Forest Ecology and Management 430 (2018) 94–104

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Spatiotemporal patterns of forest damage and disturbance in the northeastern United States: 2000–2016

Alexandra M. Kosiba[a,b,*], Garrett W. Meigs[a,c,d], James A. Duncan[a,b], Jennifer A. Pontius[a,b,e], William S. Keeton[a,c], Emma R. Tait[a,b]

[a] University of Vermont, Rubenstein School of Environment and Natural Resources, 81 Carrigan Drive, Burlington, VT, USA
[b] Forest Ecosystem Monitoring Cooperative, 705 Spear Street, South Burlington, VT, USA
[c] University of Vermont, Gund Institute for Environment, 617 Main Street, Burlington, VT, USA
[d] Oregon State University, College of Forestry, 3100 SW Jefferson Way, Corvallis, OR, USA
[e] USDA Forest Service, Northern Research Station, 81 Carrigan Drive, Burlington, VT, USA

ARTICLE INFO

Keywords:
Aerial detection surveys
Ecosystem services
Forest health
Tree mortality
Insects and disease
Disturbance

ABSTRACT

Forest damage and disturbance can have significant influences on tree vigor, species composition, biodiversity, and associated ecosystem services. Recognizing the importance of monitoring spatiotemporal patterns of forest health, federal and state agencies in the United States (US) have conducted aerial insect and disease surveys (IDS) annually to quantify the extent of forest damage by type and causal agent. Although agencies have collected these geospatial data for decades, long-term trends and patterns have not been synthesized across the predominantly forested region of northern New England and New York. Here, we utilized a novel, online forest damage and disturbance mapping portal, the Northeastern Forest Health Atlas, to investigate inter-annual and long-term patterns (2000–2016). Our analysis indicated that ~11.0 million ha of forestland (10% of the study region) experienced at least one damage event (i.e., an IDS polygon) over the 17-year period, averaging 647,425 ± 215,482 ha (3.4 ± 1.1% of the region's forestland) annually. While there were no detectable linear, long-term trends in annual extent or relative abundance of damage by agent category, we found that some ecoregions experienced relatively higher damage rates (e.g., Acadian Plains and Hills, Atlantic Coastal Pine Barrens). Across the region, insects were the most extensive damage agent category mapped (~8 million ha), with a relatively small number of invasive insects (19 species) accounting for half of this damage. Because climate change may alter the type, severity, and frequency of forest disturbance, quantifying baseline patterns of forest damage is critical for detecting shifts in forest dynamics and developing adaptive management strategies.

1. Introduction

Tree damage and disturbance are essential drivers of forest ecosystem dynamics. Because damage agents vary widely in their spatiotemporal effects (Franklin et al., 2002; Thompson et al., 2013), they can contribute to structural and compositional complexity of forests at multiple scales in space and time (Seymour and White, 2002; Meigs and Keeton, 2018). By impacting forest productivity, composition, and structure (Fahey et al., 2018), damage agents also can alter the provisioning of important ecosystem services (e.g., timber production, carbon storage, biodiversity, wildlife habitat) (Thom and Seidl, 2016). However, the variability, complexity, and multi-scalar nature of damage agents present fundamental challenges to research and management efforts. These factors, coupled with projections that climate change may alter the nature and frequency of forest disturbances (Dukes et al., 2009), highlight the need for better understanding and monitoring of both historical and current patterns of forest damage and disturbance across the full suite of causes.

Here, we define forest damage broadly to include visual symptoms of acute and non-acute canopy damage that results from either abiotic or biotic causal agents. Acute damage agents include ice, wind, insect herbivory, fire, and animals, whereas non-acute damage agents include disease, unfavorable weather conditions (e.g., drought), fungi, and air pollution. While non-acute agents can influence tree vigor and mortality directly, also they can contribute to further decline when combined with inciting stressors (Manion and Lachance, 1992). As such, forest damage can encompass both abrupt and gradual changes associated with tree mortality and decline from the spatial scale of

* Corresponding author at: University of Vermont, Rubenstein School of Environment and Natural Resources, 81 Carrigan Drive, Burlington, VT, USA.
E-mail address: akosiba@uvm.edu (A.M. Kosiba).

https://doi.org/10.1016/j.foreco.2018.07.047
Received 4 May 2018; Received in revised form 23 July 2018; Accepted 26 July 2018

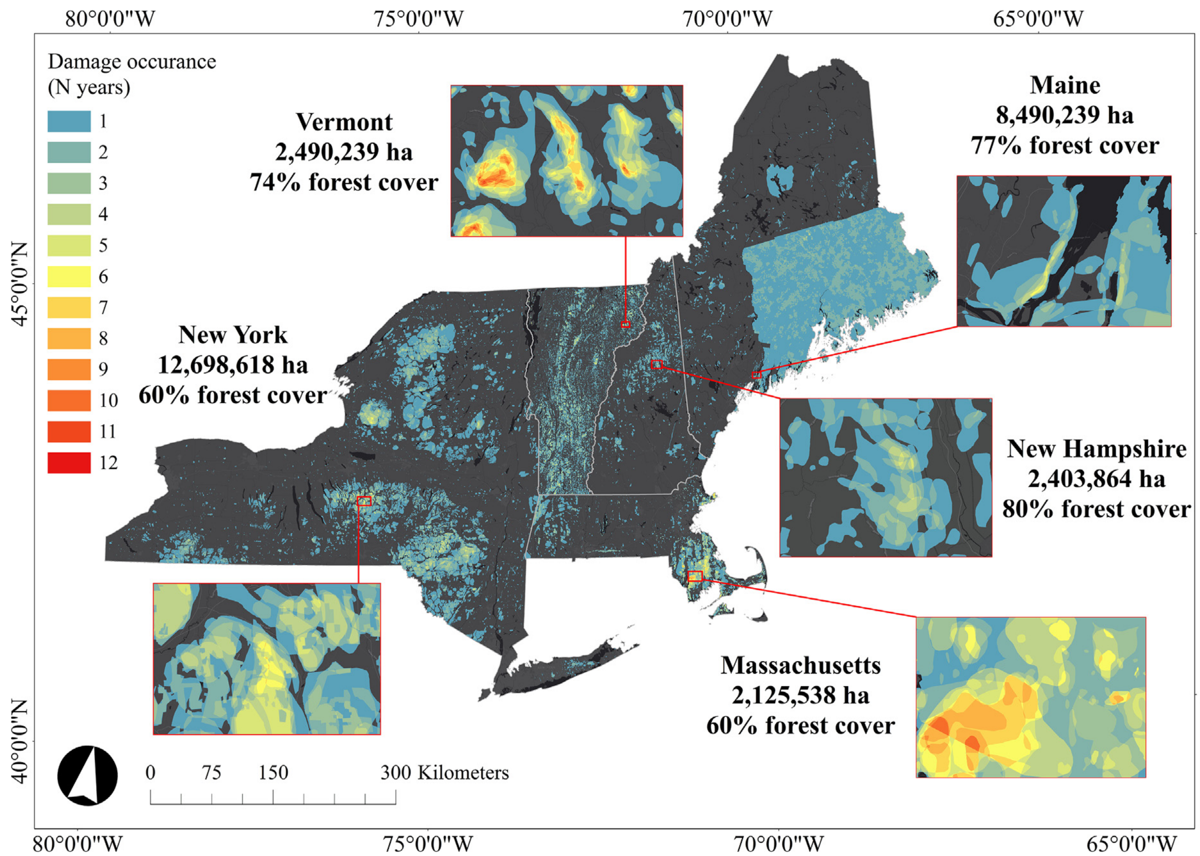

Fig. 1. Locations of mapped forest damage polygons in the study region (MA, ME, NH, NY, VT) from 2000 to 2016 according to insect and disease surveys, including the total area (ha) and percent forest cover per state. Different colors indicate the number of years that damage was mapped over the 17-year record. Insets show examples of high damage occurrence in each state.

individual trees to forest stands, landscapes, and regions (e.g., Pickett and White, 1985; Frelich, 2002; Vanderwel et al., 2013; Cohen et al., 2016).

Forest managers, policy makers, and key stakeholders are concerned that the severity and frequency of forest disturbance may be shifting with ongoing changes to land use, climate patterns, and native and invasive species distributions (Dale et al., 2001; Dukes et al., 2009; Hulme, 2009; Sturrock et al., 2011; Weed et al., 2013; Dale et al., 2016; Kolb et al., 2016). Specifically, the frequency and severity of damage caused by some insects and diseases are projected to increase, as are destructive weather events, droughts, and wildfires (Ayres and Lombardero, 2000; Bentz et al., 2010, Dale et al., 2001; Dukes et al., 2009; Littell et al., 2010; Sturrock et al., 2011). Although previous studies have suggested that increasing disturbance could enable some forests to adapt to climate change by allowing for more frequent pulse regeneration, thus facilitating species range shifts (e.g., Overpeck et al., 1990), recurrent or severe damage could compromise ecosystem integrity. Thus, quantifying the variability in frequency and extent of specific forest damage agents will provide timely and necessary information for managers working to sustain forests during a time of significant global change.

Throughout the US, annual insect and disease surveys (IDS; formerly known as "aerial detection surveys" or ADS) have been conducted by state and federal agencies for decades to assess forest health by mapping locations of biotic and abiotic forest damage (McConnell, 1999; Johnson and Wittwer, 2008). Aerial sketch-mapping surveys have been considered relatively cost-effective assessments of current forest condition that allow technicians to respond quickly to reports of damage (Johnson and Wittwer, 2008). However, there are well-known limitations to collecting IDS from fixed-wing aircraft, including inconsistencies in attribution among personnel, visibility of damage symptoms, time of year, tree phenology, weather conditions, changing survey protocols, and availability of ground-based validation observations (Johnson and Ross, 2008; Johnson and Wittwer, 2008).

Nevertheless, these aerial surveys provide the only long-term, spatially explicit record of damage agents for the predominatly forested region of the northeastern US (hereafter "region"). Because of the region's large number of forest damage agents, expanding populations of invasive insects and diseases, and heterogeneous forest composition and structure, most causes of damage must be identified at the time of disturbance or during symptomatic periods for correct attribution. The IDS program has warranted sufficient interest from the forest management community to sustain funding across the region for decades, due in part to the substantial socioeconomic impacts that have resulted from forest damage. For example, damage to regional forests has disrupted power transmission lines, hindered transportation, harmed structures, and depressed property values (Ayres and Lombardero, 2000; Irland, 1998; Lovett et al., 2006).

Despite the interest in and potential utility of IDS data for multiyear, regional assessments, previous efforts have focused on annual summaries for individual states or municipalities. To date, the use of IDS data in peer-reviewed literature has been limited to specific decline concerns in the western or midwestern US (e.g., Woodall et al., 2010; Hicke et al., 2012; Meddens et al., 2012; Meigs et al., 2015). Moreover, state and federal agencies have not made IDS data publically available in a consistent format that enables users to assess multiple years of spatial damage efficiently. Although IDS data synthesis in the region has been complicated by historically disparate methods and survey foci among the states, these data are valuable in understanding spatio-temporal patterns of forest damage, particularly in terms of inter-annual variability, cumulative effects, and the potential consequences of shifting disturbance regimes.