Applications of Growth and Survival Equations for Oregon White Oak in the Pacific Northwest[1]

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Abstract

Urban and agricultural development has greatly reduced the area of Oregon white oak (*Quercus garryana*; also known as Garry oak) woodlands and savannas in the Pacific Northwest, and much of the remainder is succeeding, or has already succeeded, to conifer-dominated forests. Conifer encroachment and, in some cases, the development of dense oak stands present significant management challenges. In this paper, new equations, now available in ORGANON, are used to predict oak growth and survival with and without management in three stands: a single-storied conifer-oak stand, a two-storied conifer-oak stand where conifers were overtopping the oaks, and a dense pure oak stand. Without conifer removal, oak basal area was projected to decline in the single-storied stand and oak mortality was projected to accelerate. Very high oak mortality (90 percent over the 50-yr projection period) was projected in the two-storied stand. Conifer removal was projected to greatly reduce mortality and increase the diameter growth of oaks in both stands. Thinning in the pure oak stand was projected to nearly triple the average diameter growth of surviving trees. The three examples indicate that management can have a dramatic effect on Oregon white oaks under stand conditions that are now common throughout the species' range.

Ke words: Garry oak, modeling, restoration, silviculture.

Introduction

Oregon white oak (*Quercus garryana*; also known as Garry oak) has the greatest latitudinal distribution of any western oak, stretching from Southern California to Vancouver Island, British Columbia (Stein 1990). Oaks are an ecologically and culturally important part of the landscape, particularly in the conifer-dominated Pacific Northwest. Many oak communities in the region are legacies of Native American land use practices, which included frequent burning to maintain prairies, savannas, and open woodlands (Sprague and Hansen 1946, Thilenius 1968). Although oaks are more widely distributed on somewhat drier sites, areas that historically supported oaks (e.g., the Willamette Valley and South Puget Sound) can typically also support conifers, particularly Douglas-fir (*Pseudotsuga menziesii*). Without fire or other repeated disturbance, oaks are often replaced by conifers, which gain a tremendous height advantage over time (Cole 1977, Foster and Shaff 2003). Succession from oaks to conifers is an on-going process in the region. Contemporary oak communities currently only cover a small fraction of their pre-settlement extent (Crawford and Hall 1997); the majority has been lost to urban and agricultural development. Some wildlife species, such as the western gray squirrel (*Sciurus griseus*, a state-listed threatened species in WA) are highly dependant on oak habitat

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(Ryan and Carey 1995). Thus, maintaining and restoring oak communities is a high conservation priority in the region.

Developing appropriate strategies for oak restoration depends, in part, on expected outcomes. Predictive models are useful tools for evaluating expected outcomes under different management approaches. New equations to predict the growth and survival of Oregon white oak have recently been developed and incorporated into ORGANON, an individual-tree stand-development model for forests in the Pacific Northwest (Hann 2005). The equations were developed using a larger and geographically broader dataset than those used to develop previous equations. The dataset was assembled from several sources in Oregon and southwestern Washington. Diameter growth is calculated as a function of initial tree diameter and live-crown ratio, stand basal area, and site productivity (measured using Douglas-fir site index). Survival is calculated using the same variables, except stand basal area is replaced by the basal area of trees with diameters larger than the target tree, which better reflects Oregon white oak's intolerance to shade (Stein 1990). The new equations predict more rapid growth, but poorer survival than the equations previously used in ORGANON, which were developed using very few observations of Oregon white oak from a small portion of the species' range. The development of the new equations is described in detail elsewhere (Gould and others in press)

In this paper, we apply the new equations to evaluate stand development with and without management intervention in three stands that represent a range of restoration challenges. Two conifer-oak stands were selected to evaluate conifer removal (or a no-action alternative) as conifers begin to overtop oaks (single-storied stand) and after oaks are already overtopped by conifers, creating a two-storied stand. A pure oak stand was selected to evaluate the use of oak thinning to accelerate the development of young stands towards a savanna structure. The three examples demonstrate the utility of the new equations and provide general insight into how management (or lack of management) is expected to affect oaks growing under different conditions.

Methods

Data from three stands were used to develop tree lists for input into a version of ORGANON that includes the new equations. Data from a conifer-oak stand located on Oregon State University's McDonald-Dunn Forest were used for the single-storied stand. The stand had 90 ft^2/acre of basal area, with about 15 percent oak and the rest Douglas-fir. The height of the tallest oak was about equal to that of the tallest Douglas-fir, indicating that the oak had not yet become overtopped. Data for the two-storied stand were collected in a conifer-oak stand on the Fort Lewis Military Reservation in southwestern Washington. Total stand basal area was 273 ft^2/acre, with 6 percent oak and the rest Douglas-fir. Although the tallest oaks were about the same height as those in the single-storied stand (70 ft), the Douglas-fir were much taller (about 120 ft) and oaks were overtopped or in small openings. Data for the pure oak stand were also collected on Fort Lewis. The initial basal area of the pure oak stand was 123 ft^2/acre with 1,494 oaks/acre.

ORGANON projections were run without any management for all three stands. For the conifer-oak stands, projections were also run assuming all conifers were removed in year 0 (conifer removal). The pure oak stand was projected following thinning from below in year 0 to the approximate density of an oak savanna (30 trees/acre). The projection period was 50 yrs for all projections. Regeneration was not modeled under any of the scenarios. In addition to tables and graphs, some results were summarized using the stand visualization systems (SVS) to help illustrate projected changes in stand conditions (McGaughey 2004). Oak crown diameters in the visualizations were calculated from projected diameter at breast height (DBH).

Results

Without management intervention, the single-storied stand was projected to transition into a two-storied stand, where oaks are overtopped and mortality begins to accelerate (*fig. 1*). The Douglas-fir were predicted to outgrow the oaks by a large margin. The rate of oak mortality accelerated during the projection period; annual mortality was 0.6 percent in the first decade of the projection and 1.4 percent in the fifth decade (*table 1*). About 40 percent of oaks were ultimately projected to die. Oak basal area increased slightly in the first three decades of the projection, indicating that diameter growth initially compensated for mortality, but it began to decline in the final decades. The mean diameter growth of surviving oaks was 2.4 inches over the entire projection period.

Table 1—*Results of the ORGANON projections for the single-storied conifer-oak, two-storied conifer-oak, and pure oak stands. Number of oak trees per acre (TPA) and basal area (BA, ft^2/acre) are shown by year for the single-storied and two-storied conifer-oak stands with and without conifer removal for the pure oak stand with and without thinning.*

	Single-storied				Two-storied				Pure Oak			
	No Removal		Removal		No Removal		Removal		No Thin		Thin	
Yr	TPA	BA	TPA	BA	TPA	BA	TPA	BA	TPA	BA	TPA	BA
0	10.1	13.3	10.1	13.3	31.4	14.8	31.4	14.8	1494.0	123.3	30.0	7.6
10	9.5	13.9	9.9	15.4	19.1	10.9	29.9	17.4	1131.7	122.2	29.5	8.8
20	8.6	14.0	9.7	16.9	12.1	8.1	28.4	19.5	873.9	121.0	29.0	10.1
30	7.7	13.9	9.5	18.4	7.8	6.0	27.1	21.4	687.4	119.4	28.5	11.3
40	6.7	13.6	9.3	19.9	5.2	4.5	25.8	23.4	550.2	118.6	28.0	12.5
50	5.8	13.2	9.1	21.4	3.5	3.4	24.4	25.2	447.5	117.7	27.5	13.6

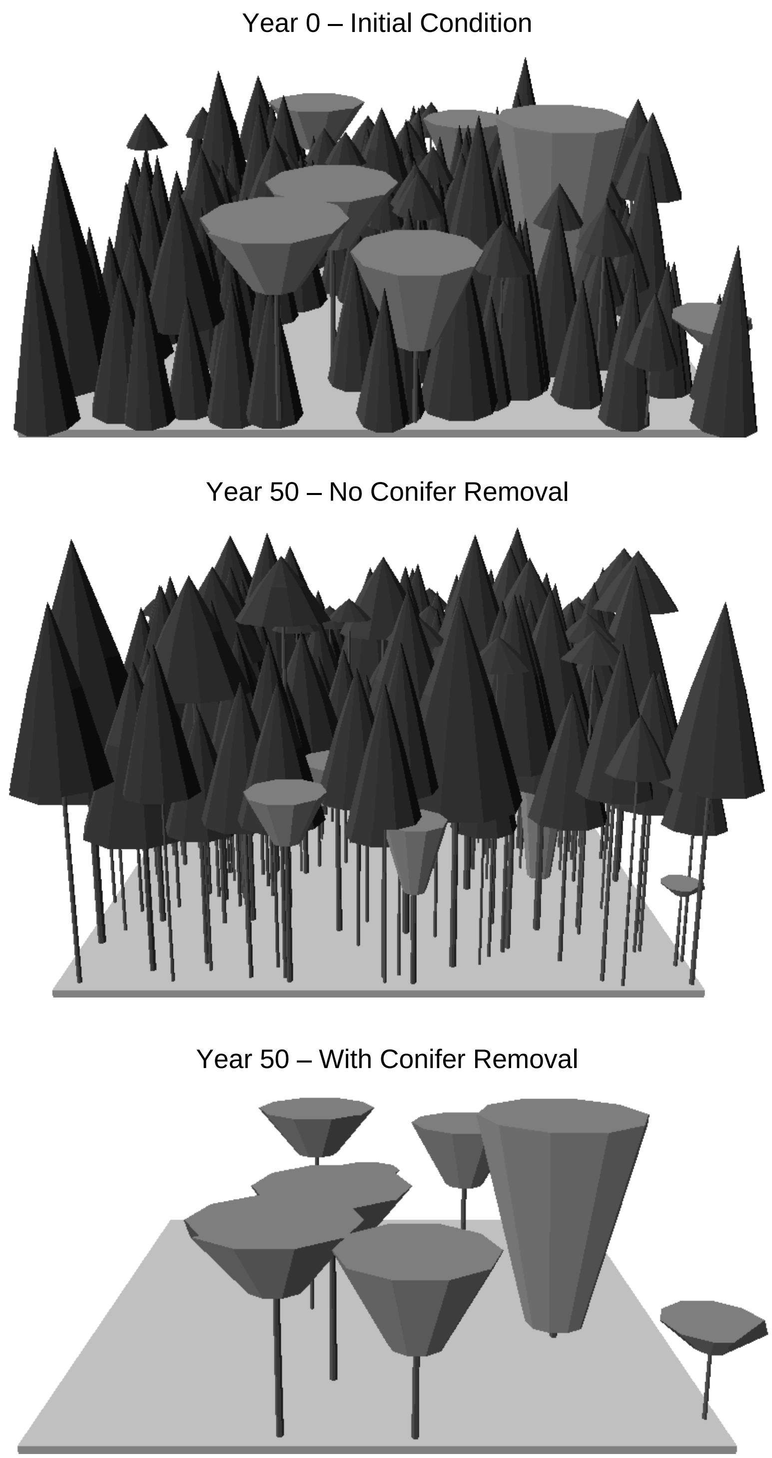

Figure 1—One-acre SVS representation of the single-storied stand in year 0 (top), year 50 without conifer removal (middle), and year 50 with conifer removal (bottom).

Oaks in the two-storied stand were already overtopped by Douglas-fir at the beginning of the projection period (*fig. 2*). Without management intervention, oaks were predicted to be nearly eliminated from the stand. Projected oak mortality was severe (*table 1*). The annual mortality rate was about 5 percent in the first decade and declined somewhat to about 4 percent in the final decade, at which point the density of oaks was already greatly reduced. In total, nearly 90 percent of oaks were expected to die during the projection period. Surviving oaks were expected to grow slowly (about 1.5 inches over the entire period) and oak basal area was projected to decline by nearly 80 percent.

Conifer removal was predicted to have a very strong impact on oak growth and mortality in both conifer-oak stands (*table 1*). Mortality over the entire projection period was reduced to about 10 percent in the single-storied stand and to 20 percent in the two-storied stand. Oak basal area was projected to increase by 60 and 70 percent in the single-storied and two-storied stands, respectively. The mean diameter growth of surviving oaks doubled in the single-storied stand (to 4.8 inches) and more than doubled in the two-storied stand (to 4.0 inches). Both stands were projected to be oak savannas at the end of the projection period (*fig. 1 and 2*).

Without thinning, the pure oak stand was projected to experience high mortality and a small decrease in basal area (*table 1*). Stand density was projected to decrease by 70 percent and the diameter growth of surviving oaks was expected to be low, averaging 2.1 inches over the entire projection period. Thinning in year 0 greatly reduced stand density and basal area. Following thinning, the stand was projected to experience little additional mortality and the expected average diameter growth of surviving trees (6.0 inches over the projection period) was nearly three times that of the unthinned stand.

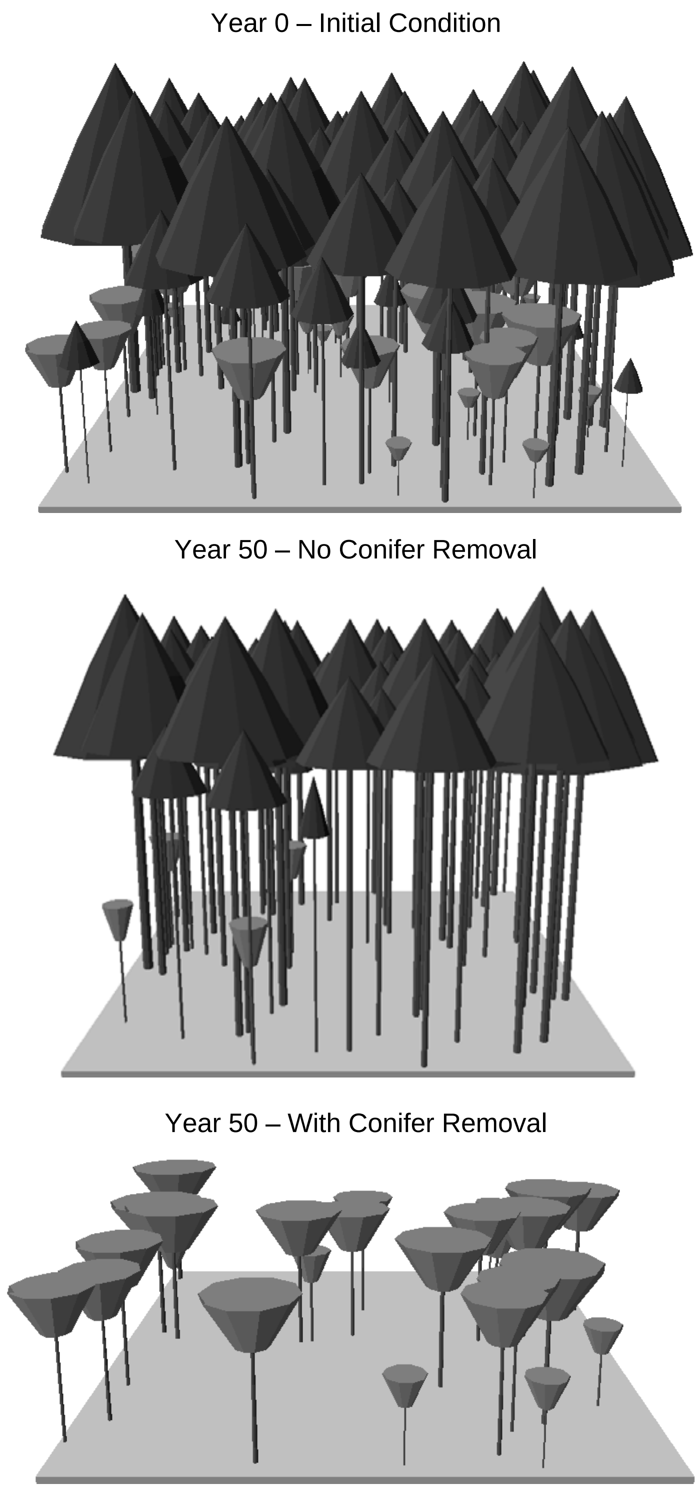

Figure 2—One-acre SVS representation of the two-storied stand in year 0 (top), year 50 without conifer removal (middle), and year 50 with conifer removal (bottom).

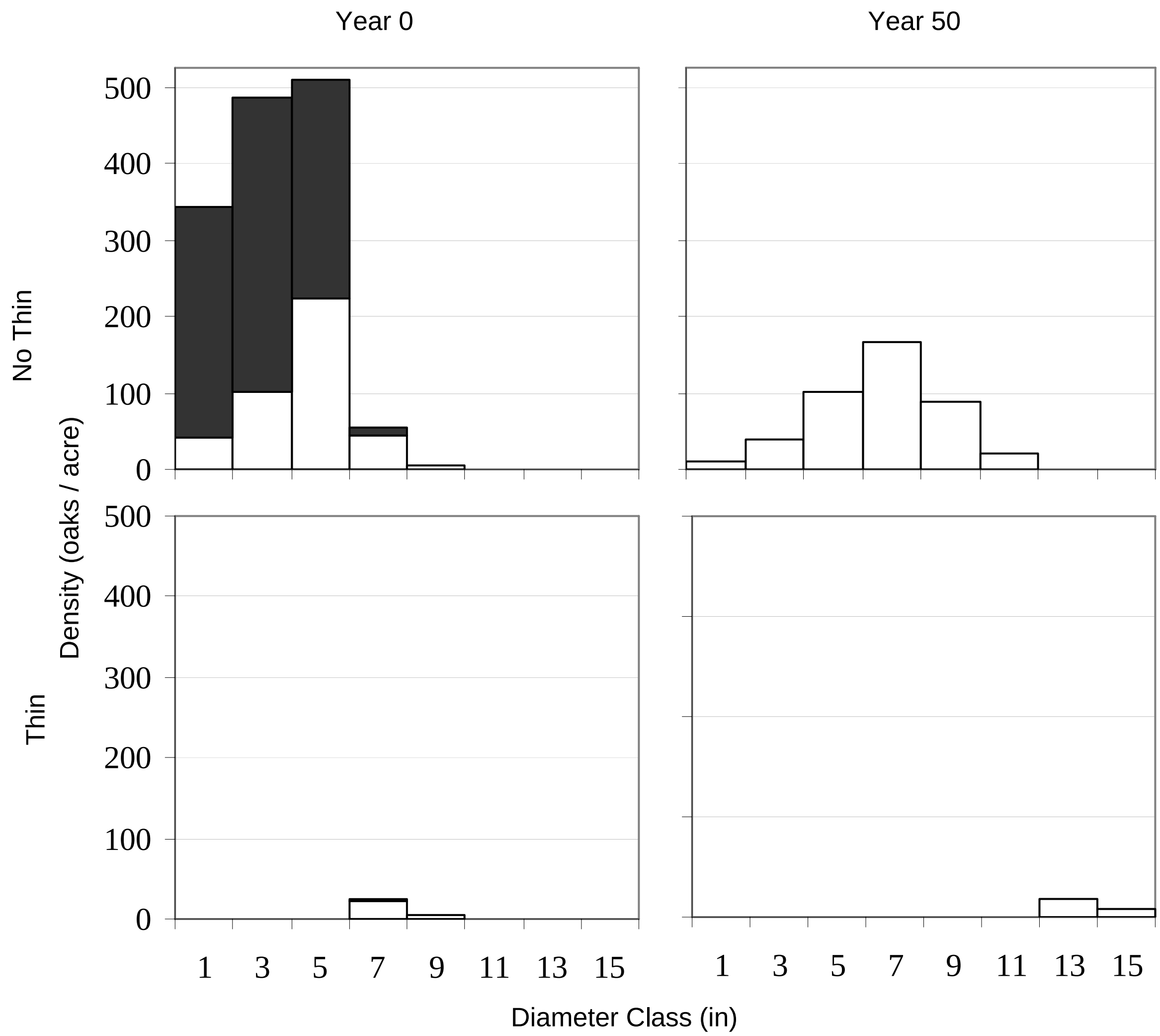

Figure 3—Initial (left) and 50-yr projected diameter distributions (right) for the pure oak stand without thinning (top) and with thinning (bottom). Black bars in the initial distributions denote expected mortality.

Without thinning, many of the small oaks in the pure oak stand were expected to die, and the mean diameter of survivors was expected to be 6.6 inches at the end of the projection period (*fig. 3*). Thinning removed nearly all the trees that were expected to die without thinning, and also many that were expected to survive. All of the residual oaks in the thinned stand were expected to be > 12 inches DBH at the end of the projection period (mean diameter 13.6 inches). Stand visualizations illustrate the more rapid development of oaks following thinning compared with the scenario without thinning (*fig. 4*).

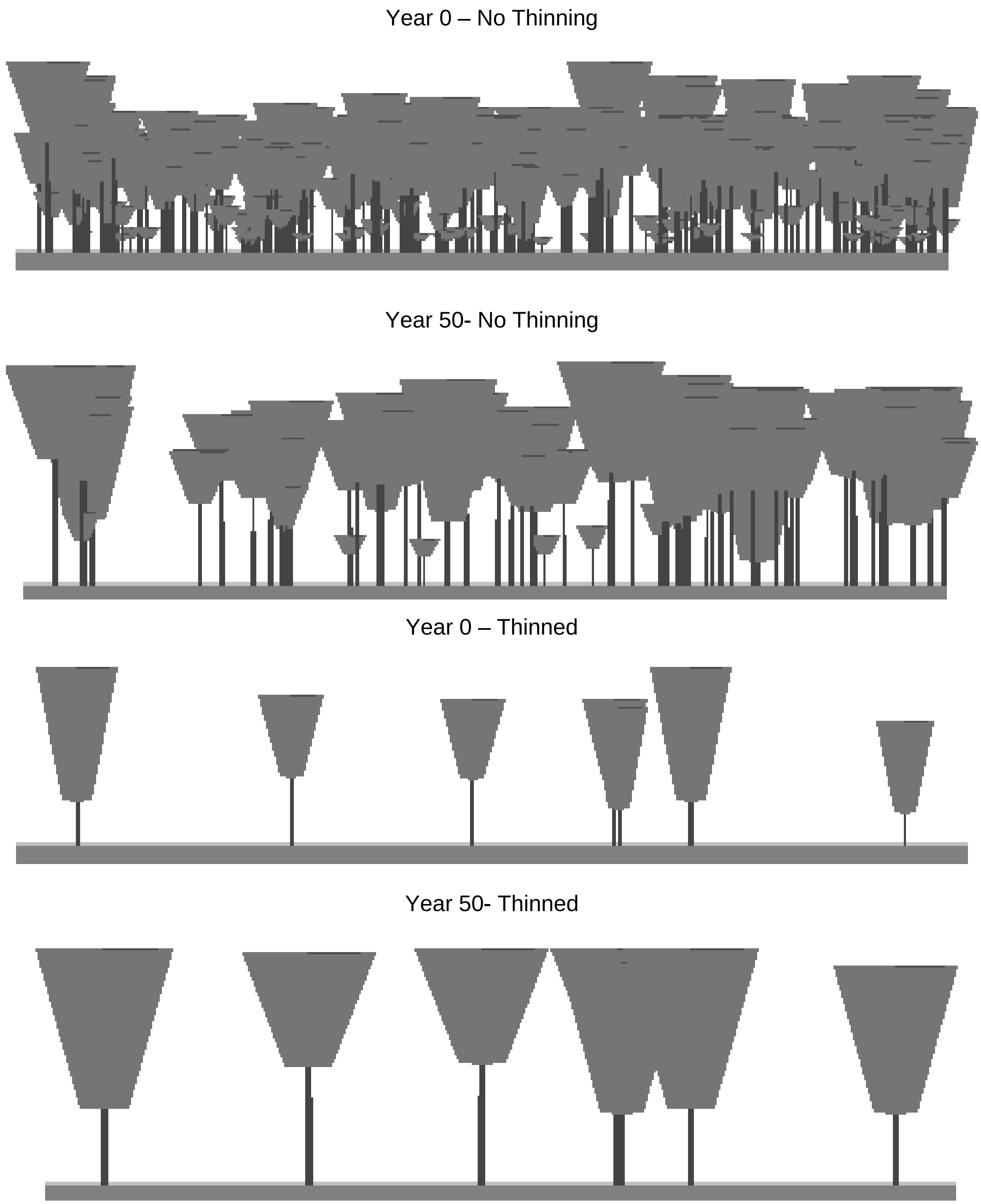

Figure 4—SVS profile view of the pure oak stand in year 0 and year 50 with and without thinning. Profiles represent an area 208 ft long and 40 ft wide.

Discussion

The conifer-oak stands represent different stages of the on-going process of succession from oak to conifers. The single-storied stand appeared to be near the tipping point where oak mortality would begin to accelerate and reduce oak basal area. Predicted mortality in the two-storied stand was severe beginning in the first decade of the projection. Most conifer stands are thinned about every 10 years on Fort Lewis, which may have allowed oaks to persist up to the present in the two-storied stand. However, the examples presented here suggest that competition with conifers becomes more severe over time. Periodic thinning may become less effective as the difference in size between oaks and conifers increases and the vigor of surviving oaks declines. Even under favorable conditions (e.g., after complete conifer removal), released oaks are expected to grow fairly slowly as they often have low crown ratios. The loss of oaks can significantly reduce the restoration potential of a stand as a great deal of time is required to replace them. Our results suggest that oaks will respond to release even in a later stage of conifer succession, but earlier intervention is needed to prevent oak mortality. The need for management intervention becomes much more urgent as succession continues and the density and vigor of surviving oaks decline.

The density of oaks, much like that of conifers, has increased in some areas following fire suppression and other changes in land use (Gedalof and others 2006, Tveten and Fonda 1999). Thinning oak stands should appreciably accelerate the development of large trees and help to maintain the more open character of historic oak woodlands and savannas. The question of how much thinning is appropriate will depend on the particular objectives of the project. Based on oak's shade intolerance and the potential for two-sided competition for water during dry summers (Kelty and others 1987), it may be desirable to maintain low stand densities through some combination of thinning and prescribed fire. Mixed-hardwood stands where oaks are overtopped or compete with non-oaks in the upper canopy may also benefit from some combination of release and thinning treatment.

Additional factors that are not considered in the ORGANON model can also affect oak development. Some mechanical damage is likely to occur during release or thinning operations. Extensive damage may reduce oak growth and survival relative to the model predictions since such treatment impacts are not specifically considered in the model. ORGANON estimates the effects of competition at the stand level, which does not consider the spatial arrangement of trees. Conifer removal within the vicinity of individual oaks may be as beneficial as stand-wide removal in some cases. The best approach in such cases may be to collect data only within the vicinity of oaks and use ORGANON to model the portion of the stand that is likely to be treated.

Predictive models are useful tools for evaluating the effects of alternative management strategies. The new equations for Oregon white oak, which are based on considerably more information than previous ones, can give users greater confidence in ORGANON's projections. The stand conditions evaluated here represent some of the challenges faced by land managers. ORGANON can be used to evaluate specific stands and, if needed, to tailor more complex prescriptions.

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