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Edge influence detection using aerial LiDAR in Northeastern US deciduous forests

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ABSTRACT

The northeastern United States is currently experiencing a decline in forested lands, primarily due to the expansion of human development. Of particular concern is the loss of "core areas" or the areas within forests that are not influenced by other land cover types. Core areas are of significant importance to native flora and fauna, since they generally are less vulnerable to invasion by exotics and are more resilient to the effects of climate change. However, the exact reduction of core area in the northeast is still unknown. Current methods of estimation are not particularly precise, since areas of edge influence are quite variable and situational. Therefore, the purpose of this study is to devise a new method for identifying edge influence areas using remote sensing techniques. Eight transects were sampled perpendicular to the edge of an abandoned golf course within Harvard Forest in Petersham, MA. Vegetation inventories as well as Photosynthetically Active Radiation (PAR) at different heights within the canopy were used to determine edge depth in the field. Small-footprint discrete aerial LiDAR datasets were comparatively used to identify edge depths. LiDAR returns were binned and transformed into canopy height profiles before the sum of squared differences was used to determine where edge influence diminished, creating a LiDAR derived edge depth. LiDAR estimated edge depths were not significantly different from the field identified edge depths, indicating it might be a low-cost method for estimating edge depths.

1. Introduction

Habitat loss and fragmentation due to increasing populations and development is currently a major concern of ecologists all over the world (Andrén, 1994) as well as in the northeastern United States (Thompson et al., 2011). In the northeastern United States, most of this habitat fragmentation is primarily within historically forested habitat. Many previous studies have looked at the long term and far reaching effects of forest loss, fragmentation, and change from anthropogenic forces on the landscape (e.g. Haila, 2002; With, 2002; Fahrig, 2003; Turner, 2005; Fischer and Lindenmayer, 2007; Wiens, 2008). In these studies, forest modification, or the combined effects of loss and fragmentation, has been linked to losses in biodiversity, changes in carbon storage, reduction in water quality, and impacts on many other ecosystem services (Andrén, 1994; Riitters et al., 2002; Vogt et al., 2007).

Of particular importance to forest modification studies is the identification of "core" and "edge" or "edge influence" habitats (Harris, 1988). Core habitat, as defined by Harper et al. (2005) is "the total patch or landscape area that consists of interior forest outside the zone of significant edge influence (EI)". Contrarily, edge influence (EI) is "the effect of processes (both abiotic and biotic) at the edge that result in a detectable difference in composition, structure, or function near the edge, as compared with the ecosystem on either side of the edge"; and edge is the "interface between different ecosystem types" (Harper et al., 2005). EI areas are more susceptible to invasion by exotic species, biodiversity changes, and climate stressors, while core habitats have been shown to be more resilient to these effects (Harper et al., 2005; Campbell et al., 2009). Therefore, depth of EI, particularly when compared to amount of adjacent core habitat, is a good indicator for ecosystem health.

However, depth of EI is often very difficult to identify over large areas, since it is site specific (Matlack, 1994; Newmark, 2001). Previous studies have predicted or found that depth of EI, or edge depth, varies over space due to stand age, patch contrast, core canopy diversity or closure, aspect, slope, and even soil type, and those edge depths can then vary over time as edges mature (e.g.

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Matlack 1994; Newmark 2001; Harper et al., 2005). Since the edge depth can be so variable over short distances and time, estimating edge depth at a landscape scale to identify areas of forest core can be very difficult to do accurately without extensive field surveys, which require a large amount of time and money. Therefore, remote sensing may be a useful tool in identifying edge depth in certain habitats on a relatively short time scale and with little monetary investment. Since edge depth is often associated with local processes such as canopy closure and structure, the general research question addressed in this paper is if LiDAR (Light Detection and Ranging) is a useful tool for creating better estimates of EI as it varies over the landscape.

LiDAR has been used in the past to look at forest structure, even at particular forest edge characteristics (Parker et al., 2001; Lefsky et al., 2002; Lesak et al., 2011; Stark et al., 2012), but it has not been used to identify edge depth within a larger landscape context. Advances in LiDAR and new campaigns by many public and private agencies, such as the recent launch of the NEON airborne observation platform (AOP; NEON, 2016.), have made both full waveform and discrete return aerial LiDAR easier to obtain. While full waveform LiDAR has proven its' worth in assessing forest structure, discrete return LiDAR is more often available (publicly or for a small fee) and easier to process for a novice. Therefore, the specific objective of this study is to determine whether aerial derived discrete return LiDAR is well suited to determine depth of EI at the landscape scale as a simple method for assessing the effects of forest fragmentation.

2. Methods

2.1. Study site

The research was carried out at the Harvard Forest Long Term Ecological Research site, in Petersham, MA at a recently acquired property ideally situated for a study of edge depth (Fig. 1). The study site is on land that had been used as a golf course for approximately 90 years before Harvard Forest obtained the land in 2012. Harvard Forest has since prepared the land to become rangeland for sheep and cattle allowing natural grasses to return to the site. Harvard Forest has also encouraged the establishment of research sites around the property to learn about the ecology of the historically cleared land and its surrounding Transition Hardwood-White Pine-Hemlock forest. Coincidentally, there is also aerial LiDAR available for the site; creating perfect conditions for testing the feasibility of using LiDAR in edge depth detection.

2.2. Field methods

Eight transects were established at the research site to measure edge depth (Fig. 1). For this study, edge depth, or area of EI, is defined as how far into the forest you must travel before the structure and composition of the canopy becomes consistent with that of the interior forest as you move away from the field edge. Therefore, the transects were set up so that they began at the intersection of the maintained cleared area and the forest (i.e. the edge) and con-

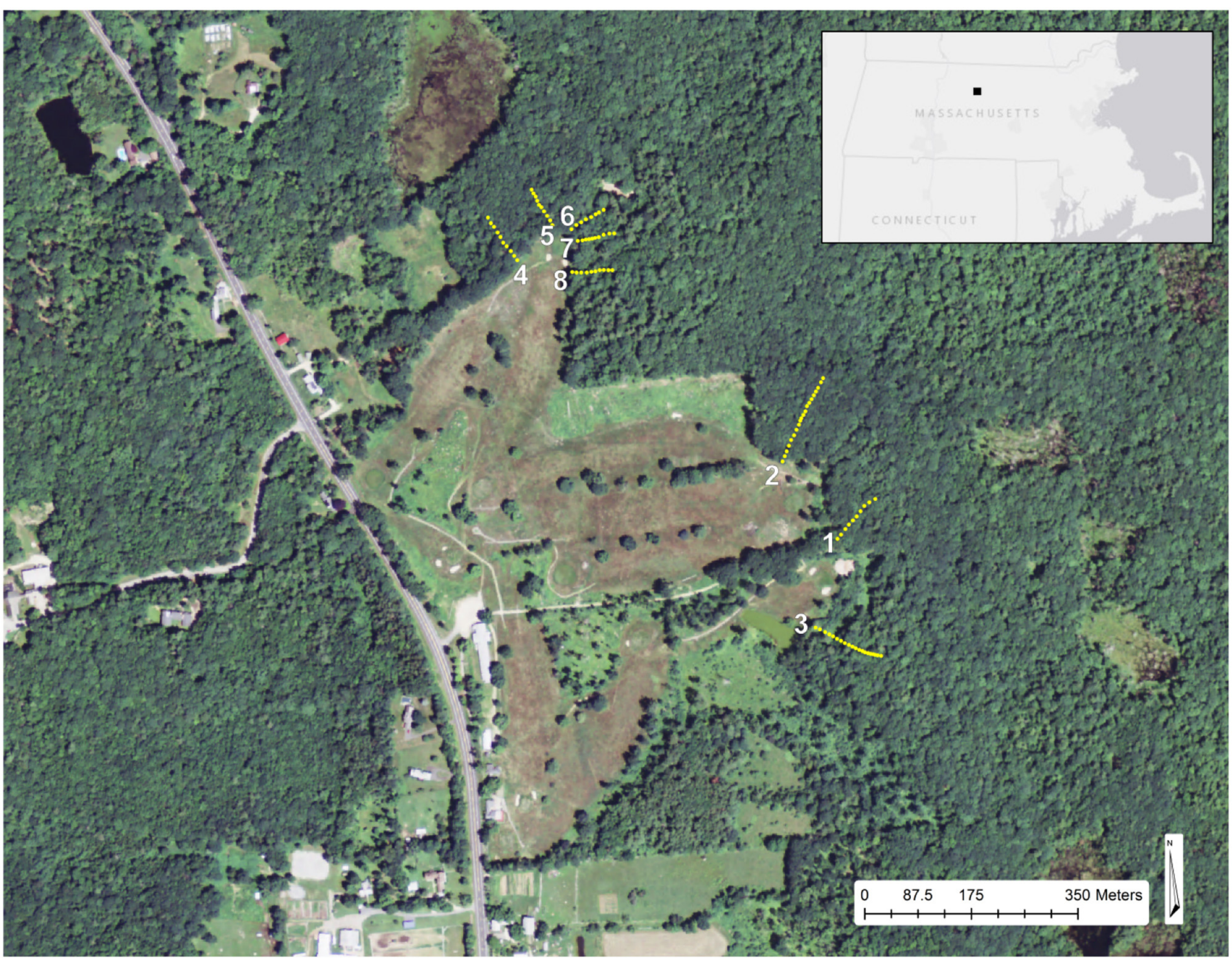

Fig. 1. Transects at the Harvard Forest Long Term Research site in Petersham, MA. Each dot represents a sample location along each transect and the inset map shows the location of the transects within Massachusetts.