciduous forest province (Bailey, 1983).

Historically, the Driftless Area was composed of diverse land cover types including tallgrass prairie, oak savanna, and sugar maple-basswood forest (Albert, 1995; Shea et al., 2014). The landscape has experienced pronounced changes in land cover over the last century and half, as much of the savanna and prairie were replaced by agricultural lands (Rhemtulla et al., 2007) and the suppression of fire promoted a greater extent of closed-canopy forests (Curtis, 1959). Currently the landscape is composed primarily of agricultural lands and deciduous forest (Fry et al., 2011).

2.2. Description of data

We evaluated changes in tree species group relative dominance in the Driftless Area using Public Land Survey (PLS) and the USDA Forest Service Forest Inventory and Analysis (FIA) program data. Pre-settlement relative dominance was derived from Public Land Survey records collected in the Driftless Area from 1832 to 1857. The PLS was established by the U.S. General Land Office as a means of demarcating 1.6 km by 1.6 km (1 mi by 1 mi) section boundaries for sale and settlement. PLS surveyors marked the intersection points of each section (section corners) and halfway between the section corners (quarter corners), while also blazing and taking notes on two to four "witness" trees near corner points. In their notes, surveyors kept track of species, diameter, azimuth, and distance from corner for each witness tree. In the Driftless Area, surveys were completed before widespread Euro-American settlement. Because these records are extensive and provide spatially explicit information on vegetation and other landscape features, PLS records have been widely used by researchers to identify pre-settlement vegetation in various regions of the Midwest and elsewhere (Schulte and Mladenoff, 2001). We used data from a geographic information system (GIS) database containing PLS witness tree information (the species, diameter, azimuth, and distance from corner) for all section and quarter corners in the Driftless Area (Shea et al., 2014). While there is some degree of error in the PLS witness tree records, typically associated with surveyor bias, our use of the data to assess relative changes in species group dominance across broad spatial scales limits the impact of surveyor bias (Schulte and Mladenoff, 2001; Liu et al., 2011).