Available online at www.sciencedirect.com

SCIENCE DIRECT®

Forest Ecology and Management 227 (2006) 31–41

Forest Ecology and Management

www.elsevier.com/locate/foreco

Forest harvesting and land-use conversion over two decades in Massachusetts

Robert I. McDonald [a,*], Glenn Motzkin [a], Michael S. Bank [a], David B. Kittredge [b], John Burk [a], David R. Foster [a]

[a] Harvard Forest, Harvard University, Petersham, MA 01366-0068, United States

[b] Department of Natural Resources Conservation, University of Massachusetts, Amherst, MA 01003, United States

Received 30 August 2005; received in revised form 6 February 2006; accepted 6 February 2006

Abstract

Forest harvesting is an important, ongoing disturbance that affects the composition, structure, and ecological function of the majority of the world's forests. However, few studies have examined the interaction between land-use conversion and harvesting. We utilize a unique, spatially explicit database of all cutting events ($n > 13{,}000$) and land-cover conversions for Massachusetts over the past 20 years to characterize the interactions between land-use conversion and harvesting, and their relationship to physical, social, and economic factors. We examined three key variables: the proportion of forest harvested within an ecoregion (%), the mean harvest intensity ($m^3\ ha^{-1}$), and the mean harvest event area (ha). The mean harvest intensity ($43\ m^3\ ha^{-1}$), mean harvest area (15 ha), and average species composition of harvests were remarkably constant over time. However, the proportion of forest harvested varied widely across the state, ranging from 0.01 to 1.48% annually. Harvesting activity ceases near the far outer suburbs of major metropolitan areas, as well as along the coast. There is a strong negative correlation ($r = -0.89$) between the proportion of forest lost to land-use conversion and the proportion of forest harvested. CART analysis shows that road density is the most important overall predictor of probability of forest harvest, with median house price also an important predictor. Harvest intensity, in contrast, appears related to ownership type, with state-owned lands having more intensive harvests ($53\ m^3\ ha^{-1}$). Our results suggest that current forest management regimes are determined largely by the economic influence of nearby urban centers.

Keywords: Harvest intensity; Forest fragmentation; Forest management; Massachusetts; New England; Non-industrial private forests

1. Introduction

Forested landscapes in the eastern United States have been dramatically transformed over the last 300 years, as forests were widely cleared for agriculture through the mid 19th century and farmland was subsequently abandoned and allowed to become reforested through natural successional processes (Cronon, 1983; Foster et al., 1998; Foster, 2000). Modern forests continue to be dramatically altered by two major anthropogenic disturbances: timber harvesting (Kittredge et al., 2003) and permanent conversion due to land-use change (Riitters et al., 2002). However, few studies have examined the interaction between these two dominant land uses (viz., Wear et al., 1999). As harvesting is common across the eastern US (Kittredge, 1996), understanding both land conversion and harvesting patterns has implications for many ecological processes, such as invasive species spread (cf., Lundgren et al., 2004) and wildlife habitat (DeStefano and DeGraaf, 2003). In this paper, we examine the spatial and temporal variability of harvesting patterns across the state of Massachusetts and model the interaction between harvesting and land-use change, particularly the expansion of suburban and exurban settlement into previously rural timber-producing areas.

We utilize a unique database of all cutting events conducted in Massachusetts over a 20-year period (1984–2003) to quantify the spatial patterns of harvesting in a region characterized by low to moderate intensity harvests, primarily on non-industrial private forest lands. This database has two advantages over other databases of timber harvesting. First, it is spatially explicit, allowing for detailed analysis of causes, patterns, and consequences of forest harvesting. Second, previous studies of forest harvesting patterns have focused primarily on public or large industrial lands, as reliable spatial information on forest harvesting is often lacking for private ownerships (Spies and

* Corresponding author. Tel.: +1 978 724 3302; fax: +1 978 724 3595.
E-mail address: rimcdon@fas.harvard.edu (R.I. McDonald).

0378-1127/$ – see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.foreco.2006.02.006

Turner, 1999). This is particularly true for forests in the eastern US where most land is in small parcels owned by private landowners (Kittredge et al., 2003). Our dataset overcomes these restrictions and allows a full examination of non-industrial forest logging patterns.

Furthermore, there have been only a few studies on how land-use change (Houghton, 1994), and specifically suburban and exurban development (cf., Theobald, 2001), affect forest harvesting patterns across a broader region. Several studies have suggested that logging ceases above a threshold population density (Wear et al., 1999). Recent work by Liu et al. (2003) suggests that household density might be a more proximate predictor in such cases, as it is more directly related to many important land-development processes. In a related vein, Kittredge (1996) and Kittredge et al. (2003) have suggested that parcel size is an important determinant of rates of logging, as it directly relates to the scale at which forest harvesting may be economically feasible. Lacking information on parcel boundaries for the entire state, we examine forest patch size and local road density as proxy variables for this parcel size effect. As the Massachusetts landscape has a relatively dense network of roads compared with more rural areas, we do not believe road density is indicative of ease of access, as almost all forests in Massachusetts are within 2 km of a road (cf., Riitters and Wickham, 2003), and we thus use road density simply as a correlate of parcel size. Finally, some economists have suggested that land price (cf., Lambin et al., 2001) will influence the cost–benefit analysis of the decision to harvest a forest. It has proven difficult to separate these factors, as few studies have spatially explicit forest harvesting data at scales that correspond with the scale at which harvesting decisions are made. Moreover, to some extent these factors are correlated spatially. For example, development scenarios that increase housing density in a region will likely increase road density, decrease forest patch size, and raise local land prices. Nevertheless, this correlation will not be perfect, and potentially different factors could be important in different regions.

The specific objectives of this investigation are to:

- quantify and evaluate spatial patterns of forest harvesting from 1984 to 2003;
- identify spatial and temporal variation in species composition of forest harvesting;
- evaluate trends in forest harvesting with respect to ownership type and landscape characteristics;
- model the effect of suburban and exurban development on forest harvesting rates.

2. Study area

The physiography of Massachusetts varies widely, from the sandy coastal region to upland regions of granite, schist, and gneiss, to the deep lowlands of the Connecticut and Housatonic rivers (Motts and O'Brien, 1981). Soils for much of the state are Inceptisols, with the valley floodplains and the sandy coastal region dominated by Entisols, and the western upland (between the Connecticut and Housatonic valleys—Fig. 1) being characterized by Spodisols (Brady and Weil, 2002). For the purposes of this paper, 'eastern Massachusetts' is used to refer to the southern New England Coastal Plain and points eastward, and 'western Massachusetts' refers to the regions of the state west of the coastal plain (Fig. 1). Temperature varies somewhat with distance from the ocean, from a mean high of 25.5 °C in August and a mean low of −6.1 °C in January at the coast to a mean high of 27.8 °C in August and a mean low of −10.0 °C in the Connecticut River valley (NOAA-CIRES Climatology Center). Precipitation is greatest in the western upland region (147 cm year^{-1}), and is lower in the Connecticut River valley (97 cm year^{-1}), with snowfall being more prevalent in interior regions of the state (USDA-NRCS).

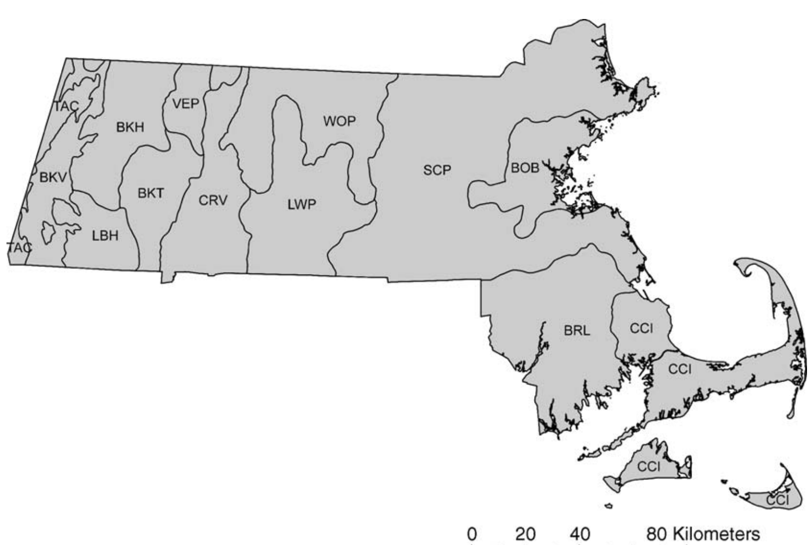

Fig. 1. Ecoregions of Masschusetts: Taconic Mountains (labeled as TAC), Berkshire Valley (BRV), Berkshire Highlands (BKH), Berkshire Transition (BKT), Vermont Piedmont (VEP), Worcester Plateau (WOP), Connecticut River Valley (CRV), Lower Worcester Plateau (LWP), Southern New England Coastal Plain (SCP), Boston Basin (BOB), Bristol Lowland (BRL), Cape Cod and the Islands (CCI), and the Lower Berkshire Hills (LBH).