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Effects of rural residential development on forest communities in Oregon and Washington, USA

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ABSTRACT

Rural residential development in forests of Oregon and Washington continues to be a key driver of land use change. This type of development can have a variety of effects on the goods and services forests provide to the region. We used structure density from photo-interpreted points around forest inventory and analysis plots to examine differences in forest attributes with respect to varying development metrics. Our results demonstrate that forest ownership (public vs. private), structure density, and proximity of development are critical factors in explaining variation in forest attributes. Small-scale fragmentation, standing dead tree volume, coarse woody debris, and the propensity for introduced species are all affected by development close to the borders of public land. Differences in coarse woody debris, small-scale fragmentation, and propensity for introduced species are also affected by the density and proximity of development on private ownership.

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1. Introduction

Forest communities of the United States provide a variety of goods and services to the American public. Some of these include fresh water, wildlife habitat, wood and wood products, recreational opportunities, and carbon storage and sequestration. As populations grow and rural residential development occurs in forested communities, some of these goods and services may be at risk (Brown et al., 2005; Stein et al., 2010). The most extreme example of this risk is the conversion of forest land to other land uses, such as residential.

Oregon and Washington have some of the most productive forest lands in the United States, having 17.1 million hectares, roughly 14% of this forest land is capable of producing greater than 11.5 cubic meters-per-hectare-year of wood at culmination of mean annual increment (Donnegan et al., 2008; Campbell et al., 2010). High population growth and concern for preserving both forest and agricultural land caused both states to enact legislation addressing development, the Land Conservation and Development Act passed in Oregon in 1973, and Washington's Growth Management Act in 1990. The major concern for development involved private lands in both states, public lands are generally exempt from development, but may have development in close proximity to their borders. Although laws in both states address land use conversion, there are still concerns about the effects of rural residential development intermingling in resource areas and at the edges of public lands.

The most obvious and damaging effect of development in forested landscapes is seen when a stand of trees becomes a community of houses. On a lesser scale, a grove of trees might turn into a house and yard, with a transportation corridor creating access. Less obvious effects are those created at the edges of a site and its transportation corridor. Effects from roads can be tied to the amount of traffic, but even secondary roads may have effects that extend for more than 200 m (Forman, 2000; Trombulak and Frissell, 2000; Saunders et al., 2002). The edge may attract more of the species that thrive there as opposed to those that like large tracts of continuous forest. The more edges there are in a forested landscape, the more fragmented habitat becomes. Roads also have an effect on natural water pathways that drain forested land to streams. Once a road is installed, the impervious or semi-impervious surface directs runoff differently than a forested landscape by focusing runoff to collection points. Some of the impacts from development may be minor; others while minimal for a single developed site, could be cumulative with increasing development.

Human disturbance to forested landscapes increases as development increases. In addition to wildlife habitat fragmentation, disturbances can include introduced vegetation species, interactions

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between pets and wildlife, increased sediment runoff, alterations in biodiversity, and disruption of ecosystem processes. There are multiple studies that address effects on avian (Fraterrigo and Wiens, 2005; Marzluff, 2005) and mammalian habitat changes (Odell and Knight, 2001; Gibeau et al., 2002; Fairbanks and Tullous, 2002). Several studies investigate disruption of ecosystem processes (McDonnell et al., 1997; Hansen et al., 2005). In many areas in Oregon and Washington, private lands occupy the valley bottoms where development is most likely, focusing development effects in riparian areas. Major urban centers in Oregon are found along waterways in the Willamette Valley and in the Puget Sound area in Washington. Transportation corridors, rail lines, and roads are often located in valley floors and pose direct effects on riparian areas.

Forest management decisions can be affected by ownership changes and fragmentation on surrounding forest land. As development encroaches into privately owned forested areas, active management such as harvesting, site preparation, and thinning are less likely (Barlow et al., 1998; Wear et al., 1999; Munn et al., 2002; Kline et al., 2004). Others have hypothesized that development brings in newer owners who value forest land for purposes other than timber production, thus creating a management conflict with timber producers and that perceived impermanence of land use may discourage investment in timber production (Wear et al., 1999; Kline et al., 2004). As development occurs, forest ownership becomes more fragmented and tract sizes decrease, resulting in increases in management costs per unit area (Harris and DeForest, 1993).

Wildfire suppression and pre-fire fuels management are greatly affected by the amount of development on forest land (Radeloff et al., 2005; Gill and Stephens, 2009). Increasing development will generally result in greater potential for ignitions (Syphard et al., 2009; Narayanaraj and Wimberly, 2012; Chas-Amil et al., 2013). Also, federal wildland fire policy lists protection of human life as its first priority followed by property and resource values (USDA Forest Service, 2005). Therefore areas that have houses will receive suppression efforts before other resource areas, and public land owners may focus funds for fuel reduction in areas that have adjacent homes. Knowledgeable owners of individual houses will strive to maintain a defensible space around their homes, which may include structural changes to the immediate forest surroundings. Finally, prescribed fire will be difficult to implement in forested areas with intermixed housing, thus forest land owners may be forced to use more costly measures such as mechanical or manual treatments to reduce fuel around their homes (Calkin and Gebert, 2006).

There is adequate research focusing on changes in forest area, forest management, and wildlife habitat resulting from urban development, but few studies have investigated differences in forest attributes due to small amounts of development (Russell et al., 2011).

Our study uses USDA Forest Service Forest Inventory and Analysis (FIA) plot data along with data from land use change studies in Oregon and Washington to examine how forest attributes can change with increasing development in close proximity. A broad scale of development is examined here; in some cases the development is extremely minor such as a single house within 2000 m of the plot center, in other cases there is urban development in close proximity. The objective of this study is to identify various development metrics that show an effect on properties of forested or partially forested FIA plots. A second objective is to identify what levels of development might be associated with a change in forest attributes.

2. Methods

2.1. Study area

The study area consists of all forested land in Oregon and Washington as represented by FIA field plots collected between 2001 and 2010. Elevation ranges from sea level to over 4200 m. The majority of the population in both Oregon and Washington occurs on the western side of the Cascade Range, with smaller population centers on the east side. In both eastern Oregon and eastern Washington, forest land is associated with increasing elevation. Both states have a considerable area of "non-forest" zone at lower elevations on the east side of the Cascade Range. Forests are dominated by Douglas-fir and spruce/fir/hemlock types on the west side and Douglas-fir and ponderosa pine types on the east side. The ownership of forest lands in Oregon and Washington is almost evenly distributed between public and private ownership, with the major public owners being the US Forest Service (NFS), the Bureau of Land Management (BLM), the National Park Service (NPS), the Oregon Department of Forestry (ODF), and Washington's Department of Natural Resources (DNR). Private ownership is split roughly evenly between corporate and non-corporate. Public ownerships tend to have higher average elevation with both the NFS and the NPS having the highest elevations.

2.2. Photo-interpreted points

We used 44.5 thousand photo-interpreted points in Washington with a latest image date of 2006 and 37 thousand points in Oregon with an image date of 2005. Points were placed on a systematic grid to estimate structure density. The imagery consisted of 1-m resolution color digital imagery from the National Agriculture Imagery Program acquired from the Farm Service Agency. Imagery for earlier dates was based on digitally scanned aerial photos that were georegistered in a geographic information system (GIS). The original use of the grid was for stratification for inventory estimates and was later used in land use change studies (Lettman et al., 2011; Gray et al., 2013). Structure density information was not collected on federal lands because land use change and development rarely occur there. Data collected at each of the photo-interpreted points includes, but was not limited to, land use that the point fell in, the number of structures in the surrounding 32.4 ha, and the area of various land uses within the 32.4 ha.

Due to varying grid intensities between the field plot and photo-interpreted grids, there could be as many as nine photo-interpreted points within 2 km of a field plot (Fig. 1). We averaged the structure density (DEN), the increase in structure density from the 1970s to the 2000s (DCHG), and the structure density divided by the distance from point to the plot (DEND) for all the photo-interpreted points that fell within a 2-km radius circle of each forested FIA field plot. We also computed the minimum distance from the field plot to a point that had at least one structure (MDP). The occurrence of a low-density residential or urban zone on any point within 2 km of the plot was also recorded (URB). These various development metrics were used in linear regression and generalized linear models to explain variation in forest attributes computed from FIA field plots as described in the next section.

2.3. FIA field plots

FIA plots represent a spatially balanced sample of field measured plots on a rough 4.8 km grid across the landscape where ten percent are sampled each year (Bechtold and Patterson, 2005). The information collected on each plot included, but was not limited to, tree information, understory vegetation, coarse woody debris, forest land conditions, ownership, tree damages, disturbances, and non-forest land uses. FIA plots can be segmented in several different conditions, for example a plot could have two distinct tree size classes or owner groups. Plots can also be segmented for non-forest conditions, the most common being a road intersecting the plot. This study included only those plots that contain a piece of forest land, defined by FIA as being at least 0.4 ha in