Intensive Silviculture of Planted Douglas-fir Forests: Opportunities for Increased Productivity
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Wood Quality: Growing Quantity vs Quality vs Value

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Outline

I. Defining Wood Quality
II. Determinants of Wood Quality
III. Influence of Silviculture

   Planting spacing, Thinning, Fertilization

I. Quality along the Tree/Log/Product Value Chain
II. Measuring Quality in Standing Trees
III. Implications for Managers
IV. Conclusions
I. Defining Wood Quality

“fitness for use”

Questions to answer

1. What is the product?
   lumber, telephone pole, toilet paper, …

2. What is the end use of the product?
   Lumber as floor joist, wall stud, door framing

3. What are the performance requirements of the product in this use? Floor joist: stiffness, strength, straightness

4. How do tree/wood characteristics affect these performance requirements?
Example: Floor joist

Floor joists

Performance (Quality) is driven by
- stiffness (MOE): resistance to deformation (sag) under load
- strength (MOR): load bearing capacity
- straightness (dimensional stability)
- Treatability (preservatives)

Size
- need long, deep dimensions
### Floor Joist, cont.

<table>
<thead>
<tr>
<th>Performance property</th>
<th>Influencing biochemical wood properties</th>
<th>Effect of shorter rotation</th>
<th>Net effect on performance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Juvenile¹ wood</td>
<td>Sapwood² effect</td>
</tr>
<tr>
<td>1. Stiffness (MOE) &amp; strength (MOR)</td>
<td>Knots</td>
<td>Increase</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td>Density</td>
<td>Decrease</td>
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<tr>
<td></td>
<td>Microfibril angle</td>
<td>Increase</td>
<td>?</td>
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<tr>
<td></td>
<td>Slope of grain</td>
<td>Increase</td>
<td>?</td>
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<tr>
<td>2. Dimensional stability (warp)</td>
<td>Slope of grain</td>
<td>Increase</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td>Microfibril angle</td>
<td>Increase</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td>Extractives content</td>
<td>?</td>
<td>Decrease</td>
</tr>
<tr>
<td>3. Treatability</td>
<td>Sapwood %</td>
<td>?</td>
<td>Increase</td>
</tr>
</tbody>
</table>

? = effect uncertain

¹ juvenile wood refers to the growth rings at the center of a cross-section

² sapwood refers to the growth rings just under the bark that are actively conducting water and nutrients from the soil to the crown
II. Determinants of Wood Quality

A. Basic Patterns of Clear Wood Properties

1. Vertical & Radial Patterns
a. Height Growth

- In spring (late March) apical buds activate.

- Cells in apical meristem divide to produce shoot elongation ➔ generally done by late June.

- Apical meristems produce “growth regulators” influencing growth (apical control) elsewhere along the stem.
b. Diameter (radial) Growth

- Cambium produces both wood (xylem) and bark (phloem) cells

- Cambial activity follows resumption of bud activity in spring.
  - Growth regulators from apical meristems affect rate of division and subsequent wood cell characteristics
  - Remains active until
c  - dormancy is induced by drought (temporary)
  - Permanent dormancy (late fall triggers)
c. Tracheids (~95% of wood cells in conifers)

- **Tangential diameter** is constant; the cambium starts new files of tracheids as the tree circumference increases.

- **Radial diameter** is controlled by hormones from apical meristem

- **Wall thickness** depends on the amount of photosynthate

Length depends on rate of cambial division

**Wood properties differ in these 3 directions!**

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d. EW/LW Transition

- Transition time near base of older trees is roughly the same time as when height growth ceases.

- Transition time in young trees and near top of older trees is later ➔ this is why rings near the pith tend to have low LW%.
e. Microfibril angle (MFA)

Note: “grain direction” is the orientation of the fibers within the wood due to taper, knots, etc.

Microfibril angle (MFA)
Orientation of cellulose within the wall of the fiber
f. Specific Gravity (SG; relative or basic density)

Specific gravity, SG (relative density, basic density)

\[
SG = \frac{\text{density of wood}}{\text{density of water}} = \frac{\text{oven dryweight}}{\text{green volume}} \times \frac{\text{density of water}}{(62,4 \text{ lb/ft}^3, 1000 \text{kg/m}^3)}
\]

Wood Quality Indicator
SG is correlated with most other properties of clear wood (ex stiffness, strength)

Carbon & energy content
1 kg of oven dry wood = 0.5 kg Carbon
20 MJ energy

SG of a Whole Ring

\[
RSG = EWSG \times EW\% + LWSG \times LW\% = EWSG \times (100 - LW\%) + LWSG \times LW\%
\]

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g. Stiffness and Strength of Clear Wood

Combination of
✓ Microfibril angle (orientation of cellulose microfibrils in the cell wall)
✓ Specific gravity (how much cell wall substance is present)
h. Vertical property pattern

Tracheid formation: 5th growing season

- At tip, apical meristem produces growth regulators leading to tracheids that are
  - Short in length, have large radial diameter, have large MFA
- Most photosynthesis production goes to new growth so little goes into cell wall so these cells have thin walls
- For most of growing season tracheids look like EW form but may get a narrow band of LW at the end

- Impact:
  - Low LW% $\Rightarrow$ low SG
  - Low SG & large MFA $\Rightarrow$ low stiffness and strength
  - Large MFA $\Rightarrow$ high longitudinal shrinkage/warp in products
Tracheid formation: 9th growing season

- Tracheids at tip (apical meristem) are similar to those produced in the tip of the tree at age 5

- Here, where the tip was located at age 5, the cambium is older, further from the apical meristem, receives different concentration of growth regulators, and receives more photosynthesis production for cell wall thickness
  - Racheids are longer, smaller MFA,
  - Earlier shift from large diameter, thin wall (EW) to small diameter thick wall (LW)

- Impact: higher LW%, higher SG, lower MFA, higher stiffness and strength, less longitudinal shrinkage
Tracheid formation: 16th growing season

- Tracheids at tip (apical meristem) are similar to those produced in the tip of 5 & 9 year old
  - Here, where the tip was located at age 9, the cambium is older and further from the apical meristem. Tracheids are longer, smaller MFA, earlier shift from large diameter, thin wall (EW) to small diameter thick wall (LW)
  - Here, where tip was located at age 5, the cambium here is older and further from the apical meristem. Tracheids are longer, smaller MFA, earlier shift from large diameter, thin wall (EW) to small diameter thick wall (LW)
  - Therefore a vertical gradient of properties in the current year’s ring that is related to age of the cambium (distance from the apical meristem).
i. Radial (pith to bark) property pattern

- History at any height is captured in the cross section
- Plot property value by ring number from the pith (note that this is age of the cambium at this height level)
- This reflects increasing distance from the apical meristem.
Radial/vertical pattern examples

Fiber length

Specific gravity

Microfibril angle

Longitudinal shrinkage

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j. Juvenile (JW) vs Mature Wood MW

JW is region of rapid change (rings near pith)
MW is region outside JW with little/no change

(Seeft et al 1985)
Juvenile Wood Percent

• The percentage of wood contained within rings 1-20 (Douglas-fir)
  ✓ Red = rings 1-10 plus Yellow = rings 11-20
• Both logs are in the same grade
  ✓ Left log has 70 rings & low JW%
  ✓ Right log has 30 rings & high JW% ➔ could grow 2 of these trees in the time to get one of the other
• How much lumber from each has JW & low stiffness & strength?
JW/MW vs Heartwood (HW)/Sapwood (SW)

- SW: outer rings involved in transport of water & nutrients
- HW: old SW that is inert
- JW: inner rings with generally undesirable properties
- MW: outer rings with generally desirable properties
- SW/HW and JW/MW overlap in all combinations in older trees
- A very young tree only has JW that is also SW
2. Effect of Growth Rate

- With little management, rings near tree center tend to be wider than later rings
  - wide rings (few rings/inch) tend to overlap JW region
  - narrow rings (many rings/inch) tend to overlap MW region

- But with change of competition, tree can produce MW rings as wide as in JW

- Do wide MW rings have the same (i.e. poor) properties as similarly wide JW rings?
a. Confounding Ring Width with Age Effects

- Relationship between ring width and most properties is weak when wood of the same cambial age (ring count from the pith) is compared.

- We see similar weak relationships if plot a property vs dbh of trees within a stand (trees are the same age).

- Many studies have shown that the effect of growth rate (ring width, rings/inch) on properties is weak after accounting for any difference in age.
b. Confounding pre- vs post-treatment effects

- Average fiber length for 5 years after thin is greater than the average fiber length for 5 years before thin
- Pre vs post thin differences are confounded with
  - Different positions along the cambial age curve
  - Possible effects of local climate during pre- vs post-treatment periods
- Need to compare same age rings of thinned vs unthinned trees
3. Geographic Variation

Western Wood Density Survey 1965

- Latitude, longitude, & elevation are a rough proxies for local climate & soil
- Current work is modeling DF SG in terms of local soil, precipitation and temperature variables
- For loblolly pine have current geographic maps for SG, MOE, MOR
4. Stand Conditions & Local Environment

- Stand Conditions (ex. density) will be discussed later

- Local Environment
  - Soil (nutrients, water capacity, etc.)
  - Climate ➔ Temperature and Precipitation
    - Tree rings commonly used to reconstruct past climate
    - Now using climate to predict growth and properties of rings
  - Soil/climate interaction
    - Water balance
    - Soil moisture deficit
    - Drought can induce dormancy and loss of productivity commonly when LW would be produced
C. Branches (knots & deviant grain)

major factors limiting MOE & MOR of structural members
Slope of grain & strength properties

A 15 degree deviation of fibers decreases tensile strength in the longitudinal direction by 50%

Knots, spiral grain, diagonal grain from log taper, etc. cause grain deviation

![Graph showing strength loss with angle deviation](image-url)
D. Compression wood

- Leaning trees; in and around knots
- Unstable trees after thinning, fertilizing) ➔ wind sway, heavier crowns
E. Genetics (Heritability)

- Genetic improvement programs are sifting their focus to improving clear wood properties
- This is facilitated by
  - new lab technologies, such as Silviscan, that can measure multiple properties from an increment core sample
  - new nondestructive testing tools that can be used in the field to measure stiffness and density in standing trees (more on these later)
III. Influence of Silviculture

Questions to ask

1. At what age was stand treated? Age 10?, Age 20?, Age 70?
2. Where are you looking along the stem?
   • Below are above live crown
   • Butt, middle, top log
3. Were other treatments performed concurrently?
4. What limits growth on the site?
   • Temperature, precipitation, soil
     ✓ water balance, soil moisture deficit, nutrition
   • Inter-tree competition, other vegetation
5. Were treatments done once or repeatedly?
   • Once ➔ may be short duration “pulse” in properties
   • Repeated ➔ may sustain change for a long time
A. Planting Density (Spacing)

Crossover effect
- Trees at narrow spacing are larger in height and dbh until about age 13
- After age 13 trees at wider spacing catch up and become larger
# Tree & Wood Quality Effects at Harvest

<table>
<thead>
<tr>
<th></th>
<th>Wide Spacing</th>
<th>Tight Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rings/inch</td>
<td>lower</td>
<td>higher</td>
</tr>
<tr>
<td>DBH</td>
<td>larger</td>
<td>smaller</td>
</tr>
<tr>
<td>JW diameter</td>
<td>larger</td>
<td>smaller</td>
</tr>
<tr>
<td>Crown ratio</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td>Branch (knot) diam</td>
<td>larger</td>
<td>smaller</td>
</tr>
<tr>
<td>Taper</td>
<td>more</td>
<td>less</td>
</tr>
<tr>
<td>Rotation age</td>
<td>shorter</td>
<td>longer</td>
</tr>
<tr>
<td>SG, MOE, MOR</td>
<td>lower</td>
<td>longer</td>
</tr>
</tbody>
</table>

**Note:**
- Before, and for a while after crossover, some of the comparisons may be the reverse of what is found at the end of the rotation.
B. Thinning

Reduces competition for light, water & nutrients

- **Was the thinning from above? below? uniform? Systematic? selective?**
  - Residual stand may be
  - Better, worse or the same quality as pre-thinning: “chainsaw effect

- **How severe was the thinning?**
  - Affects duration of response until pre-thinning status is restored

- **Was thinning repeated?**
  - “pulse” vs sustained effect
1. Chainsaw effect

Be sure to distinguish the immediate effect of thinning on the residual stand from its subsequent growth response.

**Acoustic velocity (MOE) at BH vs dbh**

*Removing trees in box results in residual stand with lower stiffness*

**Diameter of largest limb (knot) in BH region (DLLBH), mm vs dbh of tree, mm**

*Removing trees in box results in residual stand with bigger knots*
2. Thin Effect on Clear Mature Wood

- Research is limited and piecemeal
  - Fibers:
    ✓ shorter, larger diameter, thinner walls ➔ small changes; important (?)
  - Microfibril angle:
    ✓ May increase ➔ impact seems to be small
  - Specific gravity: ➔ change generally within ±5%
    ✓ Increase (drought prone or very dense stands where LW is truncated by summer moisture stress)
    ✓ Decrease, not change
  - Stiffness and Strength:
    ✓ depends on changes in SG and MFA
  - Ring width:
    ✓ abrupt change from narrow to wide
    ✓ may exceed desired ring per inch limits
  - Compression wood:
    ✓ may form ➔ heavier crown & wind/snow loads

- As stand rebuilds toward competitive state, effects diminish
3. Thin Effect on Clear Juvenile Wood

- Little research
- Near top (pith), effects appear to be minimal due to the strong effects of apical control on wood development
- Effects gradually change
  - within a given ring as distance ( cambium age) from the apical meristem increases
  - From pith to bark as ring count (age of cambium) increases

Young JW

Older JW, Transition Wood
4. Thin Effect Branch (Knot) Diameter

<table>
<thead>
<tr>
<th>Live branch</th>
</tr>
</thead>
<tbody>
<tr>
<td>• More light to reaches lower branches</td>
</tr>
<tr>
<td>• Crown recession slows</td>
</tr>
<tr>
<td>• Branches live longer and get larger so diameter on tree/log surface increases</td>
</tr>
<tr>
<td>• As trees build crowns and grow faster a live branch will be subject to more shading from higher branches and neighboring trees and will die.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dead branch</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Does not grow; stem grows over dead, tapered branch so diameter on tree/log surface decreases</td>
</tr>
<tr>
<td>• Faster stem growth over dead tapered branch so diameter on tree/log surface is smaller than it would be without thinning</td>
</tr>
</tbody>
</table>

**Importance depends on life stage (young vs old) and log position (butt, middle, top)**
## 5. Thinning Effect on JW & MW

### Where transition to MW occurred before thinning

- Diameter of JW core fixed by prior growth
- Adding MW only
- % JW decreases

### Where transition to MW has not yet occurred

- Diameter of JW core increases
- May delay age of transition to MW
- % JW increases depending on time until transition and time after transition to harvest

Importance depends on life stage (young vs old) and log position (butt, middle, top)
6. Thin effect by log: 35 yr old tree

**Butt log**
- **Below live crown**
- **Knot diameter** on log surface decreases as grow over dead tapered branches

- **JW diameter**: JW/MW transition occurred in past so JW diameter is fixed, % JW decreases as add MW only

- **Ring width**: Add MW faster so RW increases; small impact on clear wood properties but may exceed desired rings/inch

- **Piece size**: Larger pieces possible
Thin effect by log: 35 yr old tree

**Middle Log**
- Within lower live crown
- Live branches get more light so slower crown recession; branches live longer, grow faster so have larger knots
- JW/MW transition complete at log bottom & will soon migrate past log top; JW diameter may increase a bit at upper end
- Volume added: some extra JW at top but mostly MW
- Log will have high JW %, increased ring width, and may yield somewhat larger pieces
Thin effect by log: 35 yr old tree

**Top Log**
- Upper live crown
- Log will become longer due to height growth
- Vigorous live branches ➔ larger knots
- Volume added: all JW until transition to MW moves into this position
- 100% JW % until MW transition enters the log
- Increased ring width (?)
- Pieces small but longer
- Log/lumber grades (low)
Thin effect by log: 10-15 yr old tree

**Butt Log**

- **Within live crown**
- Knot diameter on log surface increases with faster growth and longer branch life

- **JW diameter** increases with faster growth and possible delayed transition to MW

- **Ring width** increases; small impact on clear wood properties but may exceed desired rings/inch

- **Piece size**: Larger pieces possible sooner. Achieving larger diameter more quickly is incentive to cut earlier and shorten rotation so get high % JW in products
C. Fertilization

Add nutrients to the site

- **Was fertilization done once (pulse effect) or repeated (sustained effect)?**
  - If some other factor (ex. moisture) limits growth on the site could have no response

- **What was the stand density?**
  - If low density, accelerate growth & level of competition
  - If high density, accelerate growth of larger, stronger trees and mortality of smaller weaker trees altering average quality of survivors

- **Was the stand also thinned?**
  - Affects duration of response until pre-thinning status is restored
1. Fertilization Effect on Clear Mature Wood

<table>
<thead>
<tr>
<th>Without Thinning</th>
<th>With Thinning</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fiber</strong> shorter, larger diameter, thinner walls, larger microfibril angle</td>
<td><strong>Fiber</strong> shorter, larger diameter, thinner walls, larger microfibril angle</td>
</tr>
<tr>
<td>(small changes; important??)</td>
<td>(small changes; important??)</td>
</tr>
<tr>
<td><strong>Specific gravity</strong> usually decreases; peak change 5-10% &amp; return to normal</td>
<td><strong>Specific gravity</strong> decreases up to 25%; return to normal over time (~5 years)</td>
</tr>
<tr>
<td>over time (~ 5 years)</td>
<td>( ~5 years); may have lowered latewood %</td>
</tr>
<tr>
<td><strong>Growth rings</strong> abrupt change from narrow to wide</td>
<td><strong>Growth rings</strong> abrupt change from narrow to very wide</td>
</tr>
<tr>
<td><strong>Compression wood</strong> may form due to heavier crown &amp; wind</td>
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</tr>
<tr>
<td>**If fertilize dense stand competition may intensify self thinning with some</td>
<td></td>
</tr>
<tr>
<td>effect on average quality of survivors</td>
<td></td>
</tr>
</tbody>
</table>

With Thinning with some effect on average quality of survivors
2. Fertilization Effect on Clear Juvenile Wood

- Little research
- Near top (pith), effects appear to be minimal due to the strong effects of apical control on wood development
- Effects gradually change
  - within a given ring as distance ( cambium age) from the apical meristem increases
  - From pith to bark as ring count (age of cambium) increases

- Young JW
- Older JW

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## 3. Fertilization Effect Branch (Knot) Diameter

### Live branch
- Fertilizer promotes healthier crown
- Initially slows crown recession
- Live branches live longer and get larger
- As trees build crowns and grow faster a live branch is subject to more shading from higher branches and neighboring trees & dies.

### Dead branch
- Does not grow
- Faster stem growth over dead tapered branch ➔ knot diameter on surface is smaller than it would be without fertilizer

**Importance depends on life stage (young vs old) and log position (butt, middle, top)**
4. Fertilization Effect on JW & MW

Where transition to MW occurred before fertilizing
- Diameter of JW core fixed by prior growth
- Adding MW only
- % JW decreases

Where transition to MW has not yet occurred
- Diameter of JW increases
- Possible that transition to MW is delayed
- % JW increases

Importance depends on life stage (young vs old) and log position (butt, middle, top)
5. Fertilization Effect on Logs

Similar to previous discussion of thinning effects
6. Fertilization plus Thinning

Limited literature but generally effects seem to be additive
IV. Quality along the Tree/Log/Product Value Chain
A. Product Recovered from a Log

Overall yield of lumber or veneer is dependent on log diameter and process technology (log geometry vs product geometry).

1. Yield of visually graded lumber & veneer

**LLAD** “largest limb average diameter” = branch index (bix)

LLAD ➞ Get diameter of largest knot in each face & average

If LLAD >= 1.5 inches, yield of high value grades ceases
2. Yield of Machine Stress Rated Lumber

each piece tested for stiffness & strength

Top vs bottom:
- As the juvenile wood percent of logs increases yield of stiff, strong pieces decreases

Left to right” (dashed vs solid boxes)
- as the largest limb average diameter (llad) of logs increases yield of stiff, strong pieces decreases
- As llad increases, importance of JW% decreases (top vs bottom in red box are almost the same)
V. Measuring Quality in Standing Trees

- Technology enables measurement of quality characteristics of standing trees and logs for
  - Inventory, pre-harvest planning, and timber marketing
  - Monitoring stands as part of silvicultural planning
  - Genetic Improvement programs
A. Knots: LLAD of a log is correlated with diameter of largest limb in the BH region of the tree (DLLBH)

- **Focus on BH region**
  - Simple to measure
  - Part of butt log

[Diagram showing tree measurement with labels: B.IX or BIX of 16 ft butt log, Next higher whorl, Next lower whorl, Breast height, WHL (Whorl Above BH)]

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Convert a simple BH measurement into a log quality index or vice-versa

LLAD of 5m (16 ft) butt log vs DLLBH of tree,

\[
y = 0.7045x + 10.718
\]

\[
R^2 = 0.5813
\]
B. Acoustic velocity to estimate stiffness

FibreGEN ST-300  Fakopp TreeSonic

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Standing tree & log acoustic velocities are correlated

- Can translate a specification (grade) for log acoustic velocity into a specification for tree acoustic
  - Pre-harvest planning
  - Progeny trials
Average MOE of lumber (or veneer) recoverable from log can be predicted by acoustic velocity of the log

- Can translate a specification (grade) for product MOE into a specification for log acoustic velocity
  - Sorting at woods landing
  - Sorting in log yard
  - Many mills use acoustic tools to align log purchasing with customer needs
C. Resistance (specific gravity)

Resistograph F400_S
Increment core for SG

Costly, time consuming x-ray densitometry to measure SG
Bark to Pith Resistance Profile

- Little resistance by bark
- EW/LW resistance variation of rings becomes less near pith (juvenile wood).
- Increasing resistance with depth into wood
  - sawdust in the drill hole
  - drill can bend as it travels through the wood

3/25/2011
Resistance is a good estimator of SG from cores

VI. Implications for Managers

Statistical Quality Control can to characterize and monitor properties

1. Take a sample of a product from a process
2. Measure a product property
3. Obtain mean and variation (range, standard deviation)
4. Compare
   - To history of prior samples ➔ Control Charts (monitoring via repeated samples over time)
   - To specifications for degree of conformance ➔ Process Capability Analysis (single time assessment or derive from control chart)
Compare Process to External Specifications

- Customer specifies a range (Upper and Lower Specification Limits) for the property
- Compare USL & LSL with frequency distribution of the property
- Process Capability = % outside specification (not conforming)

Example: specification for diameter of a machined part: 4.00±0.01

Here 56% conform (pass) ➔ 44% non-conform (fail)

Note: bin labels are highest value in class
Example: DLLBH

- **PCT at age 12 to 1/2 of original TPA; fertilized 200lb/ac N as urea at PCT every 4 years until 1000 lb total**

- **USL (<= 35 mm) & LSL (0 mm) with frequency distribution of DLLBH**

- **Process Capability = % outside spec. (not conforming) 14% (86% pass)**
Example: Acoustic Velocity

- USL (no limit) & LSL (> 3.5 km/sec)
- Process Capability = % outside spec. (not conforming) 60% (40% pass)

Conformance to Both DLLBH and Acoustic specifications

- Process Capability = % outside spec. (not conforming) 67% (33% pass)
B. Harvest Scheduling/Marketing & Timber Purchasing

Seller or Buyer Perspective: Measure Properties of
- Standing trees as part of inventory for pre-harvest assessment
  - What is the degree of conformance of harvestable stands to quality specifications of purchasers?
  - Which stands best match market/mill spec’s?
  - If a large % of a stand does not conform to the spec’s, what are the options?
  - PCA at a single point in time

- Log Sorting
  - on landings for market destinations
  - in mill yards to improve match with to customer orders
C. Silviculture & Stand Management

- What is the current conformance of a stand to quality targets?
- How will conformance change in the future?
- How will a cultural treatment affect conformance?
- What can be done to improve conformance?
- What should be done with stands unlikely to ever conform?
- Assessment at multiple time points ➔ monitoring (control charts?)
**Example of Monitoring:**

**DLLBH for 100 tpa (21ft x 21ft) stand**

- Presently conforms with the DLLBH specification target (< 1.5 inches) but
  - Crown base < 2 ft ➞ knots are still growing toward the 1.5 inch limit
- How will this stand progress in the future? Respond to cultural treatments?

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**Diagram:**

- Y-axis values are upper limits of class
- **USL**
- **LSL**

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Example Treatment Strategies

- Conformance to 1.5 inch limit on BH knot diameter and 4 to 8 rpi limits are stratified into trees < 10” dbh (top) and >= 10” dbh (bottom)

- What happens if the non-conformers are removed in a thinning
  - Conformance of residual stand is immediately improved but what will happen as these grow in the future?

- Growth models need to be enhanced to provide these PCA summaries
D. Genetic Improvement

- New technologies permit affordable, reliable measurement of properties on large numbers of trees
- Enabling shift of genetic improvement programs to consider wood stiffness, density, etc.

PNWTIRC – SMC Stiffness Progeny Trial
VII. Conclusions

Wood quality is a complex topic

A. Understand context of quality discussion

1. What is the product focus?
2. What are its performance requirements?
3. How do the performance needs translate into log and tree properties?
Conclusions, cont.

B. Ask & understand the answers to the 5 silviculture questions

1. At what age was stand treated?
2. Where are you looking along the stem?
3. Were other treatments performed concurrently?
4. What limits growth on the site?
5. Were treatments done once or repeatedly?
Conclusions, cont.

C. New Technologies Provide Affordable Means to Quantify Some Wood Quality Characteristics

1. Trees
   - Pre-harvest inventory
   - Stratifying and assessing conformance to specifications
   - Timber sales/purchases
   - Planning and monitoring effects of silvicultural treatments
   - Harvest planning and marketing
   - Genetic improvement

2. Logs
   - Sort at landing
   - Sort in Mill Yard
Questions

- References