Spatial Pattern and Dynamics of Hardwood Patches in a Multi-Ownership Landscape in the Coast Range of Oregon, 1939 to 1993

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INTRODUCTION

Understanding the effects of environment and history on forest pattern is a fundamental problem in landscape ecology and management. To examine hardwood patch dynamics in this context of disturbance history and environment, we evaluated hardwood patch dynamics over a half-century of active logging in the Central Coast Range, from the years 1939 to 1993.

The prevailing view at present is that the spatial extent of hardwood tree patches in Oregon's Coast Range has increased from mid-1800-European settlement times to the present in response to catastrophic fire and logging. Based on field reconnaissance and evaluation of remote sensing imagery we hypothesized that hardwood cover and patch size has actually declined and patch distribution has undergone topographic constriction toward near-stream areas, where hardwoods are highly competitive, from early to recent forest management years across all ownerships. We hypothesized that declines would be most strongly apparent on industrial private forestlands.

OBJECTIVES

(1) **Characterize the spatial extent of patches**

(2) **Evaluate patch variation in size, shape, and within-patch cover type composition**

(3) **Characterize patch spatial distribution across ownerships and environmental gradients**

(4) **Characterize changes in these patch attributes over time**

METHODS

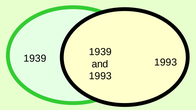

Fig. 1. To achieve our objectives, we measured: (1) the characteristics of two populations of patches separated by time (ovals); and (2) the change in a population of patches over time (intersection of ovals)

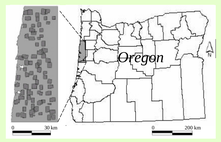

Fig. 2. Location of study area and aerial photograph coverage (darker polygons in enlarged area) in the Coast Range of Oregon.

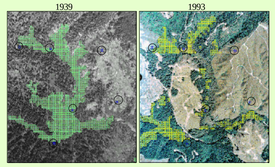

Fig. 3. Hardwood patch initiation plots and patch designation of a 1939 and several 1993 patches in a heterogeneous, dynamic landscape. Rings demarcate 20 m patch initiation plots. The large clear-cut at right of 1993 photo in area was open in 1939. A stream runs N-S in the center of both photos. A single patch in 1939 fragmented into multiple, smaller patches by 1993. Patch areas at the top center and lower left of the 1939 patch expanded along streams by 1993.

Our approach involved sampling two populations separated by time (Fig. 1). We scanned and georeferenced historical (1939) and recent (1993) aerial photographs (Fig. 2) and used GIS techniques to randomly sample and digitally classify 1500 20-meter plots into 14 land cover types (Fig. 3, above right), including hardwood. We delineated hardwood patches from these hardwood patch initiation plots (268 patches obtained from 336 plots in 1939; 244 patches obtained from 294 plots in 1993).

We compared patch characteristics to a suite of GIS-based environmental and ownership information (Fig. 4) for each plot-photo date combination. We used FRAGSTATS software to obtain measures for patch shape, core to edge ratios, and fragmentation.

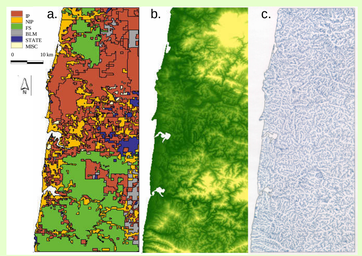

Fig. 4. Selected attributes of the study area.
a. Land ownership.
b. Elevation. Green to yellow gradient reflects lower to higher elevations.
c. Streams.

KEY FINDINGS

? All Patches

Total area in hardwood cover, number of patches, and patch sizes declined.

Total area of the sampled patches declined from 984 to 585 ha, a 40% decrease. Patch number fell from 268 to 244. Mean patch size decreased (Fig. 5) ($p<0.001$; t-test), especially in riparian areas (Fig. 9 a).

Changes in hardwood area and number of patches differed by ownership.

Hardwoods decreased on Forest Service lands, increased on non-industrial private lands, and did not change on industrial private lands (Fig. 6). The distribution of hardwood patches by ownership changed ($p=0.01$; X^2 test).

Hardwoods occurred at a narrower range of site conditions in 1993 than 1939.

In general, hardwoods were found on more moderate slopes, at lower elevations, along higher order streams, closer to the ocean, and on lower radiation sites than the study area as a whole (Fig. 7). Hardwood patches became restricted to a narrower range of site conditions by 1993: lower slope positions ($p=0.03$), nearer streams ($p=0.04$), within 60 m of streams ($p=0.04$; p-values from X^2 tests) (Fig. 8). Patterns of change were similar for hardwood area (Fig. 7).

Shapes of hardwood patches were more complex in 1993, especially in riparian areas.

Mean patch shape complexity increased from 1.85 to 1.96 (shape values farther from 1 are more complex) ($p=0.01$; t-test), and core to edge area ratios declined from 0.24 to 0.1 (s.e. 0.02 and 0.01). The shape of riparian patches was more complex than that of upland patches, and riparian patch shape complexity increased over time (Fig. 9), regardless of patch ownership.

Within-patch heterogeneity varied with distance to stream and time.

The number of heterogeneous patches dropped from 230 to 63, a decline from 86% to 26% of all patches. This reflected the removal of large conifers, because the number of patches with large conifers declined, from 57% to 13% of all patches. Within-patch pasture/meadow occurrence declined, being found in from 14% to 1% of all patches (Figure 10). Open shrub fields were a minor component of patches. The size of non-hardwood patch inclusions remained fairly constant at 6 to 7% of the hardwood patch. Heterogeneous patches reflected the all-patch tendency to be located closer to streams in 1993 (Figure 10).

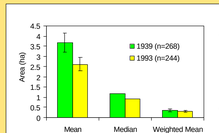

Fig. 5. (at left) Changes in mean patch area (weighted and un-weighted) and median patch area from 1939 to 1993.

Fig. 6. (below) Ownership-related characteristics of hardwoods, by date. a. Percent of study area occupied by major ownership types and percent of area of hardwood cover across these ownerships. b. Percent of hardwood patches across ownerships, normalized by number of patches at each date. c. Percent of patches in riparian and upland areas of ownership classes, normalized by riparian type and date.

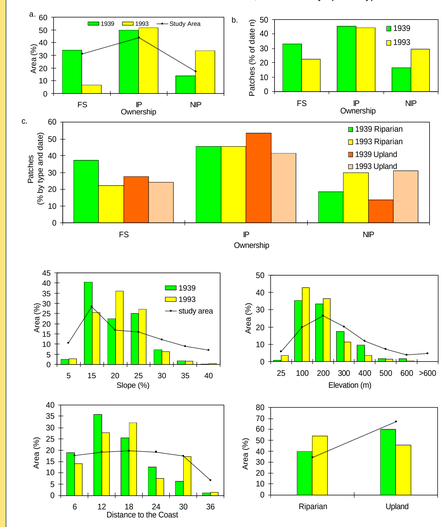

Fig. 7. (above) Percent of study area occupied by selected environmental strata (lines) and percent of hardwood cover along strata gradients in 1939 and 1993 (bars).

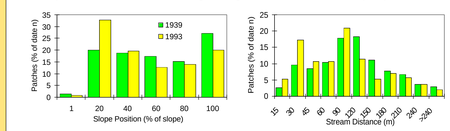

Fig. 8. (above) Frequency distribution of hardwood patches across environmental strata of slope position and stream distance in 1939 and 1993. For each date, values for each stratum are normalized by the total number of patches.

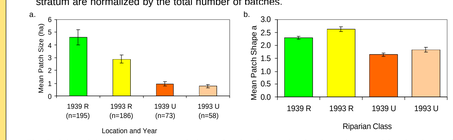

Fig. 9. (above) Mean patch size and shape for riparian and upland patches, and for riparian patches along different stream orders, by date. The riparian zone is within 60 m of each side of the stream. In figures, R is riparian; U is upland. a. Mean patch size in riparian and upland areas. b. Mean patch shape in riparian and upland areas.

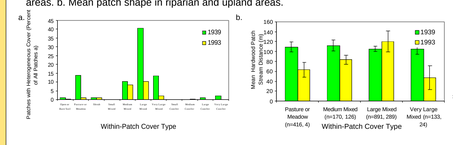

Figure 10. (above) Within-patch cover type heterogeneity of hardwood patches in 1939 and 1993. Multiple non-hardwood within-patch cover types may occur in a patch. Number of patches of major cover types, by year, given in figure b. a. Frequency distribution of non-hardwood cover type in-holdings among hardwood patches. b. Within-patch cover type and mean patch stream distance for 1939 and 1993. Distances below dashed line at 60 m are within the riparian zone.
* Percent of all patches = patches with in-holding of selected cover type/total patches*100.

? Patch Fates for Tracked Patches

Most often, patches disappeared or were fragmented.

Tracked patches disappeared 44% of the time and were fragmented into multiple sub-patches 33% of the time (Fig. 11). Thus, 40% of patches measured in 1993 were either new patches or pre-existing border-migrating patches. This indicates a high level of patch locational instability. Small patches disappeared more often than large patches, and large patches more often decreased in area (Fig. 12 a).

Patch survivorship and size change was related to ownership and environment.

Disproportionately few patches disappeared from NIP lands, and nearly 30% of patches that gained in area were found on NIP lands, although this ownership class held only 15% of the patches. FS held over 30% of 1939 patches but only 20% of patches grew larger. Patches on IP lands tended to either disappear or increase in size (Fig. 12). Patches on gentle slopes and near streams most often increased in size.

Patches that fragmented became more complex in shape and lost the most interior habitat of those patches that persisted (Fig. 13)**.**

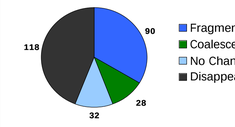

Fig. 11. Patch survivorship and change for tracked 1939 patches.

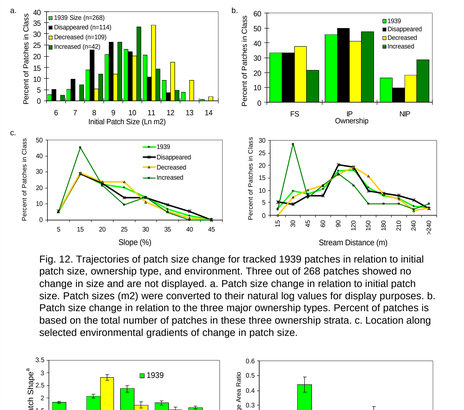

Fig. 12. Trajectories of patch size change for tracked 1939 patches in relation to initial patch size, ownership type, and environment. Three out of 268 patches showed no change in size and are not displayed. a. Patch size change in relation to initial patch size. Patch sizes (m2) were converted to their natural log values for display purposes. b. Patch size change in relation to the three major ownership types. Percent of patches is based on the total number of patches in these three ownership strata. c. Location along selected environmental gradients of change in patch size.

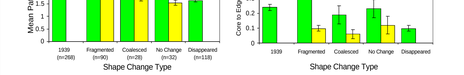

Fig. 13. Trajectories of patch shape change for tracked 1939 patches in relation to initial patch conditions. a. Mean patch shape. b. Core to edge area ratio.

DISCUSSION AND IMPLICATIONS

- Our results do not support the hypothesis that hardwoods expanded across the study area in the last 50 years. We also saw no evidence of hardwood patches transitioning into stable shrub fields.
- Expansion of hardwoods may have occurred prior to the 1940s following the large fires that occurred in the settlement period. Hardwoods are probably declining across the landscape and becoming restricted to near-stream areas partly in relation to this prior expansion, and partly because of subsequent management activities particular to the dominant ownership types of the area.
- During the 54-year period of this study, forest management practices and ecological constraints interacted to reduce hardwood area, fragment large patches, increase shape complexity, simplify within-patch cover type heterogeneity, and contract hardwood distribution into lower elevation, near-stream areas.
- Hardwoods did not decrease on IP lands as we hypothesized, but were at similar levels in 1939 and 1993. These endpoints likely mask within-study-period changes that were not captured with our two-date sample. Changes in legislation toward more stringent conifer reforestation requirements and economic trends of increasing coniferous timber value occurred during the study period. These factors probably dramatically decreased possibilities for hardwood establishment and persistence on IP lands from those early in the study period because lands were increasingly converted to coniferous cover.
- In the future, hardwoods are likely to continue to decline across the landscape through the combination of intensive management on IP lands and succession on FS lands. The future of hardwoods is uncertain on NIP lands because of the variety of management styles used there and the location of that ownership near streams where hardwoods are competitive. Hardwood-associated diversity is expected to follow these trajectories.