# Tanoak Utilization: Coordination of Tanoak Recovery and Yield Studies and Knowledge Transfer

**FINAL REPORT**

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UCFPL Technical Report Number 35.01.4xx

September 2001

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This Report is prepared as part of a project funded by the United States Forest Service,
Agreement No: G-5-97-20-065

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# Acknowledgements

In addition to the USDA Forest Service that provided the funding for this project, the following companies, organizations and individuals provided considerable assistance and support to the successful completion of the study.

**Companies**

Harwood Products, Branscomb, CA
G & S Milling, Willits, CA

**Organizations**

Mendocino Hardwood Development Association (MHDA), Fort Bragg, CA
California Department of Forestry (CDF), Parlin Fork Conservation Camp, Parlin Fork, CA
Institute for Sustainable Forestry (ISF), Piercy, CA

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## Abstract

This project was designed to develop technical information on the harvesting and milling of tanoak (*Lithocarpus densiflorus*) and furthermore to distribute this information to a wide audience. The forest products industry at large may then disseminate the information given to see whether or not tanoak is or can become an economically viable resource for their unique situation. To make this information useful for the wide range of people included in the forest products industry, trees were collected from two different sites as well as processed at two different types of mills. The two sites where the trees were harvested are referred to as ISF and MHDA. The ISF site is an uneven-aged mixture of tanoak, Douglas-fir, and redwood on steep a rugged terrain. The tanoaks in the ISF site have an average dbh of 18.1 and an average height of 40.3 feet. They are younger, smaller trees than those found at MHDA, in a moderate to highly stocked forest. The tanoaks at the MHDA site are larger, older trees averaging a dbh of 23.9 and height of 55.3 feet.[2] The trees from the two sites were processed into lumber at two different mills. The ISF trees were brought to a small band mill designed to produce about 500 board feet per hour. The logs from the MHDA site were brought to a commercial softwood mill that is capable of producing in excess of 4 thousand board feet per hour.[2] The tanoak lumber was dried by three different drying methods using various combinations of air drying, steam-heated kiln drying, and dehumidification drying. Volume and lumber size data was gathered at each step of lumber processing, starting with the standing tree and ending with dry lumber. The processed lumber from each site was graded green, stacked for drying, dried, planed, and then graded after kiln drying. While the lumber was being graded green, thickness was also measured to see how different drying methods would affect. Dry grading of the lumber was done twice, once by NHLA (National Hardwood Lumber Association) standards, where lumber stain (discoloration) is considered a defect, and once having the stain not considered as a defect. Cost data and processing times for each phase of the project was collected, unfortunately however, data collection was not done on a consistent basis and this information is incomplete. The data gathered resulted in a thorough understanding of Tanoak processing and provided the following specific results.

Best method to estimate tree volume,
Lumber yield by NHLA grade,
Lumber recovery for two types of sawmills,
Comparison of tanoak lumber yield from different sites,
Recommended methods for drying tanoak lumber,
Recommendations for minimizing drying defects,
Physical properties of Tanoak, including density, dimensional stability, and appearance,
An estimation of the timeframe and cost of production for various processing methods.

Examples of tanoak lumber were distributed to various woodworkers to produce demonstration products showcasing the woodworking properties of tanoak. The timeline and milestones for the entire project can be found in Appendix A.

## INTRODUCTION

A project was completed in order to develop recovery, yield, and cost information on the manufacturing of lumber from the tanoak resource in northwest California and to disseminate this information to the forest products industry at large.

- ❖ Progress Report 1 summarizes the project objectives, scope and the procedures for study tree selection and harvesting.[1]
- ❖ Project Report 2 describes the field activities, harvesting, milling, grading, and drying procedures at the Mendocino Hardwood Development Association (MHDA) and Institute for Sustainable Forestry (ISF) project sites.[2]
- ❖ Progress Report 3 reports the preliminary results of the green lumber production and grading as well as the partial data from the early kiln drying runs.[3]
- ❖ Progress Report 4 reports more results on the drying data as well as summarizes all the information gathered until that stage.[4]

This report will be an analysis of the data gathered throughout this study and will focus on the best estimations for lumber yields, different drying methods, the differences between the two study sites, and the cost of production. This report covers the full term of the project, including extensions, from October 1, 1997 to September 30, 2001.

## PROJECT OBJECTIVES

The specific objectives are:

- Design a work plan for studying tanoak lumber recovery and grade yield from the standing tree to kiln-dried lumber.
- Identify harvestable tanoak, which is representative of the existing northwest resource.
- Harvest and process enough timber for 70,000 board feet of tanoak lumber using industry representative harvesting and manufacturing methods.
- Develop recommended drying procedures that consider the economic and lumber quality aspects of air-drying and kiln drying.
- Record all harvesting and manufacturing time and cost data.
- Calculate lumber recovery and grade yield results and analyze with respect to manufacturing methods employed.
- Distribute lumber produced to a variety of non-profit woodworking organizations or medium-sized furniture manufactures in the Mendocino and Humboldt county study region to produce demonstration products such as furniture, flooring, and paneling for display at workshops, conventions, trade shows, and county and state fairs.

## PROCEDURES

***Site selection*** -- Two forest sites and two sawmills were selected for the project. The sites and mills were selected to provide a representation of the range of timber quality and sawmill types most likely to be used in a commercial tanoak lumber industry.

***In the field*** -- The trees were marked by the landowner's forester according to the goals of the timber management plan with input from the Woods Team. The Woods Team collected data in the forest such as tree number, DBH, DIB @ 17 feet from ground (for Girard's form class volume table), number of 16-foot logs, merchantable length, DIB @ end of merchantable length, defects, and valuable information such as problems encountered during harvesting, loading, hauling, and clean up. The leader of the Woods Team (Robin Thompson) graded the trees, defined the bucking lengths, and graded the logs to ensure consistent grading criteria and decisions between the study sites. For the purpose of this study, merchantable length is defined as the length of the tree that can produce at least a grade 3, 8-foot log, to a minimum DIB of 8 inches at the small end.

***Sawmill Procedures*** -- The goal of milling was to "mill-for-grade". It was the responsibility of the sawmill crew to optimize the highest grade in each step of the operation. Before milling, the logs were sorted by grade. Each grade was milled separately and milled to a thickness of 1.250-inch (+/- 0.050). After the lumber was milled, it was graded green according to NHLA Standard Grade Rules as well as graded without considering stain as a defect. Special consideration was taken to distinguish between the defects including mineral streaking, decay, and stain. The lumber was then dried and again graded, now dry, according to NHLA Standard Grade Rules as well as graded without considering stain as a defect. If there was any lag time between the first grading and drying times, the lumber was to be immediately stacked on 5/8-inch thick stickers. The milling procedures varied slightly between the two sites to accommodate the different sawmill equipment and set-ups used at each mill site.

***Drying*** -- Drying procedures were slightly modified at each site to accommodate differences in drying equipment and time delays in processing. The MHDA lumber was transported for drying to the G&S Milling Company, however, time delays in getting the kilns prepared for drying caused 4 MBF to be brought to Parlin Fork Conservation Camp for drying. The kilns at G&S are steam-heated kilns with excellent temperature and humidity control. Half of the lumber at G&S was put straight into the kiln green while the other half air dried for 7 1/2 months and then proceeded into the kiln. The Parlin Fork kiln is a dehumidification kiln with on-off compressor control, but no humidification system. At Parlin Fork, approximately 1 MBF of the lumber was kiln dried from the green condition, and the remainder was partially air dried, about one month, before kiln drying commenced.

ISF lumber that was produced at the Wild Iris sawmill was dried in the Wild Iris dehumidification kiln, which has good control of temperature and humidity. The ISF lumber was separated into six groups for drying. The first group of lumber was put into the kiln green. The subsequent five groups were each partially air dried before being put into the kiln. These five groups had to wait until enough lumber had been processed through the mill before it could obtain enough lumber to begin a kiln run. This caused the lumber within each of five groups to be air dried for various amounts of time.

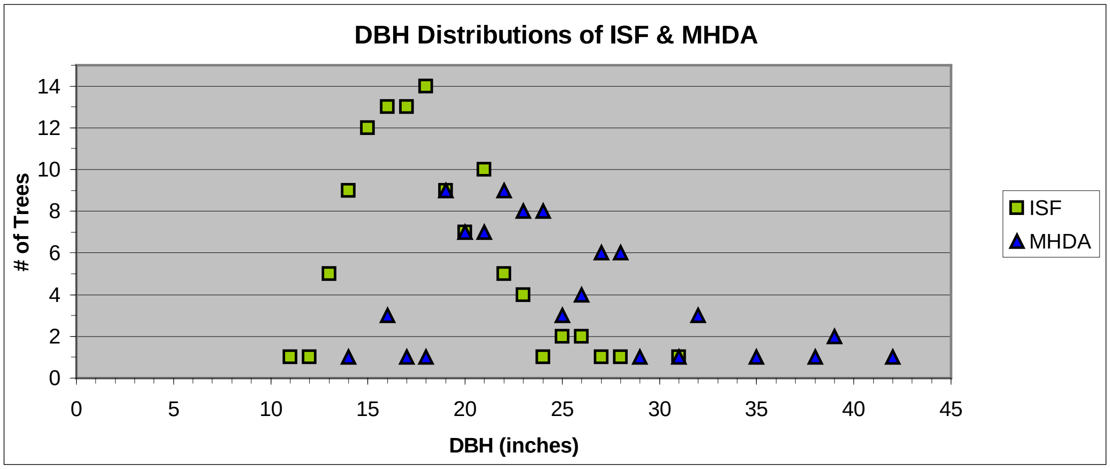
At each of the three drying sites, the lumber from each of the log grades (F1, F2, and F3) is to be equally represented in each group.

## RESULTS

Table 1. **Summary of Tree Data**

| Site | # of Trees | Weight | DBH (in.) | |
|---|---|---|---|---|
| | | | Average | Range |
| ISF | 111 | 120t | 18 | 12-31 |
| MHDA | 85 | 208t | 24 | 14-42 |

Figure 1. **DBH Distributions of ISF & MHDA**




Although the DBH's of the two sites may seem close, 18 and 24, the variation is so great that the statistical probability that the DBH's of the sites are similar is very low. P=0.0001

Table 2. **Wood Characteristics**

| Site | Log Density (Lbs/ft$^3$) | Green MC (%) | $Sg_{o2g}$ |
|---|---|---|---|
| ISF | 91 | 81 | 0.60 |
| MHDA | 80 | 95 | 0.59 |

Table 3. **Log Volume Estimations by Log Grade**

| Site | Log Grade | Scribner | Doyle | International 1/4 | Dry Lumber Yield – 4/4 |
|---|---|---|---|---|---|
| ISF | 1 | 524 | 482 | 553 | 588 |
| | 2 | 3014 | 2691 | 3272 | 3460 |
| | 3 | 8945 | 7266 | 10109 | 10362 |
| | All Grades | 12483 | 10439 | 13934 | 14410 |
| MHDA | 1 | 3938 | 3792 | 4118 | 3514 |
| | 2 | 7765 | 7187 | 8250 | 6054 |
| | 3 | 11437 | 10130 | 12545 | 10499 |
| | All Grades | 23140 | 21109 | 24913 | 20067 |

* Volumes in board feet.

Table 4. **Percentage of Difference Between Dry 4/4 Yield and Estimated Log Volumes**

| Site | Log Grade | Scribner | Doyle | International 1/4 |
|---|---|---|---|---|
| ISF | 1 | (-) 10.8% | (-) 18.0% | (-) 6.0% |
| | 2 | (-) 12.9% | (-) 22.2% | (-) 5.4% |
| | 3 | (-) 13.7% | (-) 29.9% | (-) 2.4% |
| | All Grades | (-) 13.4% | (-) 27.6% | (-) 3.3% |
| MHDA | 1 | (+) 12.1% | (+) 7.9% | (+) 17.2% |
| | 2 | (+) 28.3% | (+) 18.7% | (+) 36.3% |
| | 3 | (+) 8.9% | (-) 3.5% | (+) 19.5% |
| | All Grades | (+) 15.3% | (+) 5.2% | (+) 24.1% |

* (+) denotes an overestimation; (-) denotes an underestimation

## *VOLUME ESTIMATION*

Volume estimation is an important step in helping to determine the amount of wood in a tree and there are several different ways of estimating tree, log, and lumber volumes. Each of these methods has specific characteristics which make the estimations correlate better for different types, species, and sizes of trees. For manufacturing purposes we are more interested in the volume of lumber that will result from a specific tree than the total wood volume of the tree itself. For economic analyses as well, we want to know the best way to estimate the amount of lumber that will result from a harvest. We looked at a variety of tree and log estimations for both ISF and MHDA to see which of the existing estimations will best estimate the lumber yield for the tanoak species.

The three tree estimations used were Girard Form Class Method, Pillsbury Sawlog Volume, and a Calculated tree volume to an 8" top. Girard's method takes into account tree taper to get a more realistic view of the shape of the tree. The DIB is measured at 17 feet above the ground to determine the tree's form class and each form class has its own volume table where the volume of the tree is based on its DBH and height. The Pillsbury Sawlog Volume formula calculates the amount of wood in the tree dependent on DBH and the number of merchantable logs in the tree. More importantly, however, this method takes into account the amount of wood the saw blade consumes during milling. The last estimation method is simply a formula to calculate the total amount of wood in the tree, less defect deductions. When comparing the actual yield of one-inch thick (4/4) lumber, Girard's estimations are the most reasonable of the three listed above. Girard overestimated ISF actual yield by only 3%. See Table 5 below. It did not do nearly as well at estimating the

Table 5. **Summary of Tree Volumes**

| Site | Number of Trees | Girard Tree Volume | Pillsbury Sawlog | Calculated to an 8" top | Dry Lumber Yield – 4/4 |
|---|---|---|---|---|---|
| ISF | 111 | 14880 | 17592 | 36672 | 14410 |
| MHDA | 83 | 27816 | 29058 | 62332 | 20067 |
| Combined | 194 | 42696 | 46650 | 99004 | 34477 |

* Volume estimations are in board feet and include defect deductions.

larger trees of MHDA, overestimating by 38%. When the two sites were combined the overall estimation came down to a fairly reasonable overestimation of 23%. The Pillsbury Sawlog estimates are not that far behind Girard's, however, Girard's come closer in each instance so it does not make sense to use the Pillsbury Sawlog over Girard. The Calculated volume to an 8" top is not reasonable to estimate lumber yield at all. It assumes no waste from the entire tree and as can be easily seen above, doubles or triples the actual amount of lumber.

Four estimation methods were used after the trees were bucked into individual logs. These are the Smalian total log volume, Scribner log volume, Doyle log volume, and International 1/4 log volume. Most estimations based on the log form came closer to the actual yield than the estimations based on the tree because it is easier to take exact measurements and notice defect deductions on a downed log than a standing tree. Smalian's estimation is the exception to this. Its estimations were double the actual yields. Girard's and Pillsbury's sawlog tree estimates came closer than Smalian's.

Scribner, Doyle, and International 1/4 are all reasonable if not good estimates for approximating tanoak lumber. International 1/4 is the most accurate for small volumes and therefore had a very close estimate to ISF's yield, underestimating by only 3%. It did not do as well when estimating the MHDA lumber, it overestimated by 24%. Doyle's log rule, which is inaccurate at estimating the volume of small diameter logs, underestimated ISF's

Table 6. **Summary of Log Volumes**

| Site | Number of Trees | Smalian Log Volume | Scribner Log Volume | Doyle Log Volume | International 1/4 Log Volume | Dry Lumber Yield – 4/4 |
|---|---|---|---|---|---|---|
| ISF | 111 | 28440 | 12483 | 10439 | 13934 | 14410 |
| MHDA | 83 | 46440 | 23140 | 21109 | 24913 | 20067 |
| Combined | 194 | 74880 | 35623 | 31548 | 38847 | 34477 |

*All above estimations are in board feet and include defect deductions.

site by 27%, but did noticeably better at the MHDA site, overestimating by only 5%, for where the estimation is better designed. Scribner's estimation overestimates longer logs because it does not take taper into account, but perhaps because it does not specialize in estimating either small or large diameter logs, it did not do significantly better at estimating either site as the previous two. Scribner underestimated ISF's yield by 13% and overestimated MHDA's yield by 15%. When the actual yields and estimations of the two sites were combined, the closest estimate was Scribner, overestimating by a mere 3%, followed by Doyle with an underestimation of 8%, and then International 1/4, which overestimated by 13%. From our results of log volume estimations, Scribner's log volume is the most even keeled and reasonable estimation for estimating a wide variety of sizes and shapes of tanoak trees. If you know you are working with only small diameter trees, International 1/4 is best and Doyle works best for the large diameter trees, but overall, Scribner's estimation is most likely the safest estimation for a variety of sites.

Actual lumber yield was taken in four various measurements throughout the project. Yield was measured green with a 5/4 and 4/4-inch basis before the lumber was put aside for drying. It was then measured after it was kiln dried and surfaced on two sides in a 4/4 and 13/16-inch basis. Table 7 below shows all the values of the actual lumber yields of both

Table 7. **Summary of Lumber Yields and their Closest Tree & Log Estimates**

| Site | Number of Trees | Green Lumber Yield – 5/4 | Green Lumber Yield – 4/4 | Dry Lumber Yield - 4/4 | Dry Lumber Yield – 13/16 | Girard Tree Volume | Scribner Log Volume |
|---|---|---|---|---|---|---|---|
| ISF | 111 | 19879 | 15903 | 14410 | 11709 | 14880 | 12483 |
| MHDA | 83 | 32581 | 25514 | 20067 | 16304 | 27816 | 23140 |
| Combined | 194 | 52460 | 41417 | 34477 | 28013 | 42696 | 35623 |

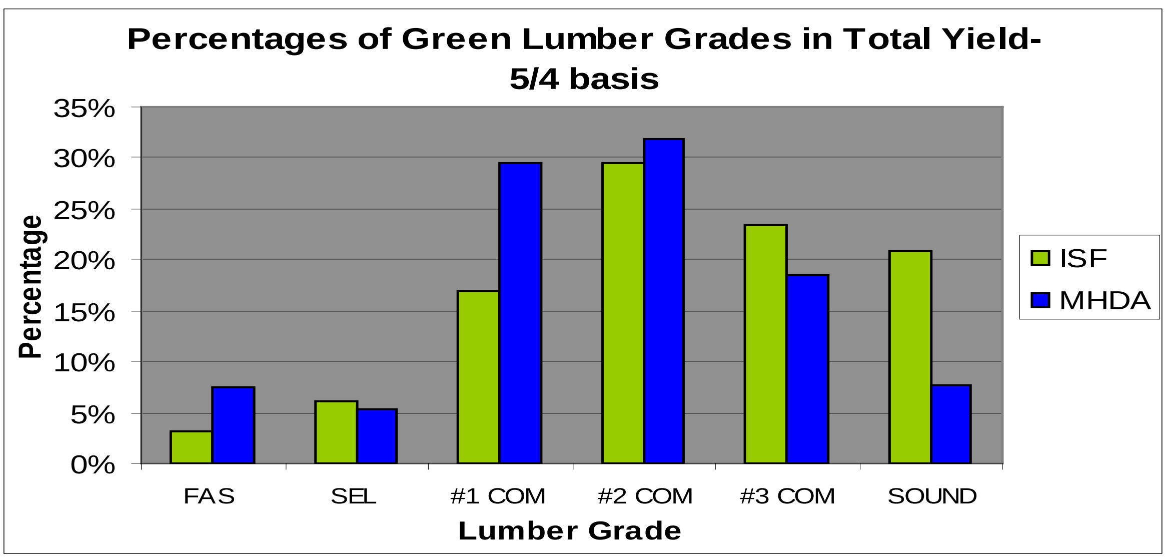
sites as well as the closest overall tree and log estimates to the one-inch thick (4/4) dry lumber yield.

## *SAWMILL OBSERVATIONS*

## *DRYING*

There was an effort to have the exact same drying methods done at both ISF and MHDA, however, the 6 month versus 8 hour milling times prevented this from taking place. The ISF lumber was dried in 6 separate kiln runs at Wild Iris, the same site where the lumber was milled. The MHDA lumber was brought to G&S Milling Company for drying, but due to complications, some of the wood was transferred to Parlin Fork Conservation Camp for drying. There were 2 kiln runs done at both G&S and Parlin Fork, four in total. The lumber was dried in steam-heated kilns at the G&S site and a dehumidification kiln at the Wild Iris and Parlin Fork sites. In Figure 2 below, you can view the green – 5/4 lumber volumes by lumber grade before they were set aside for drying.

Figure 2. **Green Lumber Yields by Lumber Grade – 5/4 basis**




Each of the three drying locations mentioned above ran one kiln run that consisted of all green lumber. All of the other kiln runs contained lumber that had been air dried for various amounts of time. At G&S, the lumber in their second kiln run was air dried for 7 1/2 months before being placed into the kiln. Parlin Fork's second kiln run was only partially air dried for one month before it too finished its drying in the kiln. Wild Iris had to wait till enough lumber had been milled before it could send its subsequent five runs into the kiln. Since the lumber was not all milled at the same time the five kiln runs that contained partially air dried lumber had all been air drying for various amounts of time before they had been sent to the kiln.

Table 8. **Summary of drying data**

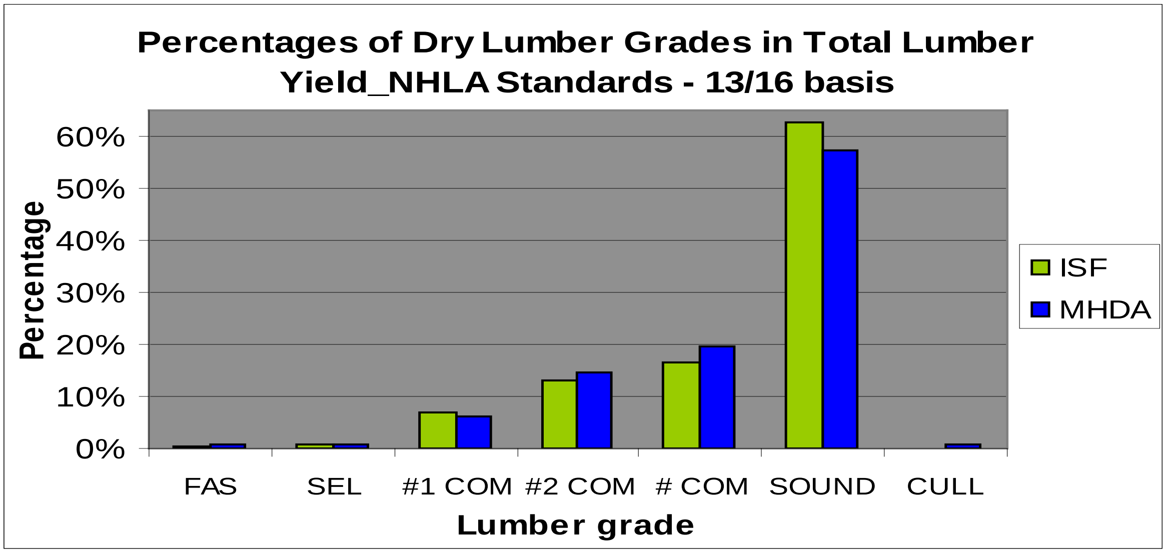
| Location | Method | % Upper Grades | | | % Increased: From stain to no stain |
|---|---|---|---|---|---|
| | | Overall Green | Dry: Stain a defect | Dry: Stain not a defect | |
| G&S 1 | Kiln dried green | 41% | 1.6% | 17% | 970% |
| G&S 2 | Air dried for 7 1/2 mo. | | 6% | 31% | 450% |
| PF-lower | Air dried for 1 month | | 25% | na | - |
| PF-upper | Kiln dried green | | 22% | na | - |
| ISF – 1 | Kiln dried green | 26% | 21% | 30% | 46% |
| ISF – 2 | Partially air dried | | 7% | 27% | 277% |
| ISF – 3 | Partially air dried | | 5% | 31% | 475% |
| ISF – 4 | Partially air dried | | 7% | 20% | 190% |
| ISF – 5 | Partially air dried | | 5% | 32% | 565% |
| ISF – 6 | Partially air dried | | 3% | 25% | 742% |

The drying of tanoak is the most intricate step in producing high quality lumber because there are substantial difficulties associated with it, the two most significant being collapse and kiln induced chemical stain. Storage amenities prior to air-drying are considerably important and it is also important to place stickers in between lumber immediately after it has been cut. At G&S the lumber did not start air-drying right away, but was stored in less than desirable conditions and this had a negative effect on the overall outcome of the distribution of lumber grades. See Table 8. As also seen above G&S 2 did slightly better than G&S 1. The lumber that was kiln dried green contained of a lot of collapse and stain. When air-dried prior to being put in the kiln there was less collapse as well as slightly less overall stain.

The storage dilemma was not of concern at Parlin Fork. In fact, the results are considerably better than G&S. The kiln run that contained lumber that had been air-dried for only a month had improved results: an increase of almost 14%. The data from both G&S and Parlin Fork support the notion that lumber that is air-dried for even a small amount of time prior to being placed into a kiln will reduce both warp and collapse, but won't do much to affect the stain. Also, lumber storage time can be seen as directly correlated with stain; as green lumber storage time increases so does the amount of stain.

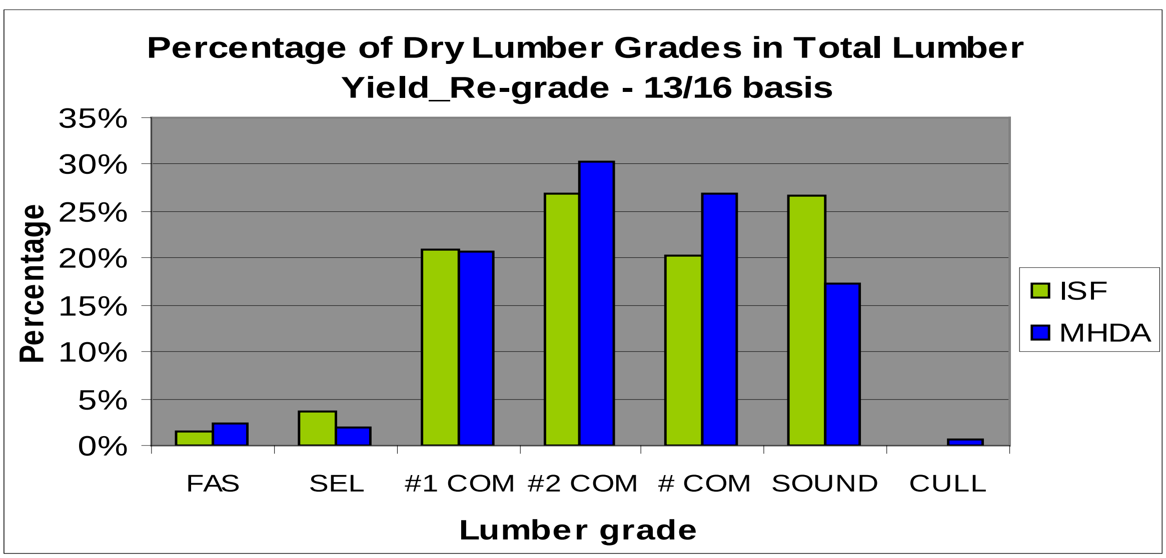
The hardest factor to manage while drying the ISF lumber was the lengthy time it took to mill all the wood into lumber. A lot of the lumber had to be air dried longer than desired for ISF to get enough lumber together for one kiln run. The run with nearly green lumber (ISF – 1) had the best outcome. Collapse and stain are undeniably the most severe problems affecting the quantity of high-grade lumber. Below in Figure 3 you can see the outcomes of the dry lumber yields when considering stain as a defect. The quantity of high-grade (upper three grades) lumber does not amount to a profitable level when stain is considered a defect, as it should be.

Figure 3. **Dry Lumber Yields of NHLA Standard Lumber – 13/16 basis**




When the lumber was graded not including the stain as a defect, the percentage of high-grade lumber is comparable to other hardwoods. Comparing Figure 3 and 4 shows the large affect that the stain has on the quality of lumber. What is clear to see, is that if we disregard the stain as a defect, tanoak can attain a good yield. More drying studies are needed to get more consistent results on the different drying methods. Specific studies need to be done to learn more about what can be done to decrease the occurrence of the stain. Initially, storing

Figure 4. **Dry Lumber Yields of Re-graded Lumber – 13/16 basis**




the lumber on stickers after milling and before drying can help decrease the occurrence of stain.

Collapse is another primary factor affecting the quality of the lumber. The highest incidence of collapse has taken place in the MHDA lumber. Secondary factors affecting not so much the quality rather than the quantity of lumber yield are shrinkage and planer loss. These are unavoidable to a certain extent; however, it is advantageous to know the magnitude of the loss. Overall, the ISF lumber has a shrinkage loss of 6.7% and planer loss of 30.7. The shrinkage loss of the MHDA lumber is somewhat higher than that of ISF, this is an indication of the more sever collapse that occurred in the MHDA lumber. What is clear to see is that if we disregard the stain as a defect, tanoak can attain a good yield. More drying studies are needed to get more consistent results on the different drying methods.

## SITE INDEX

This project started out looking at two distinct sites and now we are curious which site is the most effective at producing high quality, high-grade lumber. Is it the larger trees of MHDA or the smaller, younger trees out at ISF? Out in the field, 42% of the trees measured on the MHDA site were grades 1&2, 1 being the highest grade, 3 being the lowest. ISF had only 16% of its measured trees meet a grade 1 or 2. If these tree grades would have correlated into equivalent lumber grades, the MHDA site would have been a much more successful site than ISF. However, this did not occur. Cell collapse stood to be a major problem with the MHDA lumber, calculated at 50%. Since the trees at MHDA are older, they contain more heartwood, where "heart stain" or "mineral streaking" is found. Field observations also noted a higher incidence of this heart stain/mineral streaking in the MHDA lumber. MHDA's green moisture content of its logs were 95%, which further helps explain the large amount of mineral streaking since mineral streaking is associated with zones of high moisture content.[4] It is in these areas of heart stain and mineral streaking where drying defects are prevalent. A strong correlation is observed between the amount of heart stain and the amount of collapse in the lumber. ISF's green moisture content was 81%, which could explain the lesser amount of collapse of 41%. A study carried out by the University of California Forest Products Lab in 1965 found a higher incidence of heart stain in older trees with slow growth rates.[4] The younger, faster growing trees at the ISF site have better quality wood and has proven to be the better overall site in terms of lumber quality.

## TIME and COST DATA

The time and cost data collected reflect the high costs associated with processing lumber in a research study. More time and care was devoted to each step than would take place in a normal production operation. The relative time and costs however do reflect basic differences between a high-speed, production mill and a smaller scale sawmill.

TIME

| **Course of Action** | **ISF – 111 Trees** | **MHDA – 83 Trees** |
|---|---|---|
| Tree marking / grading | 2 people, 2 days (16 hours) | 11 1/2 hours |
| Logging | 30 hours - $35/hr | |
| Log bucking and grading | 30 hours | 24 hours |
| Milling logs into lumber | 6 months (1 log ~ 1/2hr) | 8 hours |
| Grade KD lumber | | 8.5 MBF took 7.25 hours |

COST

| ISF BUDGET ANALYSIS 6/19/01 | 10/1/98 Until 5/31/00 |
|---|---|
| BUDGET CATEGORY | |
| Logging & hauling to mill | $ 9,683.25 |
| Log bucking & grading | $ 2,806.56 |
| Milling logs into lumber | $ 10,028.91 |
| Grade 20 MBF of green lumber | $ 862.50 |
| Haul lumber | $ 1956.30 |
| Sticker lumber | $ 101.50 |
| Air/Kiln drying 10 MBF of lumber | $ 3,591.02 |
| Kiln drying 10 MBF of lumber | $ 5,335.66 |
| Plane 20 MBF of dry lumber | $ 3,738.95 |
| Grade 20 MBF of dry lumber | $ 3667.55 |
| Supplies | $ - |
| Overhead | $ 922.54 |
| **TOTAL BUDGET** | **$ 42,694.74** |
| **$42,694.74 / 11709 (13/16 yield) =** | **$3.65/bd.ft.** |

| MHDA BUDGET ANALYSIS 6/19/01 | 10/1/98 Until 10/25/99 |
|---|---|
| BUDGET CATEGORY | |
| Logging & hauling to mill | $ 5,414.00 |
| Log bucking & grading | $ 1,418.62 |
| Milling logs into lumber | $ 4,438.46 |
| Grading 20 MBF of green lumber | $ 3,210.00 |
| Haul lumber to kiln | $ 722.70 |
| Sticker lumber | $ 37.50 |
| Air/Kiln drying 10 MBF of lumber | $ - |
| Kiln drying 10 MBF of lumber | $ 2,006.25 |
| Plane 20 MBF of dry lumber | $ 4,003.50 |
| Grade 20 MBF of dry lumber | $ 1,380.00 |
| Supplies | $ 469.70 |
| Overhead | $ 4,948.39 |
| **TOTAL BUDGET** | **$ 28,049.12** |
| **$28,049.12 / 16304 (13/16 yield) =** | **$1.72/bd.ft.** |

## *TANOAK DEMONSTRATION PROJECTS*

- 2000 board feet was used by the city of Alturas in a Railroad Museum.
- ISF lumber was processed into a tanoak stool and coat rack and flooring.
- 2000 board feet was used to manufacture wainscoting and molding in a Willits Church
- 1000 board feet was converted into furniture by a local woodworker
- 4000 board feet was processed into paneling and furniture for a CDF conference room
- Remainder was discarded as waste from destructive tests or is in storage with the UC Forest Products Laboratory for future projects

## SUMMARY

Tanoak not only has the opportunity to become a utilized resource in Northern California, but an economically efficient and viable one as well. However, as indicated in this study, the costs of production are high suggested that more efficient processing must be developed or higher value markets sought. Demonstrations of the use of tanoak indicate that it can become a resouce for beautiful flooring, furniture, and other typical hardwood products. However, drying proves to be difficult. This project resulted in promising yield and recovery results under careful manufacturing and a recommended drying process that will minimize defects and increase the lumber potential of tanoak.

## *Yield and Recovery of Tanoak Lumber*

The tanoak from the ISF site gave the best results because it was less prone to develop cell collapse during drying. The tanoak from the MHDA site had a much higher percentage of trees with significant amounts of mineral heart which was found to be highly correlated with cell collapse. An example of the best case scenario for grade lumber yield is obtained from the ISF results given in Figure 5. In this scenario we assume the lumber can be processed and dried without any kiln induced chemical stain. The results of grade lumber from each log grade are very consistent with the grade yield expected from other commercial hardwoods, such as the red oak of the eastern US hardwood forests.

**Figure 5 -- Tanoak Yield -- Lumber Percentage by Log Grade** (assume no stain degrade)

| Log Grade | Dry Lumber by Grade | | | | | | |
|---|---|---|---|---|---|---|---|
| | FAS | SEL | 1COM | 2COM | 3COM | SOUND | TOTAL |
| F1 | 8.37% | 15.06% | 32.22% | 30.75% | 10.67% | 2.72% | 100.00% |
| F2 | 3.91% | 6.62% | 31.23% | 27.85% | 15.05% | 15.33% | 100.00% |
| F3 | 0.34% | 1.97% | 16.83% | 26.49% | 22.48% | 31.89% | 100.00% |

| | Green Lumber by Grade | | | | | | |
|---|---|---|---|---|---|---|---|
| | FAS | SEL | 1COM | 2COM | 3COM | SOUND | TOTAL |
| F1 | 19% | 26% | 22% | 23% | 4% | 6% | 100% |
| F2 | 7% | 11% | 24% | 31% | 15% | 11% | 100% |
| F3 | 1% | 3% | 14% | 29% | 27% | 25% | 100% |

As summarized below in Figure 6, the volume of lumber produced per thousand board feet of log volume was significantly better for ISF than it was for MHDA. Again an indication of the volume loss to the excessive shrinkage caused by cell collapse. The International ¼" Log Rule gives the best estimate of lumber yield from tanoak logs, resulting in only 3% more lumber produced than estimated (overrun). The Doyle Log Rule gave the worst estimate, yielding a 38% overrun (good for the log buyer but not for the log seller). All rules resulted in underruns for the lumber produced from the MHDA site.

**Figure 6 – Recovery for Various Log Rules**

| | BF Log Volume (Scribner) | BF Log Volume (Doyle) | BF Log Volume (International 1/4) | Actual Dry Lumber Recovery (BF) |
|---|---|---|---|---|
| ISF | 12483 | 10439 | 13934 | 14410 |
| MHDA | 23140 | 21109 | 24913 | 20067 |
| ISF BF Recovery per MBF | 1154.37 | 1380.4 | 1034.161 | |
| Percentage Overrun | 15 | 38 | 3 | |
| | | | | |
| MHDA BF Recovery per MBF | 867.1997 | 950.6372 | 805.4831 | |
| Percentage Overrun | -13 | -5 | -19 | |

## *Recommend Drying Schedule for Tanoak*

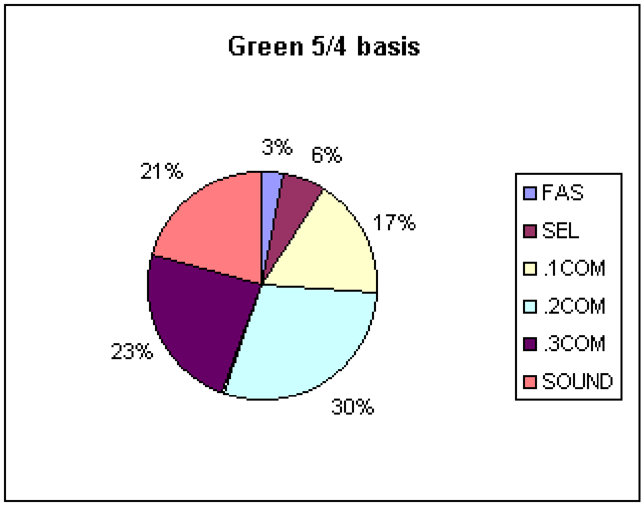
The following schedule was developed, based on the information obtained in this study on the drying rates, defect potential, and propensity of tanoak to develop a kiln/chemical stain. The first two steps are designed for a low temperature predrier. If a predrier is not available these two steps can be used as a guide for an air-drying yard or for the initial settings in a steam-heated kiln or dehumidification kiln. It is imperative that the temperature remains below 80 degrees and the relative humidity below 65% until the wood moisture content drops below 50%. Temperatures above this will create more collapse defects and humidity higher than 65% create favorable conditions for the development of stain.

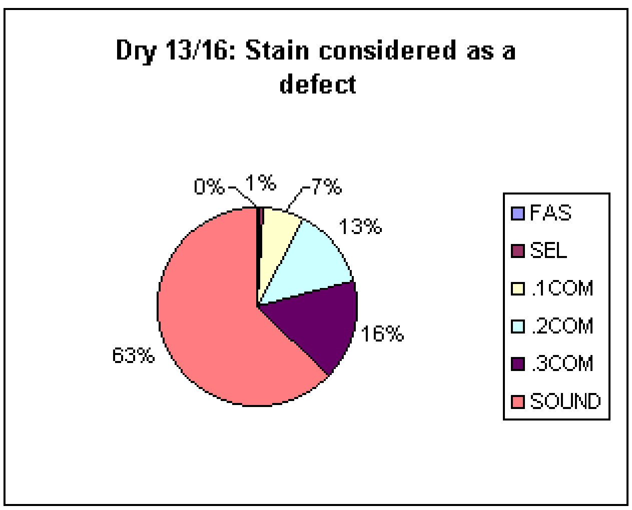
| Step | Average Sample MC | DB (F) | WB (F) | WB Depression | RH (%) | EMC |
|---|---|---|---|---|---|---|
| 1. Pre-dry | > 50 % | 80 | 70 | 10 | 61 | 11 |
| 2. Pre-dry | 50 – 30 | 90 | 85 | 5 | 81 | 16 |
| 3. | 30 - 25 | 100 | 95 | 5 | 85 | 18 |
| 4. | 25 - 20 | 110 | 100 | 10 | 70 | 12 |
| 5. | 20 - 15 | 120 | 100 | 20 | 50 | 8 |
| 6. | 15 – 7 | 140 | 110 | 30 | 38 | 5.8 |
| 7. | Equalize (72-hours) | 140 | 115 | 25 | 55 | 7 |
| 8. | Condition (8 – 16 hours) | 140 | 132 | 8 | 80 | 13 |

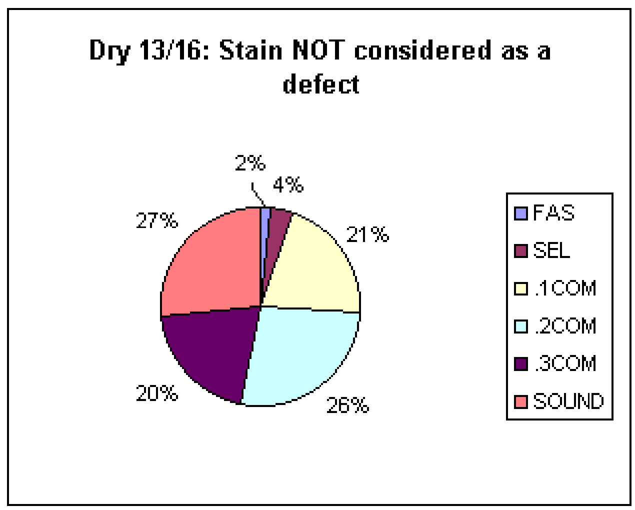
# Appendix A. Data Summaries

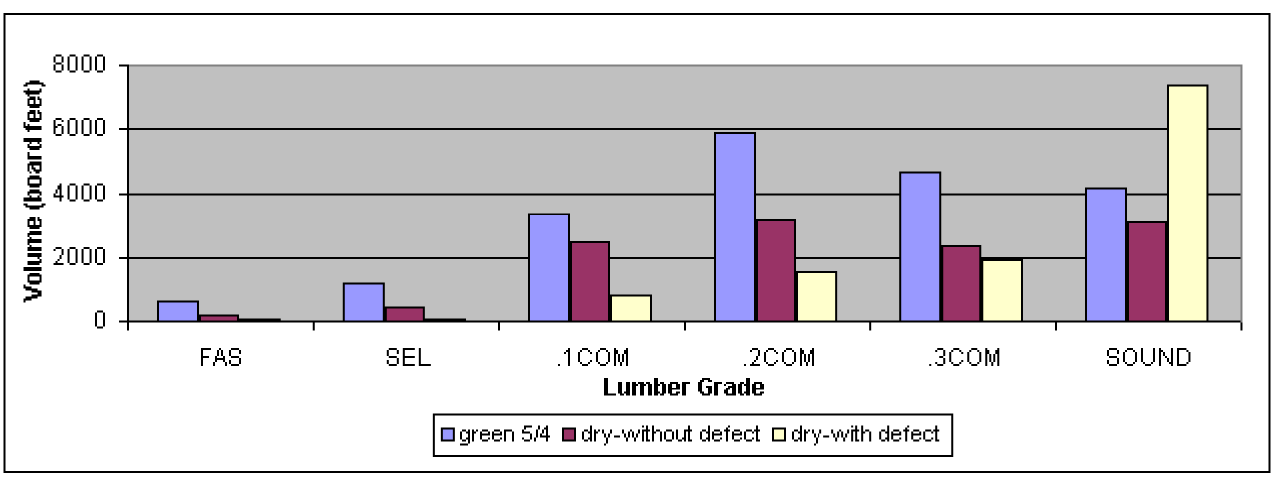
## *Figure A1 -- Yield of ISF and MHDA Green & Dry Lumber*

| | FAS | SEL | .1COM | .2COM | .3COM | SOUND | Total |
|---|---|---|---|---|---|---|---|
| Green 5/4 | 616 | 1208 | 3356 | 5880 | 4664 | 4155 | 19879 |
| Dry-without defect | 179 | 424 | 2450 | 3160 | 2367 | 3129 | 11709 |
| Dry-with defect | 41 | 76 | 793 | 1523 | 1920 | 7356 | 11709 |

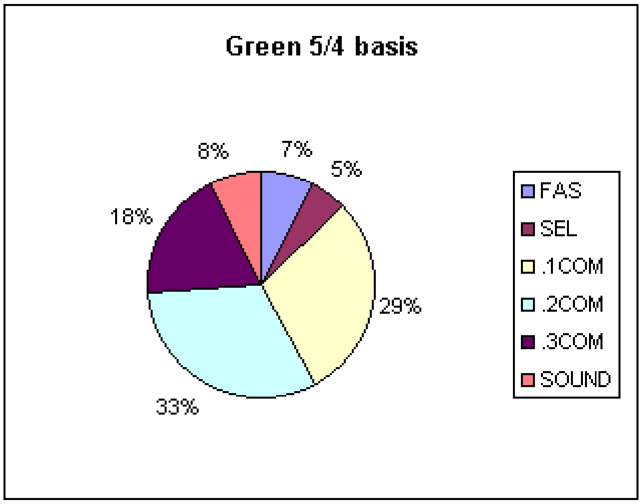


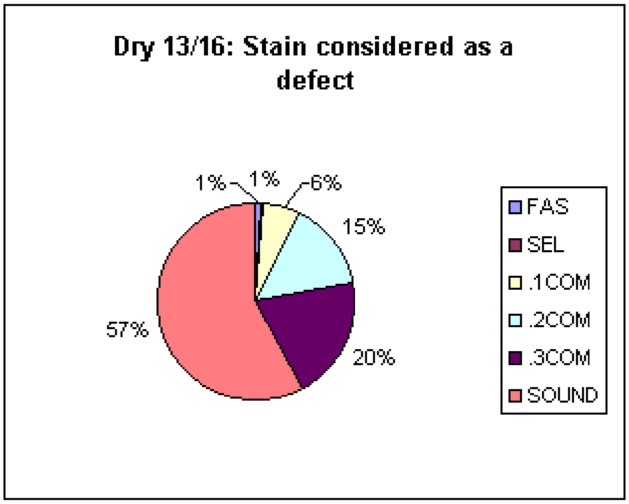



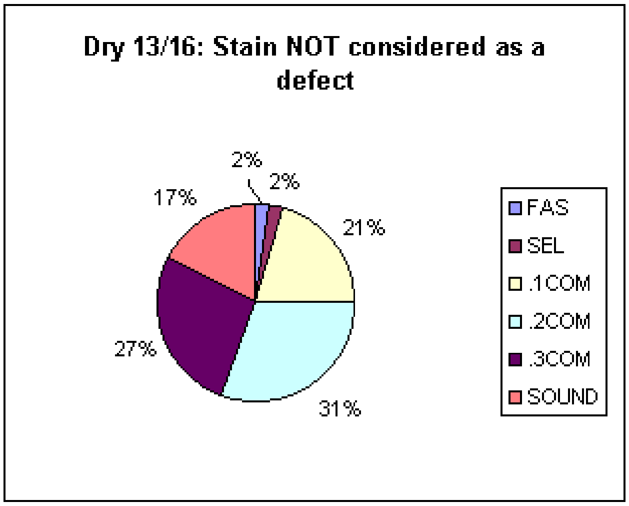



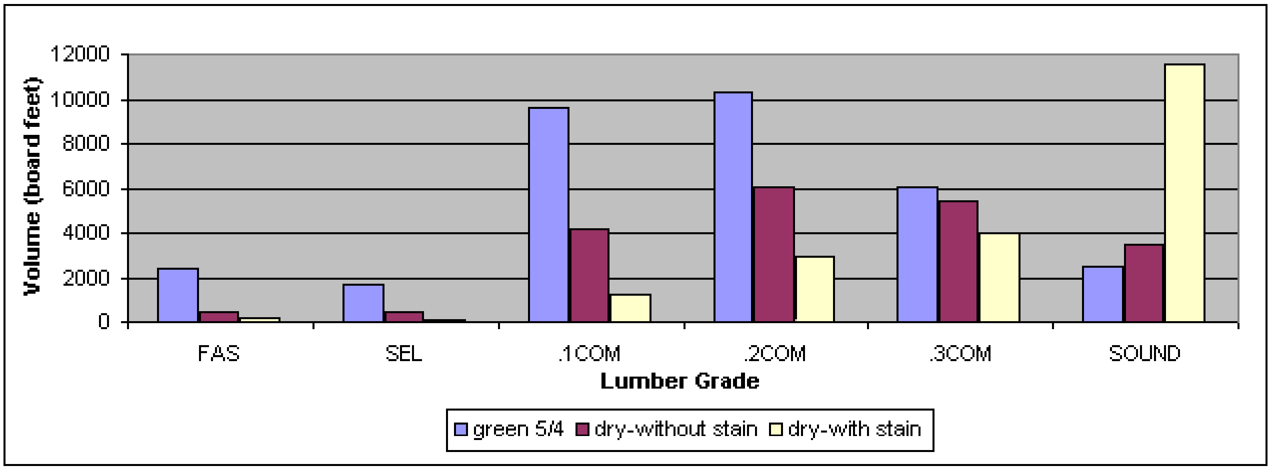



| MHDA | FAS | SEL | .1COM | .2COM | .3COM | SOUND | Total |
|---|---|---|---|---|---|---|---|
| green 5/4 | 2410 | 1730 | 9590 | 10347.5 | 6026.25 | 2477.5 | 32581.25 |
| dry-without stain | 460 | 403 | 4140 | 6062 | 5412 | 3468 | 19945 |
| dry-with stain | 142 | 120 | 1251 | 2945 | 3967 | 11520 | 19945 |

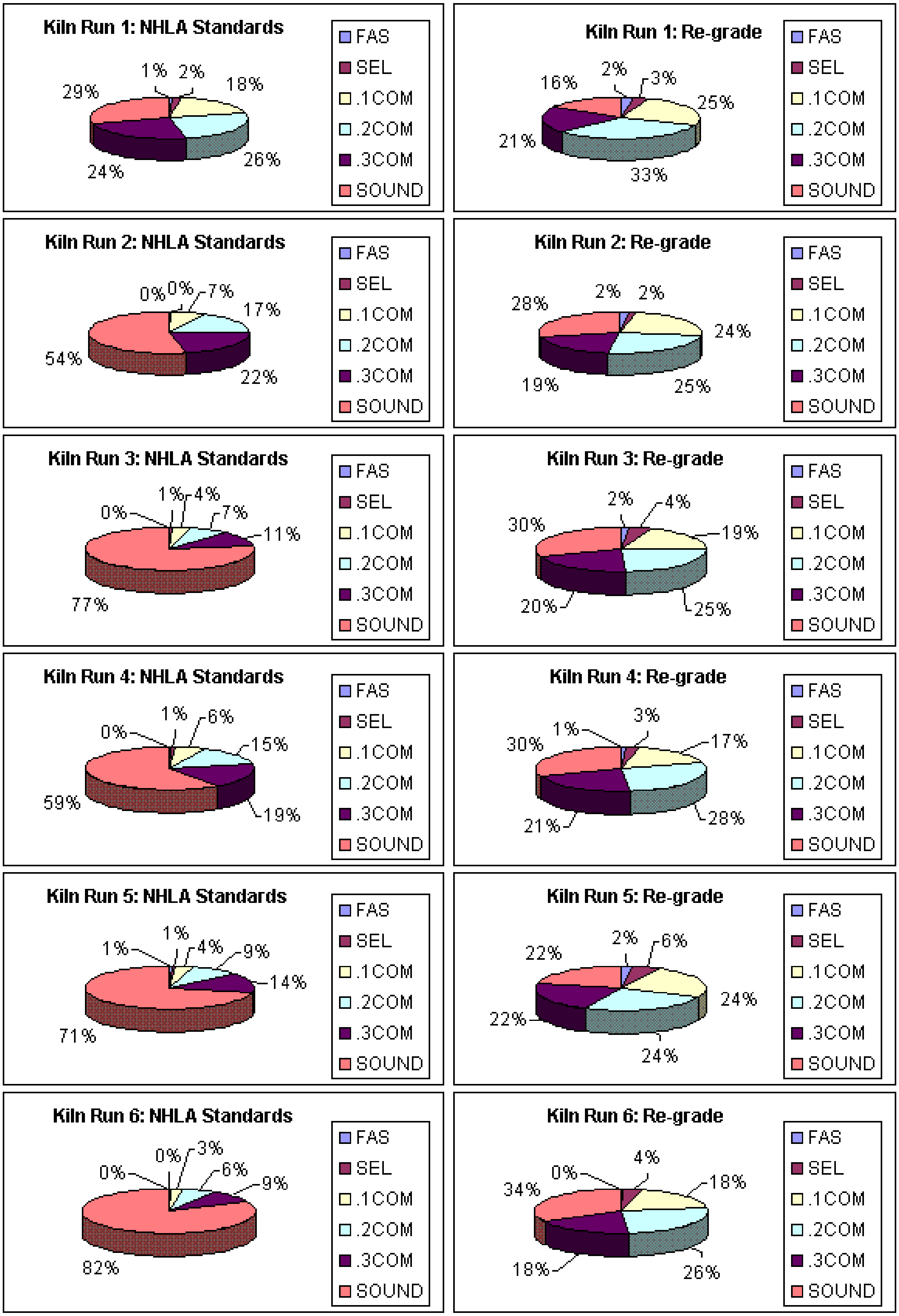


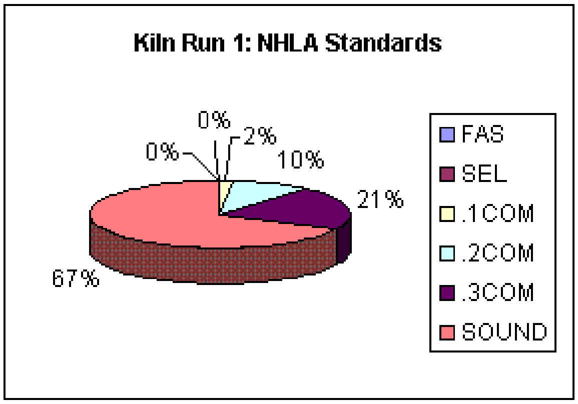



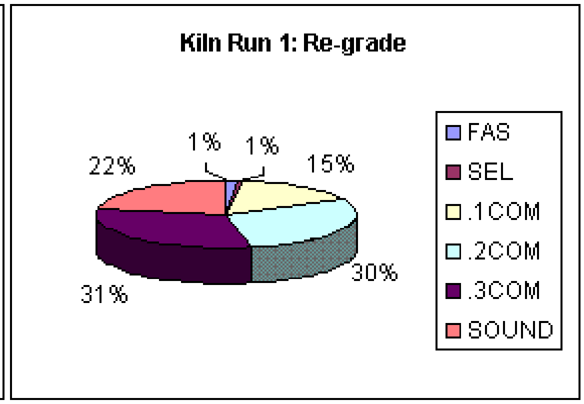
## *Figure A3 -- ISF Kiln Record: Runs 1-6*

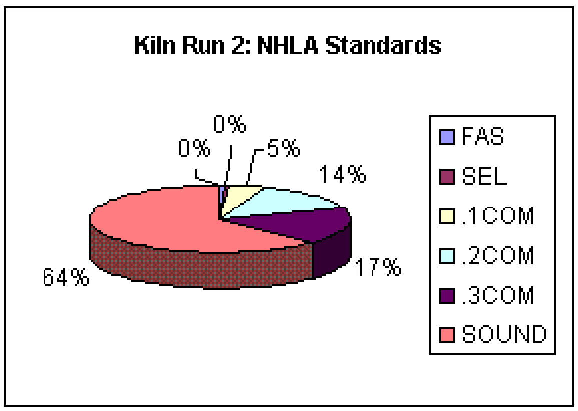


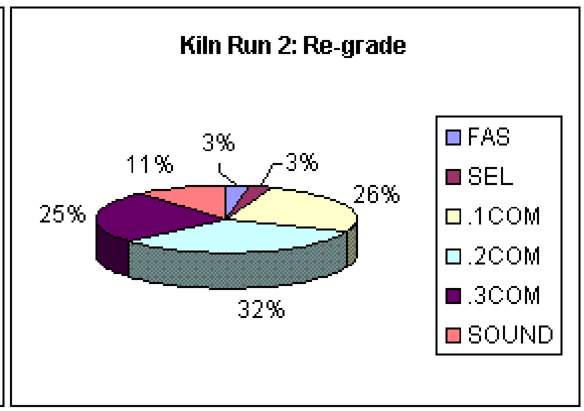
## *Figure A4 -- MHDA Kiln Records*

### G&S: Kiln Runs 1 & 2

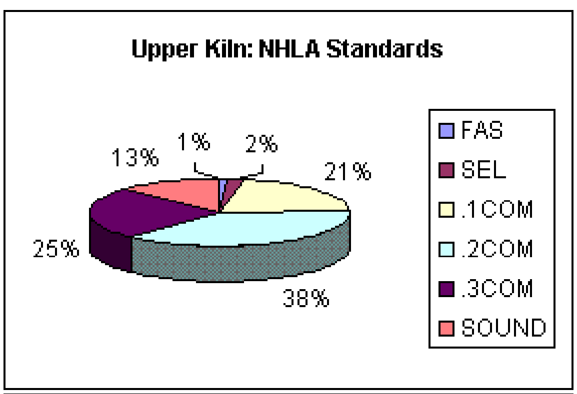


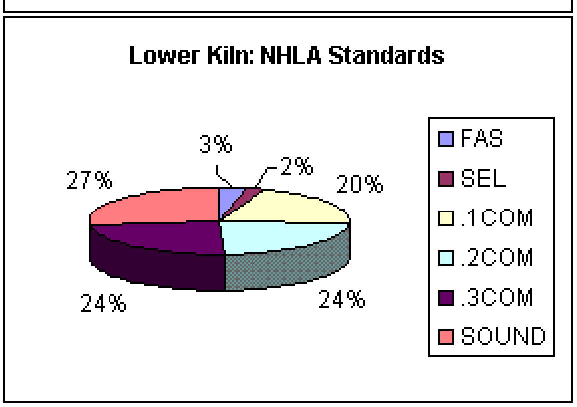




### Parlin Fork: Upper & Lower Kiln Runs



## Appendix B: Project Milestones From October 1, 1997 to July 2001

| TASK | 1998 / 1999 / 2000 / 2001<br>O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J |
| --- | --- |
| Study trees marked & graded | => |
| Trees harvested & hauled to mill | => |
| | |
| MHDA logs bucked & graded | => |
| MHDA logs milled into lumber | => |
| MHDA green lumber graded | => |
| MHDA air drying | ==================> |
| MHDA kiln drying | => ===> ===> => |
| MHDA dry lumber graded | => => |
| | |
| ISF logs bucked & graded | => => |
| ISF logs milled into lumber | =====> ==> |
| ISF green lumber graded | =============> |
| ISF air drying | ===========================> |
| ISF kiln drying | ======> ==> => ====> => => |
| ISF dry lumber graded | => => => => => |
| | |
| Field & mill site data collection | ========================================> |
| Data analysis & reporting | ==========================================================> |

# Appendix C – Newsletter Article

## **Does it Make "Cents" to Process Tanoak to Lumber?** – John R. Shelly, CE Forest Products Advisor, University of California Forest Products Laboratory

California has the potential to become an important hardwood lumber producer. It has a high demand for hardwood lumber from manufacturers and consumers, skilled timber and wood workers capable of producing the lumber, an underutilized resource of high-density hardwoods, and many rural economies in need of new businesses. Yet, the California hardwood sawmill industry remains a fragmented, loosely connected organization of small producers with significant processing and economic challenges. As a result, California meets most of its demand for hardwood lumber with imports from the eastern US or other countries. Currently a large number of hardwood trees are removed in response to the pressures of urban development, hazard tree removal, or forestland conversion. Much of this hardwood fiber is lost to low value firewood or pulp chips or ends up as landfill. In addition, if the native hardwoods succumbing to sudden oak death syndrome can be used for lumber then even more opportunities will open up to utilize large quantities of native-grown hardwoods.

Tanoak (*Lithocarpus densiflorus*), one of the major species susceptible to the sudden oak death disease, is one of the few native California hardwood species that meets the three major requirements of a viable resource for commercial lumber and value-added products.

1. Tree and wood property characteristics that are favorable to lumber and wood products.
2. A sufficient standing tree inventory to sustain harvesting volumes needed to meet economic requirements of sawmill production.
3. Trees are concentrated in regions with an existing harvesting infrastructure

Tanoak exhibits very good machining and finishing characteristics and because of its high density (40.4 $lbs/ft^3$ at 8 % moisture content) and hardness it can be an excellent choice for high quality furniture and flooring. It compares favorably in physical properties to northern red oak, a benchmark furniture species. Over the course of history tanoak has gone from a tree valued only for the high tannin content of its bark for the west coast leather tanning industry, to weed species status, to finally, recognition of some of its unique wood properties.

The US Forest Service estimates of the size of the tanoak resource at more 2 billion cubic feet of standing timber and it has been estimated that an annual harvest of about 50 million board feet could be sustained on the non-industrial private forestlands of the northern California coast region.

In spite of these favorable characteristics, a long-term tanoak industry has not materialized. A lack of information on processing characteristics and recommended manufacturing techniques continue to be a problem for efficient cost effective production. In addition, a thorough understanding of the expected lumber recovery and grade yield from the available resource is needed to understand the economic viability of tanoak lumber production. To help address these needs, a multi-year project was initiated by the University of California Forest Products Laboratory to develop recovery, yield, and processing information on the manufacturing of lumber from the tanoak resource in northwest California. The information gathered from this project will also be of value to small mill operators working with non-commercial timber resources.

This project received support from the US Forest Service, Region 5 State and Private Forestry and the cooperation of two north coast nonprofit organizations, the Mendocino Hardwood Development Association (MHDA) and the Institute of Sustainable Forestry (ISF). Timber was selected from two different northern California sites and sawn into lumber at two different mills: 1/ Harwood Inc., a commercial softwood sawmill; and, 2/ Wild Iris, a small-mill demonstration project of ISF. The sites and mills were selected to provide a representation of the range of timber quality and sawmill types most likely to be used in a commercial tanoak lumber industry. Both sites were in mixed conifer/hardwood forests of predominantly Douglas-fir, redwood, and tanoak. A common goal of both harvest plans was to thin the tanoak component and to encourage the growth of the conifers on the site.

Each selected tree and the logs produced from the trees were measured in size and form (shape) and estimates made of the lumber volume expected from each tree or log. The trees, logs, and lumber produced were also graded following standard hardwood grading rules. After the logs were processed into lumber, various combinations of ambient air, steam-heated kiln, and dehumidification kiln drying methods were used to study the effect of drying temperature and rate of drying on the quality of the lumber kiln-dried to 8% moisture content. One-half of the lumber from each site was kiln dried directly from the green condition and the other half was first air-dried to 20% MC and then kiln dried.

## Lumber Yield Estimations are Reasonable

A total of about 50 thousand board feet (MBF) of lumber (green basis) was produced from the two sites. The trees from the MHDA site were larger and of a higher grade than those from ISF. At the MHDA site, 42 percent of the trees were measured as tree grades 1 and 2 (1 being the highest grade, 3 being the lowest) with an average 24-inch DBH. Whereas, only 16 percent of ISF trees were measured as grades 1 and 2 and they averaged an 18-inch DBH. The average defect deduction in trees from both sites ranged from 10 to 15 percent. The Girard Form Class method, based on the size and taper of trees proved to be a reasonable estimate of the lumber yield; it over estimated the volume of 1-inch thick (4/4) dry lumber by 19 percent and underestimated the yield of green 1-1/4 inch thick green lumber by 23 percent. Of the common log-based estimation methods for predicting lumber yield on the basis of log size and taper the International ¼-inch log rule method, which overestimated dry lumber yield by 11 percent, and the Doyle method which underestimated yield by 9 percent, were the best (Figure 1).

The yield of green lumber from the tanoak study logs was similar to yield expected for commercial eastern hardwood species. The top log grade yielded 68 percent of No 1 Common and Better lumber (upper, most valuable grades). In the middle and lowest log grades, 49 percent and 31 percent of the lumber produced was in the upper grades, respectively.

## Drying Proves to be Problematic

Drying results from the study indicate a potentially serious drop in grade and hence lumber value when the lumber is dried (Figure 2). The major drying defects encountered were cell collapse, warp, and a drying-induced chemical discoloration of the wood (chemical stain). There was a 30 percent volume drop in No 1 Common or Better lumber from the green condition to the kiln dried condition (dry without stain) because of the cell collapse and warp. If the chemical stain was counted as a defect, which it should be, then the drop in upper grade volume was 78 percent. This is clearly an unacceptable amount of degrade. Air-drying the lumber for 6 months before kiln drying dramatically reduced the amount of warp and collapse, however stain remained a problem.

It was also noted that drying degrade was greater in the lumber produced from the older-larger trees in the study. A strong correlation was noted between the amount of collapse in the lumber produced from these trees and the high frequency of "mineral streak/heart stain", a zone of dark reddish/brown discoloration in freshly cut lumber. An observation was noted during the field trials that the lumber from the MHDA site appeared to have a higher incidence of "mineral streak/heart stain" than the ISF material. It was also evident that severe drying defects were almost always present in the zones of this "heart stain". A study conducted at the University of California Forest Products Lab in 1965 found a higher incidence of heart stain in older trees with slow growth rates. There was no apparent trend between heart stain and diameter, but trees less than 80 years old had less heart stain than trees over 100 years old. When growth rates were compared the trend was strong, with faster growing trees exhibiting the least amount of heart stain (20%) and the slowest growing trees having the most (43%). The field observations in the current project are consistent with these observations. Further study is needed to understand the mechanism of heart stain formation and its effect on drying defects.

## Summary

Tanoak has the potential to be an important hardwood resource. However, some of the unique wood properties present manufacturing challenges that require specialized techniques and extra care, especially during drying. In this study it was confirmed that tanoak is prone to warp, collapse, and discoloration (staining). The knowledge gained from the results of the study help to understand the manufacturing challenges and develop recommendations for maximizing lumber yield and value.

The importance of following good drying practices cannot be overemphasized. It is necessary to minimize the defects created as the lumber dries to achieve the full product value. The best results are obtained with partial air-drying followed by kiln drying, but with care good results can also be obtained by immediately drying from the green condition in a kiln. Based on the results of the study discussed in this article, the recommended drying practices are as follows:

1. Process logs into lumber as quickly as possible because stain is more likely in logs stored longer than 1 month.
2. Fresh cut lumber must be stacked immediately on stickers to start the drying process.
3. The initial drying conditions (for at least the first two weeks of drying) should encourage good circulation of air at a temperature between 90 and 100 degrees Fahrenheit with a relative humidity between 70 to 80 percent. This can be accomplished in either air drying or kiln drying methods. If it is not possible to maintain these air conditions than it is important to keep the temperature below 80 degrees Fahrenheit to minimize drying-induced chemical discoloration.
4. Maintain the above conditions until the average lumber moisture content reaches 30 percent and than gradually (over a period of 3 weeks) increase the drying conditions in the kiln to a temperature of 140 degrees with a relative humidity of 30 percent.
5. Dry the lumber to 6-8 percent moisture content for inland locations and 8-10 percent for coastal climates.

Tanoak certainly has utilization value. It is being increasingly accepted as hardwood flooring and furniture stock in both commodity and niche markets. Creating new markets or competing in existing wood markets with well-established species is never easy so it is extremely important to keep manufacturing costs as low as possible by doing everything right the first time. The University of California Forest Products Laboratory is willing to help.

For more information visit the UC Forest Products Laboratory web site at
www.ucfpl.ucop.edu or contact John Shelly at john.shelly@ucop.edu or telephone 510-215-4210

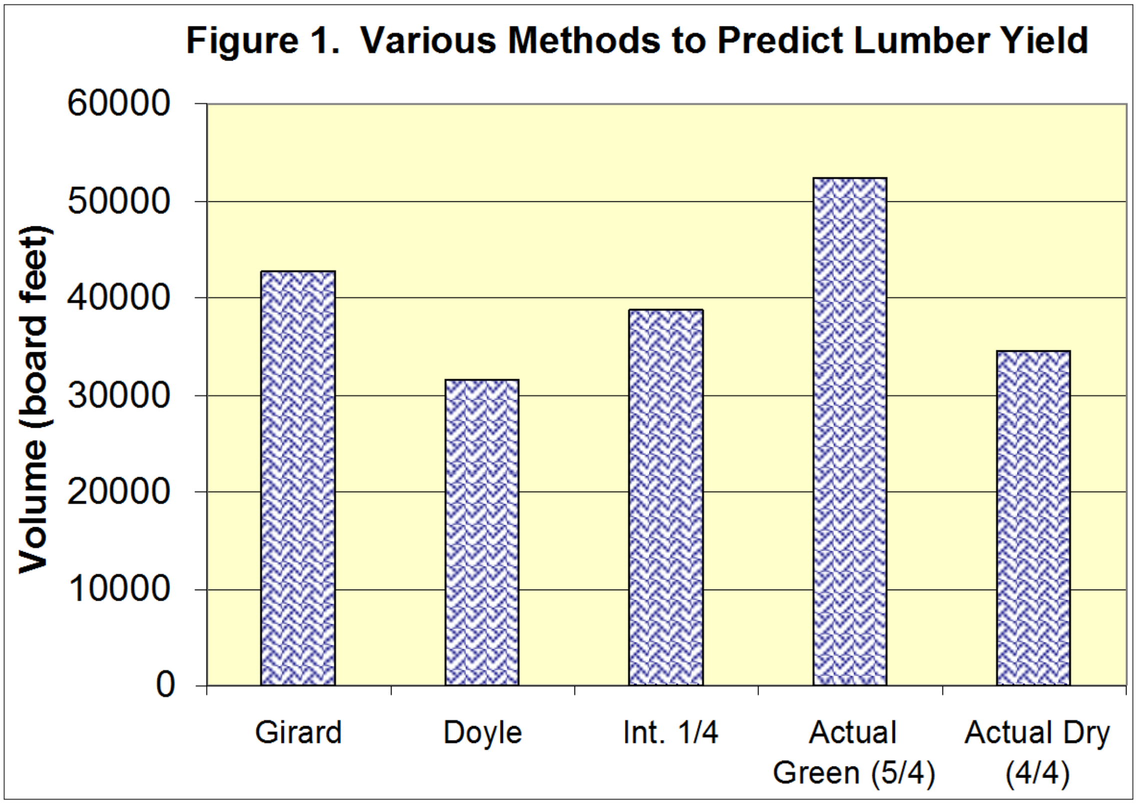


Figure 1. Various Methods to Predict Lumber Yield
Volume (board feet)
60000
50000
40000
30000
20000
10000
0
Girard
Doyle
Int. 1/4
Actual Green (5/4)
Actual Dry (4/4)

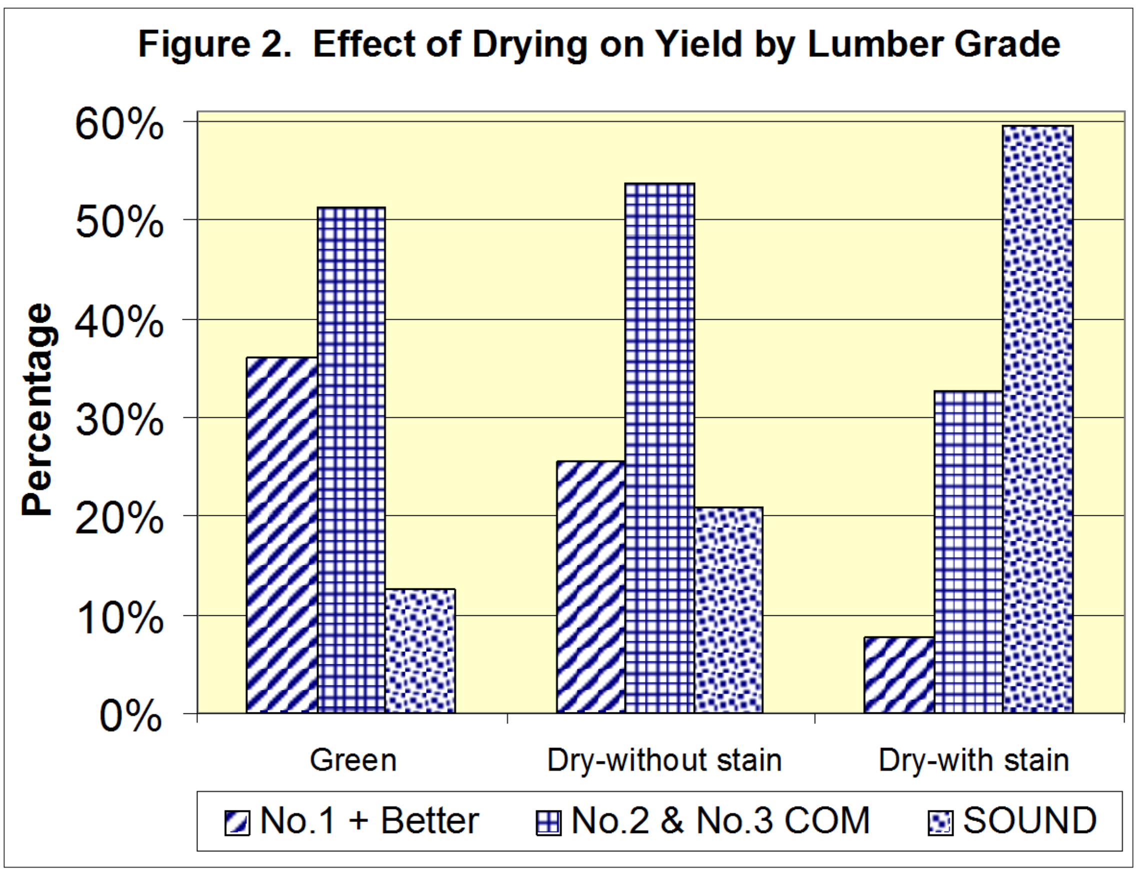


Figure 2. Effect of Drying on Yield by Lumber Grade
Percentage
60%
50%
40%
30%
20%
10%
0%
Green
Dry-without stain
Dry-with stain
No.1 + Better
No.2 & No.3 COM
SOUND

Representatives of MHDA grading kiln-dried tanoak lumber

Sawing a tanoak log at Wild Iris, the ISF demonstration sawmill

## Appendix D -- GLOSSARY

**Calculated total wood volume to an 8" top** -- Volume of whole tree up to an 8" diameter tree height. Measurement in ft3.
*Volume =* $((0.005454*(dbh^2)+0.005454*(8^2))/2*(16*\# \text{ of logs})$
**DBH** -- Diameter at base height (4.5ft above ground).
**DIB-L** -- Diameter inside bark at large end of log.
**DIB-S** -- Diameter inside bark at small end of log.
**Doyle log rule** -- Estimation of lumber volume. Dependent of dib-S & length of log. Inaccurate for small logs. Measurement in board feet.
*Volume =* $(\text{dib-S}-4)^2*\text{length of log}/16$.
**Estimated merchantable wood volume to an 8" top** -- Calculated total wood volume to an 8" top minus defects. Measurement in ft3.
**Estimated Volume from top of logs to 4" top --** *Volume = ((0.005454*(DIB @ top of grade logs^2)+0.005454*16))/2)*submerchantible length above logs to a 4" top*
**Girard form class** -- Dependent on dbh and dib(diameter inside bark) taken at height of 17ft on tree. Determines percent of taper on the tree. *(dib/dbh)*100.*
**Girard tree grade volume** -- Volumes taken from Girard's form class tables. Each form class has its own volume table. Measurement in ft3.
**International 1/4 log rule** -- Estimation of lumber volume. Dependent on dib-S & length of log. Most accurate for determining small log volume. Allowance for 1/2" taper for every 4' of length, 1/4" saw kerfs, and 1/16" thickness shrinkage for each 1" thick board.
**Log grade** -- Taken once tree is cut into logs; F1-top grade, F2-middle grade, F3-low grade, F3s- Log is less than or equal to 6ft. in length.
**Lumber grades** -- In order from highest to lowest grade: FAS, SEL, .1COM, .2COM, .3COM, SOUND.
**Merchantable length** -- The length of the tree that can produce at least a grade 3, 8-foot log, to a minimum DIB-S of 8 inches.
**NHLA Standard Grade Rules** -- Grading standards set by the National Hardwood Lumber Association, Memphis, Tennessee
**Pillsbury equation-sawlog volume** -- Computed for trees 28cm (11in) dbh or greater. Volume computed from stump height to a 23cm (9in) top outside bark for straight sections 2.5m (8ft) long. Excludes roots, bark, and foliage. Takes into account saw blade during milling. Measurement in board feet.
Volume = $0.0002526443*(dbh^{2.30949})*((\# \text{ of logs} * 16)^{1.21069})$.
**Pillsbury equation-wood volume** -- Computed from stump height (0.3m or 1.0ft) to a 10cm (4in) top outside bark. All wood inside bark, excludes roots, bark, and foliage. Measurement in board feet.
*Volume =* $0.000577497*(dbh^{2.19576})*(\text{total height to 8" top}^{1.14078})$.
**Scribner log rule** -- Estimation of lumber volume. Dependent of dib-S & length of log. Log is taper ignored so long logs are considerably overestimated. Measurement in board feet.
**Smalian total log volume –** Estimation of log volume of downed tree. Dependent on dib-S, dib-L, and length of the log. Measure in ft3.

*Volume* $= ((0.005454*(dib\text{-}L^2))+(0.005454*(dib\text{-}S^2))/2)*length\ of\ log.$
**Tree grade** -- Taken out in the field/forest of entire tree while standing.
**Upper grades** -- Consist of the top three lumber grades: FAS, SEL, and .1COM

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