IMPLEMENTING UNEVEN-AGED REDWOOD MANAGEMENT AT CAL POLY'S SCHOOL FOREST, AN UPDATE

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ABSTRACT

California Polytechnic State University's School Ranch and Forest, called Swanton Pacific Ranch, is located just north of Santa Cruz, California and encompasses approximately 3,800 acres (1,538 ha) of crop, range, and forested areas. Coast redwood *(Sequoia sempervirens* [D. Don] Endl.), Douglas-fir *(Pseudotsuga menziesii* [Mirb.] Franco var. *menziesii*) and tanoak *(Lithocarpus densiflorus* [Hook. & Arn.] Rehd.) occur on approximately 1,900 acres (769 ha) of the Swanton Pacific Ranch and at Valencia. Because of its high stumpage value, coast redwood is the preferred management species. In addition to economic reality, California Forest Practice laws severely limit the extent of stand manipulation that can occur on any one harvest entry in Santa Cruz County. In our opinion, the only suitable silvicultural system given these currently limiting circumstances is uneven-aged forest management. However, implementing uneven-aged forest management in coast redwood stands involves a number of choices on residual stand density, preferred tree species composition, maximum tree size, q-factor, stand structure, inventory design, tolerable residual stand damage, logging systems, logging costs, reforestation strategies, extent and size of group selection cuts, growth rates, monitoring criteria, ecosystem management, and much more. Single tree and group selection cutting methods have been applied in seven stands encompassing approximately 175 acres (71 ha) of the Scott Creek Watershed, habitat for the now threatened Coho salmon. Cable and tractor logging systems were used. The issues, choices, decisions and operational considerations of implementing uneven-aged coast redwood management in Santa Cruz County will be discussed in the context of needed research to support stand and forest level decision making.

INTRODUCTION

A 3,800 acre (1,538 ha) forest and ranch in Santa Cruz County was recently donated to the Forestry and Natural Resources Program at Cal Poly, San Luis Obispo. This facility possesses a wide variety of natural resources offering a valuable educational opportunity for students to participate in integrated management activities. The faculty have begun demonstration trials in several forest types at its new school forest. The purpose of this article is to inform the profession of this new educational resource and describe our plans for, and preliminary results of, intensive forest management in an environment of intensive public scrutiny and regulation.

SWANTON PACIFIC AND VALENCIA

Swanton Pacific Ranch is located approximately 12 miles (19 km) north of Santa Cruz, California, near Davenport, on the Pacific Coast. This property has about 1,500 acres (607 ha) of range, 400 acres (162 ha) of irrigated cropland, and 1,300 acres (526 ha) of coastal redwood and Monterey pine forestland. Roughly a third of the forestland is established for intensive forest management. Swanton is the largest ownership in the Scott Creek Watershed. Several major feeder streams and a large portion of Scott Creek are on the property. These are significant resource issues since Scott Creek is designated as one of the southernmost spawning runs for Coho salmon *(Oncorhynchus kisutch).*

The remaining 600 acres (243 ha) is located about 20 miles (32 km) east of the ranch, referred to as Valencia. This property is almost entirely forested, primarily coast redwood type with about 100 acres (40 ha) of mature tanoak and coast live oak.

This gift came through the generosity of an alumnus, Mr. Al Smith. Beginning in 1986 until his death in 1993, Al made his ranch and forestland available for use by faculty and students as a "living laboratory in learn-by-doing." The ranch, consisting of range, crop, and forest land, is managed with financial solvency as a goal despite the higher operating costs of providing educational opportunities.

The second-growth redwood forest in the Santa Cruz Mountains is around 90 years old thanks almost entirely to its (and tanoak's) sprouting capacity. Subsequent fires in the 40s introduced substantial disease (e.g., *Fomes pini*), particularly in the Douglas-fir. Such significant prior disturbance coupled with the silvical, economic, and societal constraints makes the implementation of uneven-age management at Swanton a highly uncertain prospect.

Several other major forest types are represented at Swanton including (Todd, 1988): riparian woodland of alder and willow; oak woodlands of coast live oak; mixed evergreen hardwoods with varying amounts of live oak, California bay laurel, madrone and tanoak; and Monterey pine in various compositions. Presently, only 320 acres (130 ha) of the approximately 1,300 acres (526 ha) of forestland at Swanton Pacific Ranch is being intensively managed for timber. This 320 acres (130 ha) is situated in the Little Creek drainage and is comprised of mostly second-growth redwood and Douglas-fir. The last remaining old-growth redwood on Swanton Pacific Ranch (an area less than 20 acres or 8 ha) is also being managed for retention of late seral stage attributes.

CIVICS AND SILVICS

Probably in no other part of the country has society so acted upon its environmental concerns than in Santa Cruz, California. The region's notoriety in environmental activism is a result of many phenomena, the same forces that are building in other parts of the country. One of the reasons is probably its proximity to the Bay Area with a population of 5 million. The extensive and rapacious logging of the landslide-prone Santa Cruz Mountains to rebuild San Francisco after the 1906 earthquake is a memory that reverberates in the local community and directly influences current silvicultural decisions. Now an urban interface region with unique aesthetic values, Santa Cruz and San Mateo counties added rules to the state's already strict forest practices law, a law that places environmental protection on par with sustained yield of timber products.

In general, the California Forest Practice rules basically limit logging to achieve maximum sustained forest productivity while protecting the environment. The instrument to meet this goal is the Timber Harvest Plan (CDF 1999), which must be prepared by a licensed forester, and is a functional equivalent to an Environmental Impact Report (CEQA, 1998). Clearcutting is still permitted under highly restricted and costly conditions. However, the Southern Coastal Subdistrict rules go further by limiting the: (1) size of openings to one-half acre (eliminating clearcutting), (2) number of trees harvested to 60 percent of the 18" (45.7 cm) DBH class and greater, and 50 percent of the 12-17" or 30-43 cm class (the 60-50 rule), and (3) stand reentry cycle to 10 years. Focused almost entirely on environmental/aesthetic values, these additional rules have the unexpressed effect of severely constraining management for a sustainable stand structure. The only option left is uneven-age management for a forest structure that is currently even-aged.

Within this wide array of resources and management constraint is an incredibly valuable teaching environment for Cal Poly's Forestry and Natural Resources students. The goal for the Little Creek Timber Management Unit is to demonstrate ecologically-sound management practices that optimize sustained timber production. This goal must complement the overall ranch goal of providing an opportunity for "learn-by-doing" in an integrated agricultural and forest resources property.

To achieve this goal several objectives have been established. First, the Little Creek unit will be managed using uneven-age silvicultural techniques. Second, any harvest will be designed to not only meet but hopefully exceed standards set forth by the state's forest practices rules. Third, timber production goals will be integrated with forest resource values to every extent possible, especially wildlife and special use areas. Fourth, environmental impacts will be monitored and tracked over time, especially in riparian areas.

STAND MANAGEMENT

Early inventories and management plans for the entire Swanton Pacific Ranch show a total standing volume of 27 MMBF-Scribner (127 thousand m^3) for the entire ranch (Piper and Anderson 1989; Big Creek Lumber Company 1991). Current merchantability standards are 16 inch (40.6 cm) DBH to a 4 inch (10 cm) top. The Little Creek Management unit is estimated to have contained about 15 MMBF (70 thousand m^3) or roughly 55 percent of the total standing ranch inventory. Composition by volume is about 60 percent redwood, 25 percent Douglas-fir and 15 percent tanoak (see Figure 1). The remaining forested areas of the ranch, referred to as satellite stands, contain a total standing volume of 12 MMBF (56 thousand m^3). About 25 percent of this volume in the satellite stands is of sufficient quality and occurs in operable locations to be considered merchantable (Big Creek Lumber Co. 1991).

The primary resource area in the forest management plan is the Little Creek unit which has been under management since 1991. It is divided into three management compartments each subject to a separate Timber Harvest Plan. The Pioneer compartment covers about 60 acres (24 ha) and contains four stands, three of which were entered in two phases: Stand B in Spring 1991 and Stands A and C in 1992. The next harvest entries were conducted under a second THP covering Stands E, F, G, and H of the 85 acre (34 ha) Tranquillity Flat compartment. Stands E and F were treated during the Spring and Summer of 1994. Stands G and H were selectively cut in the Summer of 1995. The third compartment is yet to be named and is situated downstream from the other two compartments.

The stands in the Little Creek unit vary greatly in species composition, density and site quality. The average site index in Little Creek is 130 or 40 m (base age 100) with the highest being 230 or 70 m (Lindquist and Palley, 1963). Little Creek stands average 280 ft^2/ac or 64 m^2/ha (varying between 100 and 675 ft^2/ac or 23 and 155 m^2/ha), with volumes averaging about 45 MBF/ac (530 m^3/ha). Prior to harvesting, combined redwood-fir growth increment was estimated to be about 500 BF per acre per year or 6 m^3/ha/yr (based on MAI) or about 1.3 percent, well below both species' growth potential in even-age conditions.

SUSTAINABLE STAND STRUCTURE

The average target forest structure and composition for the Little Creek unit is influenced by past research, forest practice regulations and especially field experience (Alexander and Edminster, 1977; Marquis, 1978; Cole and Helms, 1986). Given these influences, we have initially selected the BDq method for designing the uneven-age structure (deLiocourt, 1898; Guldin, 1991).

Beginning with the maximum diameter for which to manage (D), 30 inches (76 cm) was selected based upon local merchantability standards and anticipated growth rates. Selection of the q factor was the most subjective decision. A q factor of between 1.2 and 1.3 (for 2 inch or 5 cm DBH classes) was chosen based upon discussions with managers of the Jackson State Forest and the pragmatics of site occupancy discussed by Long and Daniels (1990). Last is, in our opinion, the most problematic -- the choice of residual basal area (B). This decision is heavily influenced by Santa Cruz forest practice rules but enough leeway is available to allow some flexibility. We chose 180-200 ft^2/ac (41 to 46 m^2/ha) because it provided sufficient harvestable volume based upon expected growth rates while more than satisfying the forest practice minimums.

To summarize, the general stand management target is: (1) 180-200 ft^2/ac (41 to 46 m^2/ha) of residual basal area, (2) a q of 1.2, (3) 70 percent redwood and 30 percent Douglas-fir and (4) a maximum DBH of 30 inches (76 cm). A large gap in structure exists between current conditions and the target (regulated) structure for the two commercial species -- redwood and Douglas-fir (see Figure 2). Using local volume tables, the chosen BDq criteria generate a target residual stand volume of 26 MBF/ac (300 m^3/ha). Most stands were about 50 percent overstocked by volume with harvestable stands averaging 280 ft^2 (62 m^2/ha) and 45 MBF/ac (530 m^3/ha).

The time required to achieve a regulated stand structure obviously varies with the starting stand conditions, but it is also legally constrained by the 10 year re-entry cycle limit. Based on CRYPTOS (coast redwood growth and yield prediction model) analysis, it appears that a minimum of four stand entries (40 years) is required to convert most of the stands to the target structure (Wensel et al., 1987). Even at current yields, the minimum 10 year re-entry cycle rule should be constraining in generating merchantable volumes, while still allowing for the 60-50 logging rule during the conversion period. With roughly 10 stands, once regulated, predicted yields (using the Austrian formula) and harvesting regulations should permit an LTSY of about 350 MBF/yr or 3.5 MMBF/decade (4,130 m^3/yr). Regulated yields of 12 MBF/ac (140m^3/ha) per decade should provide a harvestable volume that meets the 60 percent rule ($\geq$ 18" or 45.7 cm DBH). Again however, LTSY forecasts presume that the uneven-age stand structure is sustainable.

BDq PARAMETERS AND LONG-TERM YIELDS

To predict yield from the established uneven-age stand structure is more uncertain than with even-age structures due to lack of stands so structured. Normal even-age yields for Little Creek stands with an average site index of 130 (43 m) could be as high as 1.2 MBF/ac/yr (12 m^3/ha/yr). However, current yield is half this rate based on MAI. This is due to the wide variation in density, primarily in the redwood clumps, producing radial growth of only about 8 to 10 rings per inch. Given that densities will be reduced by about 50 percent, it is reasonable to suppose that release will occur, but how much (Oliver et al. 1992, 1994, 1996)? Answering this question is critical for selecting the initial BDq parameters.

Analysis of predicted yields was conducted using our own Stand Table Projection (STP) model since CRYPTOS was designed for even-aged, second growth redwood, and the Forest Vegetation Simulator (FVS) does not contain the redwood type. This STP model was validated against CRYPTOS using even-aged stands and verified by practicing foresters.

Choice of parameters requires understanding that they interact with one another. Decisions on regulated residual BA is a function of estimates of reasonable residual densities and choices of D and q. Nevertheless, yields are not very sensitive to B or q, where B varied between 160 and 220 ft^2/ac and q ranged between 1.1 and 1.3 for 2 inch classes. The one parameter that seems to be most easily decided upon is the maximum diameter of the residual stand (D).

The critical decision of D's value is often heavily influenced by markets for the preferred material sizes with the tendency to push D down as low as possible. Our analysis indicates however, that regulated growth rates are very sensitive to D. In the redwood type, keeping D low (around 30-32 inches) permits larger harvestable volumes but limits the ability of the redwood stand to take advantage of its ability to release greater board foot volumes on larger average residual diameters. Moving D up too high (e.g., 38-40 inches) provides less yield and slows growth rates because of stem redistribution. Thus, it seems that long-term yield has a peaking relationship to D of around 34 inches for these site qualities. This information must be balanced with the economic benefits of a lower D and ecological considerations.

One final but equally important issue in redwood timber management, whether even or uneven-aged, is how to manage coppice sprouting. This silvical characteristic provides the obvious advantages in obtaining a "jump" on in-growth but the resulting clumpiness could limit volume growth beyond what would be expected under normal yield (well-spaced) conditions. Numerous factors affect growth and yield response of redwood coppice stands such as: light availability, soil moisture availability, age of stand, sprout density, overstory density, and other ecological interrelationships (Powers and Wiant, 1970; Boe, 1974; Cole, 1983; Cole and Helms, 1986; Olson, 1990; Passof, 1993; Adams et al., 1996; Becking, 1996; Helms and Hipkin, 1996; Lindquist, 1996). Analysis using our STP model assumed only one stem arising from the root crown area of a stump and planting for spacing.

Based on borings from stands of similar site quality that contain 4 or more age classes and the assumption that growth rates will not be as rapid as in even-age stands of similar densities, we believe growth rates of 4 to 5 rings per inch are achievable upon stand regulation. This growth rate could generate up to 1.2 MBF/ac/yr (12 m^3/ha/yr), a 100% increase over current yields.

INITIAL OPERATIONAL RESULTS

Thus far, distinct silvicultural prescriptions were developed for seven stands (A through H). These site specific prescriptions documented objectives, resource considerations, regulatory issues, stand and plant aggregation boundaries and descriptions, uneven-age management criteria, marking rules, logging considerations and regeneration considerations. These prescriptions balance both existing and projected stand conditions.

In general, marking prescriptions followed the following prioritized rules (merchantability is generally ≥ 18" or 45.7 cm DBH):

1. Maintain 180 to 220 ft^2/ac (41 to 50 m^2/ha) in all areas; lighter mark to account for stand damage on cable ground.
2. Maintain 60 percent of BA in dense redwood clumps.
3. Remove surplus ≥ 24" or 61 cm DBH class (surplus being those in excess of residual J curve).
4. Remove diseased, suppressed or damaged trees in surplus classes.
5. Remove ≥ 24" or 61 cm DBH class, followed by 18 to 24" (45.7 to 61 cm) class, to optimize spacing.

Logging costs for the Pioneer project ranged from $100 to $155/MBF ($20 to $30 per m^3) with haul costs running about $25/MBF ($5 per m^3). Stands C, E and F had higher logging costs due to the use of cable logging systems. Stumpage values for the Pioneer project varied for the two-year period of 1990-91 from $274/MBF or $58 per m^3 (Stand B) to $252/MBF or $53 per m^3 (Stands A and C) for coast redwood and $147/MBF or $30 per m^3 (Stand B) to $80/MBF or $17 per m^3 (Stands A and C) for Douglas-fir. Stumpage values for the Tranquillity project also varied for the two-year period of 1994-95 from $642/MBF or $136 per m^3 (Stands E and part of F) to $620/MBF or $130 per m^3 (remaining part of Stand F, Stands G and H) for coast redwood and $460 or $97 per m^3 (Stands E and part of F) to $420 ($89 per m^3) (remaining part of Stand F, Stands G and H) for Douglas-fir, providing a gross income of $700,000 since outset of management. The road system cost for both the Pioneer and Tranquillity projects was approximately $200,000. The estimated amount of defect on the Tranquillity project ranged from 13 to 14 percent in coast redwood and 24 to 25 percent for Douglas-fir over the two-year harvest period (1994/95).

We are estimating a stand conversion period of 30 to 50 years reaching an LTSY of about 350 MBF (1,650 m^3) per year around the year 2020. Each harvested stand has approximately twelve permanent one-fifth acre (0.0810 ha) plots to enable assessment of our growth predictions. Management modifications (i.e., adaptive management) will likely be made as more growth and yield information is collected.

CONCLUSIONS

We have learned a great deal in these early trials in uneven-age redwood and Douglas-fir management in an integrated ranch setting. The following are the key conclusions:

1. Operating a demonstration ranch and forest is a complex and dynamic undertaking with changing institutional and market structures, educational requirements and the vagaries of regulations governing environmental and social impacts.
2. Debate over regulated uneven-age growth rates is instructive for both managers and students. A question receiving significant discussion relates to marking rules for highly variable stand structures.
3. Selective logging can be achieved equally well with both tractor and cable systems but special logging expertise and care is required. The switch from even-age to selective logging will require some extensive training.
4. Additional road maintenance costs are necessary in uneven-age management due to the more frequent entry rate compared to even-age management.
5. Tanoak control is possible using selective thinning for fuelwood, flooring products, or direct herbicide injection (Piirto et al. 1997b).
6. The potential exists to manage the redwood-fir type and generate fairly substantial returns to the owner on at least a biennial period on areas as small as a few hundred acres (hectares).
7. Markets for smaller logs will enhance our ability to fully implement uneven-aged management.
8. Some combination of single-tree and group-selection cutting methods will continue to be necessary to achieve a balanced age structure.

We will not know whether our initial decisions to implement uneven-age management are correct for at least forty years. We had few choices as this paper clearly documents for future reference. We will seek to monitor and encourage research to find answers to the following questions:

1. What combination of group and individual tree selection is appropriate in redwood stands?

2. How should tanoak and other hardwoods be managed in an uneven-aged redwood setting?
3. What are the long-term growth and yield effects of individual and group selection cuts in redwood stands?
4. What factors have the greatest impact on logging feasibility (i.e., technical and economic) as uneven-age management is implemented in redwood stands?
5. What is the best way to implement uneven-age management in redwood stands (e.g., Guldin's [1991] BDq approach vs. Heald's Step-Point Sampling and Hierarchical Marking Rule Approach - Heald and Haight [1979])?
6. Is mass movement more or less of a problem in selectively harvested redwood stands as compared to clearcut and unlogged landslide prone areas?
7. What short- and long-term effects on water yield and water quality if any, occur as a result of uneven-age management implementation in redwood stands?
8. What are the ecological consequences associated with uneven-age management in redwood stands (e.g., habitat effects on Coho salmon, wild boars, deer, furbearers, and other associated organisms)?
9. What are the socio/political effects/realities associated with implementation of uneven-age management in redwood stands?
10. Can implementation of uneven-age management ameliorate the effects of pitch canker in native stands of Monterey Pine which occur among the redwood stands adjacent to Scott Creek at Swanton Pacific Ranch?

These and many other questions will be the focus of our ongoing demonstration and research work at Cal Poly's School Forest. We solicit advice and counsel with publication of this paper. In conclusion, Swanton Pacific provides an excellent case study in managing natural resources for commodity and non-market values in a setting that will resemble the future for many parts of our nation and the world. Cal Poly students that are directly involved in ranch and forest management will be better prepared to face the issues in their careers.

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(Figures 1 and 2 follow)

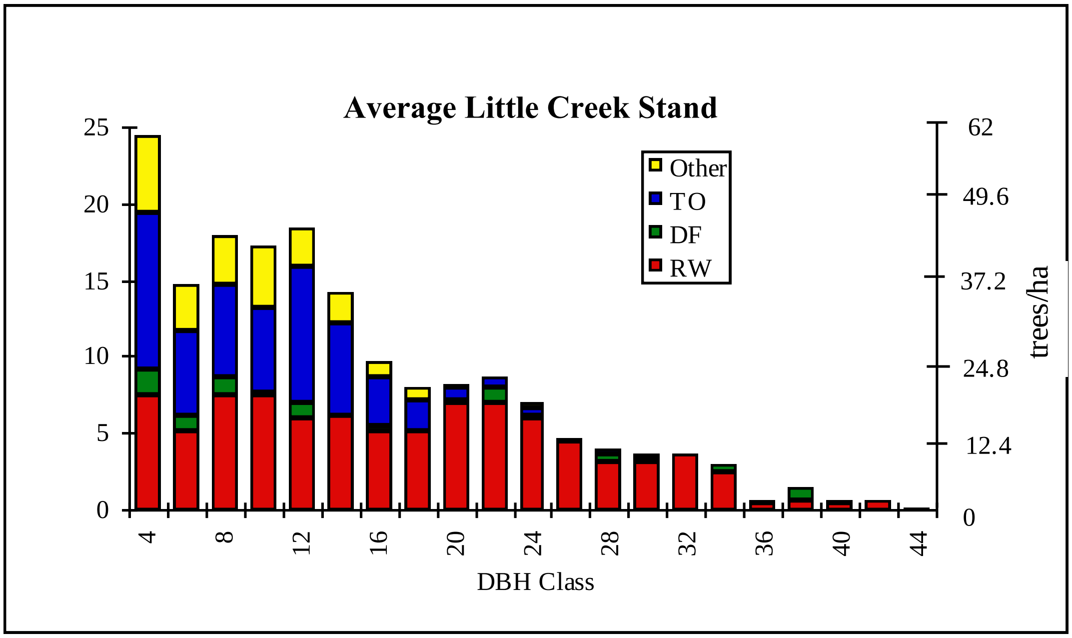

Figure 1. Average Little Creek stand structure and composition prior to harvest.

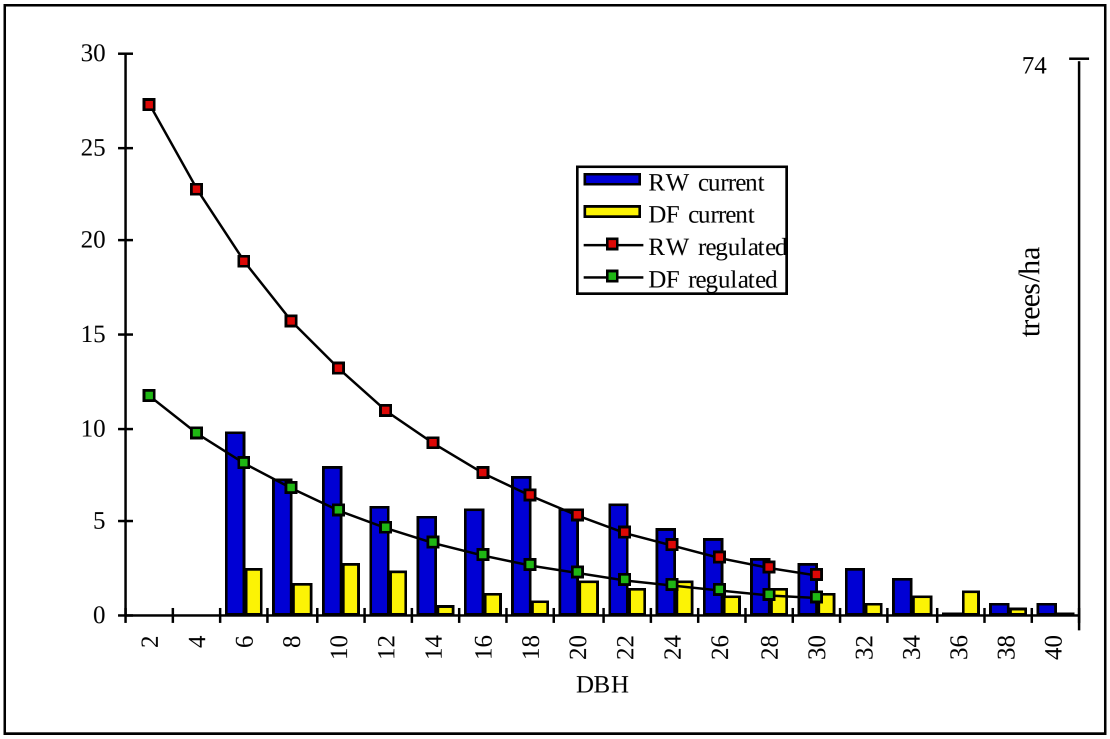

Figure 2. Comparison of current versus planned structure and composition for redwood (70 percent) and Douglas-fir (30 percent).