

Timber Quality Assessment

Barry Gardiner and Shaun Mochan
Forest Research

with thanks to Elspeth Macdonald, Dave Auty, John Moore, Alexis Achim

Improved Conifer Timber Quality through Plant Selection and Silviculture

Dunkeld, 11 February 2009

FC Scotland Timber Development Programme

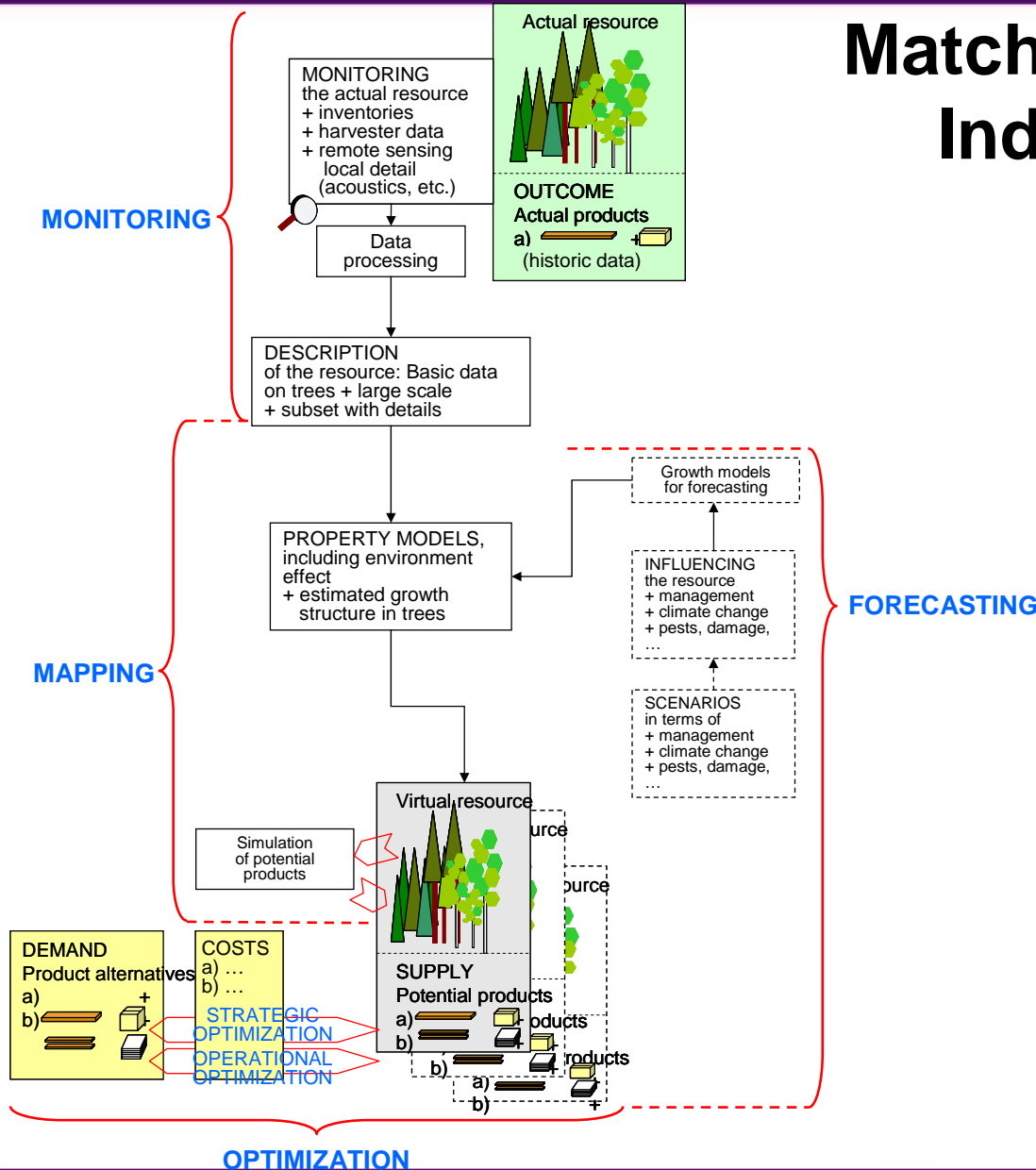
Part 1: Structure of Talk

- Why?
 - Discussion of the benefits of measuring timber quality in the field
- How?
 - Description of the methods available to measure timber quality
 - Standing trees/logs
- What?
 - Discussion of what different measurements tell us about the forest resource
- When and Where?
 - Practicalities of incorporating timber quality measurements into forest operations

Why Measure Timber Quality?

- Just knowing quantity is no longer enough
- Increasing need to match resource to industry requirements
- Help ensure “right” material goes to the “right” end-use
- Measurement can enhance (or at least maintain) value for seller
- Help removes risk to purchaser
- The industry needs to move towards the concept of “precision forestry”
 - *“Precision forestry uses high technology sensing and analytical tools to support site-specific, economic, environmental, and sustainable decision-making for the forestry sector supporting the forestry value chain from bare land to the customer buying a sheet of paper or board.”*

Matching the Resource to Industry Requirements



Part 2: Recoverable Volume

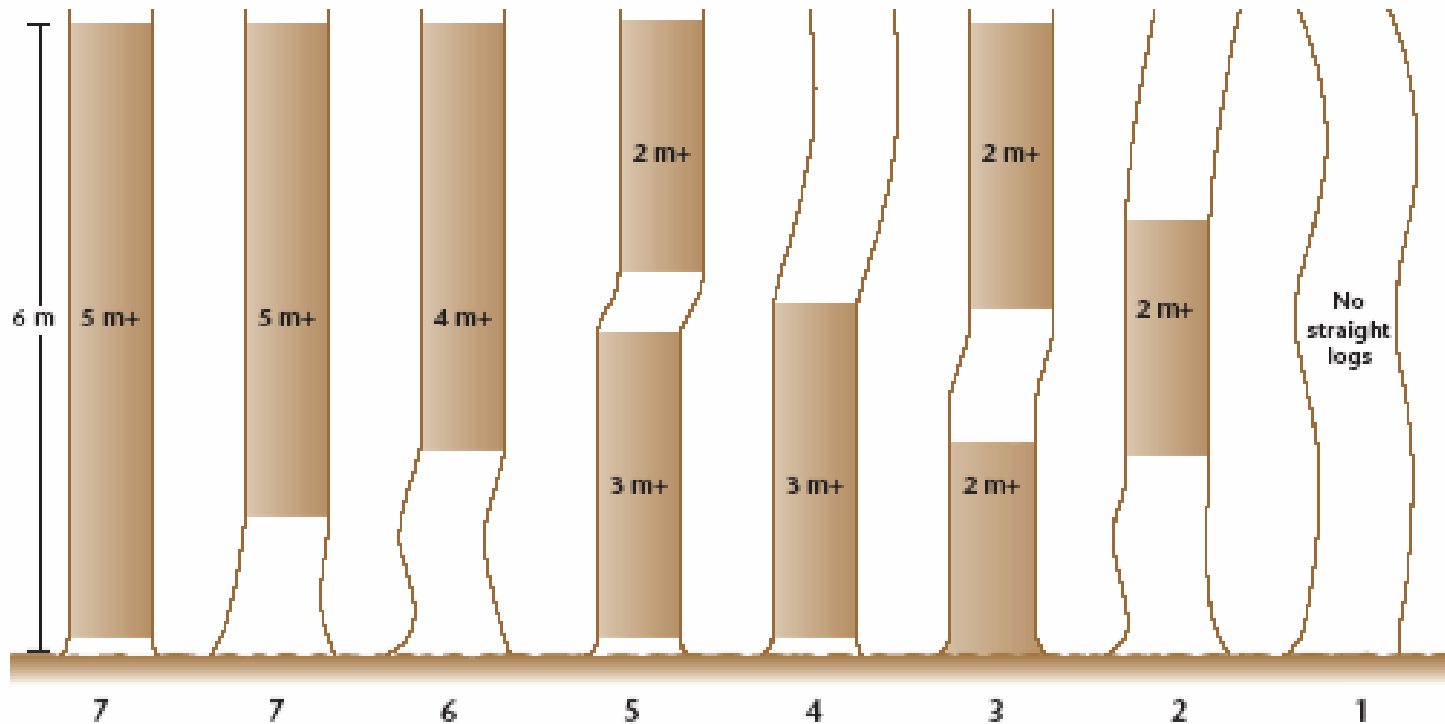
- Just measuring the volume of a tree doesn't tell us what mix of products is available
- Need tools to predict product assortments
- Need measurement of factors that affect this product assortment
- Key factors are:
 - Tree size
 - Taper
 - Straightness
 - Knot size

Tools to Measure Recoverable Volume

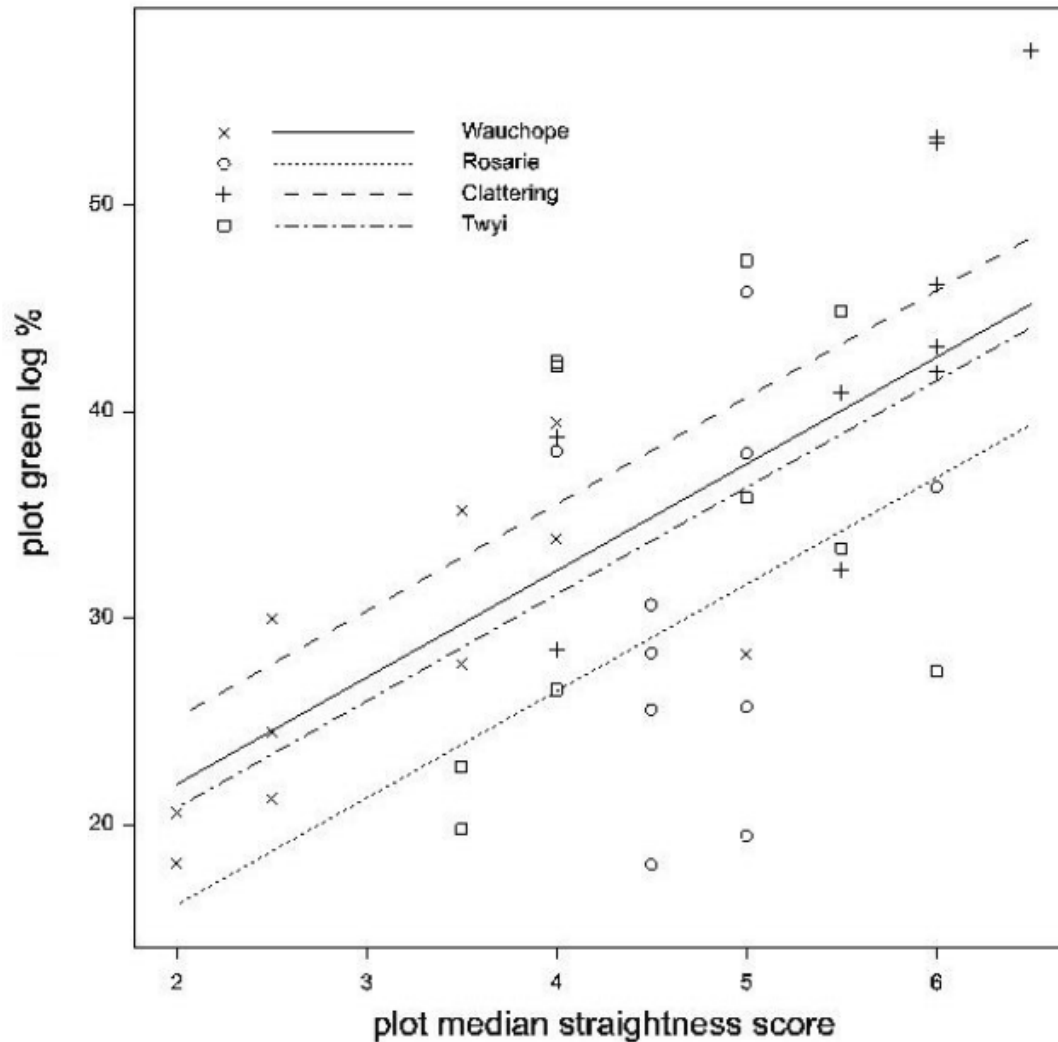
- Stem straightness assessment method
- Measurement of “height of lowest dead branch”
- Terrestrial laser scanners (TLS)
- LiDAR

Stem Straightness Scoring

- System developed for use in Sitka spruce
- Can be used to predict out-turn of “green” logs



Green Log % versus Median Straightness Score



Branching Indices

- Height of lowest dead branch commonly used as branching index in Scandinavia
- Can be estimated visually or measured with hypsometer
- $GL\% = 8.617 + s + 3.478h$

GL% = proportion of green log volume

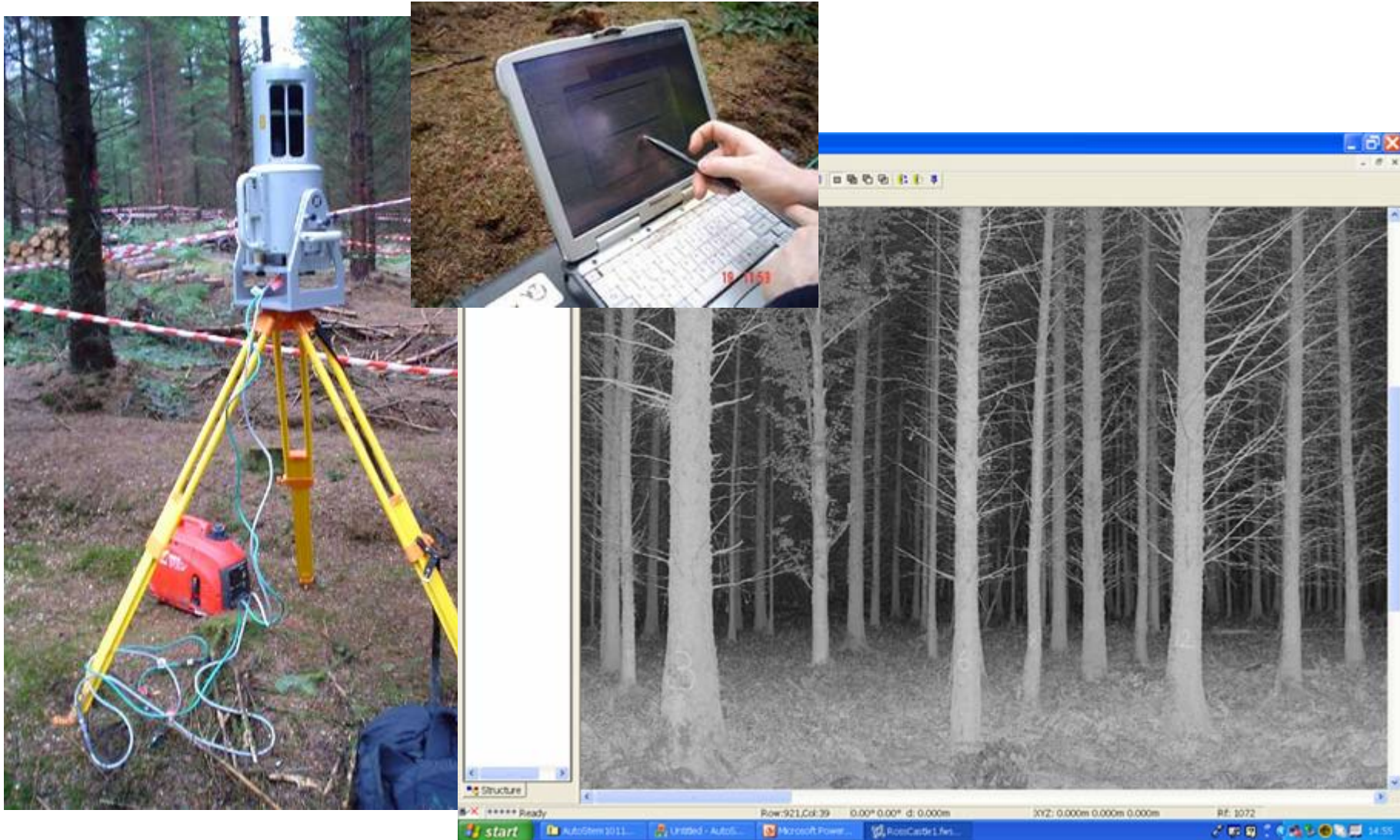
s = fixed effect for straightness score (1=0, 2=11.66, 3=17.44, 4=22.71, 5=25.74, 6=40.60 and 7=44.20)

h = height of lowest dead branch

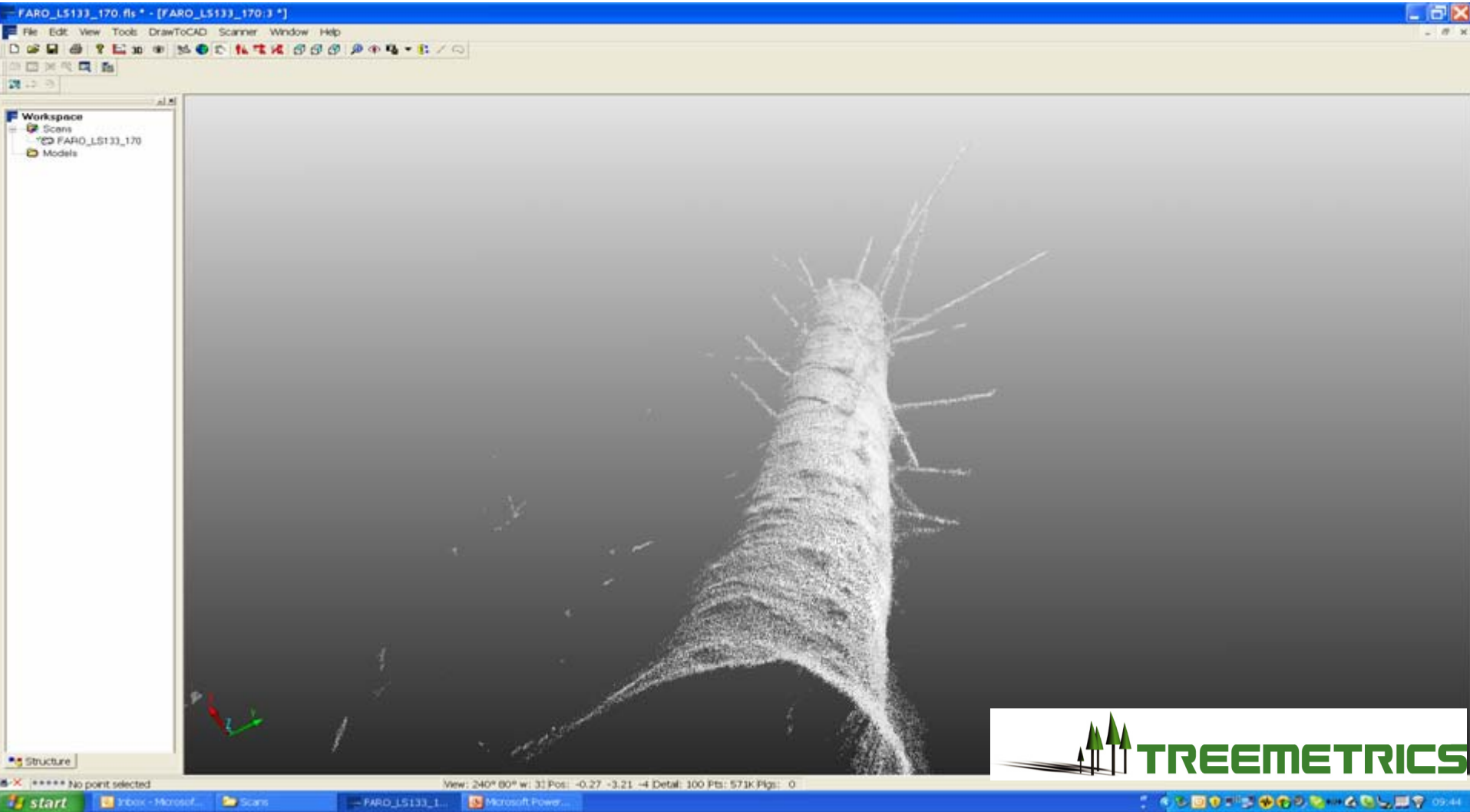
$R^2 = 0.49$



Terrestrial Laser Scanner



Stem Point Cloud

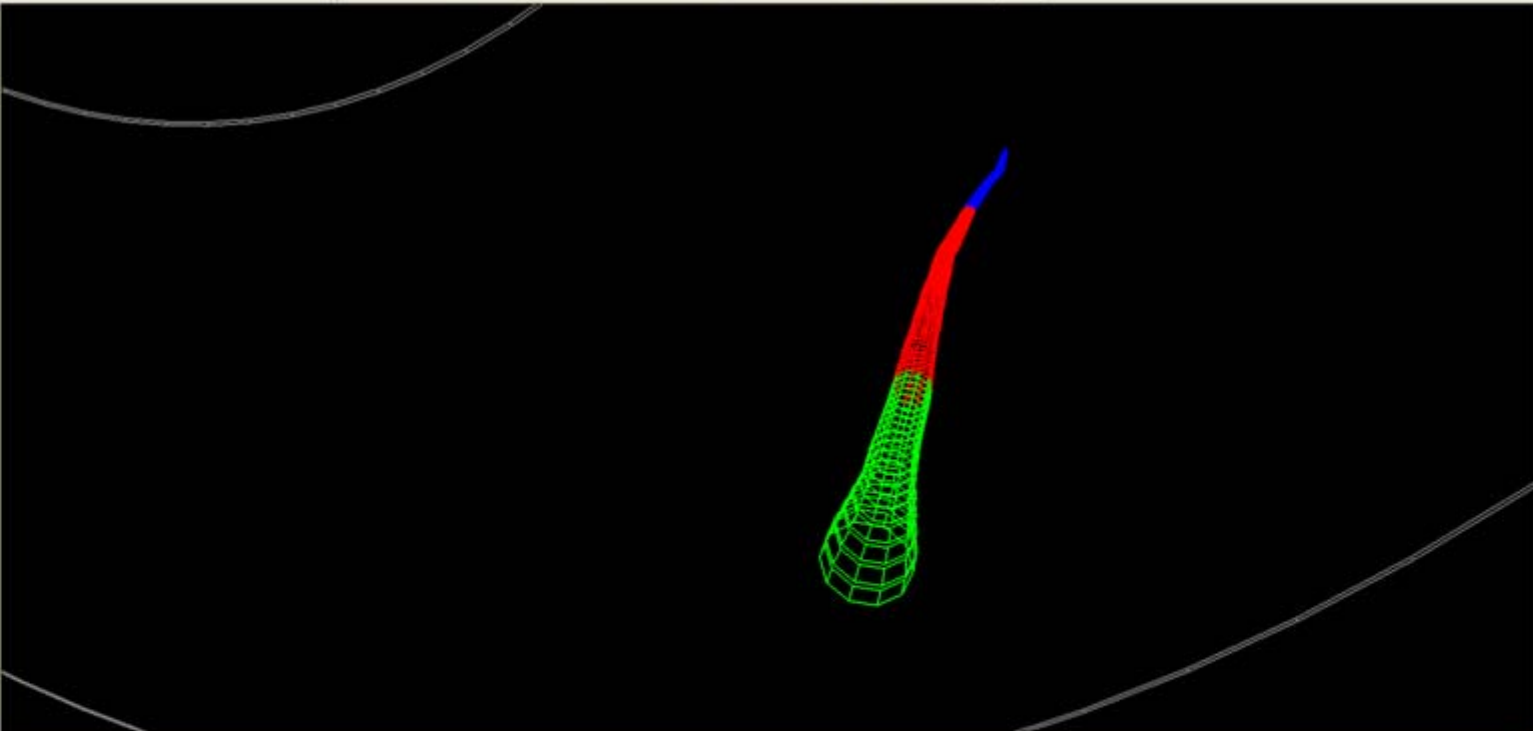


Untitled - AutoStem

File Edit View Help

Perspective Plot Stem Render Points Layer Circular Grid Show Tapering Stats

| Name | DBH | Height | Age |
|------|----------|-----------|-----|
| 1 | 0.297000 | 22.799999 | 19 |
| 2 | 0.225000 | 15.699999 | 34 |
| 3 | 0.319000 | 26.000001 | 65 |
| 4 | 0.203000 | 18.999999 | 73 |
| 5 | 0.290000 | 23.700002 | 77 |
| 6 | 0.269000 | 23.000000 | 99 |
| 7 | 0.347000 | 25.499999 | 102 |
| 8 | 0.208000 | 19.500001 | 129 |
| 9 | 0.312000 | 25.100000 | 15 |
| 10 | 0.228000 | 18.300000 | 17 |
| 11 | 0.204000 | 18.999999 | 171 |
| 12 | 0.110000 | 6.400000 | 18 |
| 13 | 0.115000 | 6.300000 | 202 |
| 14 | 0.303000 | 26.400000 | 21 |
| 15 | 0.318000 | 23.200001 | 239 |
| 16 | 0.406000 | 25.899999 | 24 |
| 17 | 0.310000 | 22.399999 | 25 |
| 18 | 0.219000 | 14.400000 | 262 |
| 19 | 0.247000 | 17.899999 | 271 |
| 20 | 0.172000 | 15.000000 | 301 |
| 21 | 0.290000 | 22.700002 | 30 |
| 22 | 0.241000 | 15.500000 | 32 |
| 23 | 0.226000 | 17.800000 | 341 |
| 24 | 0.277000 | 23.299999 | 341 |
| 25 | 0.314000 | 23.300000 | 35 |



Stem 22 Top Diameters Heights 20cm:
 Stem 23 Top Diameters Heights 20cm:
 Stem 24 Top Diameters Heights 20cm:
 Stem 25 Top Diameters Heights 20cm:
 Stem 1 Volume 0.935128(m³)
 Stem 2 Volume 0.389584(m³)
 Stem 3 Volume 1.193439(m³)
 Stem 4 Volume 0.325757(m³)
 Stem 5 Volume 0.929134(m³)
 Stem 6 Volume 0.623773(m³)
 Stem 7 Volume 1.320523(m³)
 Stem 8 Volume 0.422974(m³)
 Stem 9 Volume 1.224414(m³)

Stem
 Species: Spruce Start Height: 0
 Show Tapered Predictions Timber Height: 1910
 326 297 270 243 216 212 210 208 206 203 203 203 203 203 203 201 199 11

APT Identity: UntitledID APT
 Site
 Site 0 Compartment: 0 Lot: 0 Certified

Code Page Language: ISO 8859-1 Bark Parameter:

326 297 270 243 216 212 210 208 206 203 203 203 203 201 199 197 195 193 191 188 188 183 183 183 183 183 183 180 178

start | inbox - Microsoft... | Scans | FARO_L5133_1... | Microsoft Power... | Untitled - AutoS... | NLM | 09:58

DBH **Height** **Angle** **X-Pos** **Y-Pos** **Distance** **Taper Prediction** **Basal Area** **Tree Position** **Tree Height to 7cm**

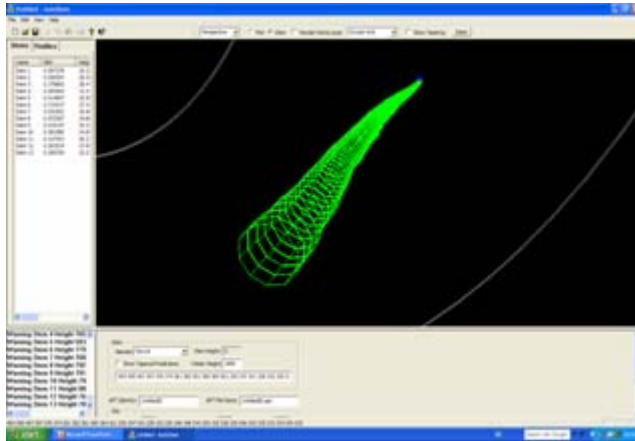
| Name | DBH | Height | Angle | Distance | X-Pos | Y-Pos |
|---------|----------|-----------|------------|-----------|-----------|-----------|
| Stem 1 | 0.587228 | 26.223453 | 9.812439 | 7.846585 | 7.731796 | -2.337242 |
| Stem 2 | 0.269393 | 28.391173 | 12.079987 | 13.833395 | 13.527074 | -2.895011 |
| Stem 3 | 0.379865 | 28.476629 | 56.29577 | 5.046435 | 2.800294 | -4.198197 |
| Stem 4 | 0.405264 | 31.411114 | 117.16643 | 7.300940 | -2.726311 | -6.772810 |
| Stem 5 | 0.414697 | 25.585144 | 116.162277 | 14.552706 | -11.49307 | -8.927024 |
| Stem 6 | 0.724337 | 27.423549 | 49.481384 | 9.517470 | -8.19877 | -4.833147 |
| Stem 7 | 0.553302 | 30.666277 | 183.242767 | 12.439001 | -12.1084 | 0.703633 |
| Stem 8 | 0.553387 | 34.866277 | 214.388031 | 3.828321 | -7.1251 | 2.162215 |
| Stem 9 | 0.419147 | 30.166277 | 221.847427 | 7.948787 | -2.1243 | 5.303028 |
| Stem 10 | 0.381580 | 30.166277 | 257.120148 | 7.223941 | 6.10271 | 7.042184 |
| Stem 11 | 0.337391 | 30.166277 | 267.778015 | 12.139481 | 10.470664 | 12.130353 |
| Stem 12 | 0.381937 | 27.695117 | 299.059937 | 12.93707 | 6.283854 | 11.308456 |
| Stem 13 | 0.381937 | 25.233354 | 317.648376 | 5.910101 | 4.367721 | 3.981518 |

Warning Stem 4 Height 7656cm Out of Bounds. Resetting Tree Height to 3141cm Estimated 1
Warning Stem 5 Height 5030cm Out of Bounds. Resetting Tree Height to 2558cm Estimated 1
Warning Stem 6 Height 7799cm Out of Bounds. Resetting Tree Height to 2742cm Estimated 1
Warning Stem 7 Height 7600cm Out of Bounds. Resetting Tree Height to 3066cm Estimated 1
Warning Stem 8 Height 7925cm Out of Bounds. Resetting Tree Height to 3486cm Estimated 1
Warning Stem 9 Height 7913cm Out of Bounds. Resetting Tree Height to 3022cm Estimated 1
Warning Stem 10 Height 7995cm Out of Bounds. Resetting Tree Height to 2499cm Estimated 1
Warning Stem 11 Height 8056cm Out of Bounds. Resetting Tree Height to 2623cm Estimated 1
Warning Stem 12 Height 7632cm Out of Bounds. Resetting Tree Height to 2769cm Estimated 1
Warning Stem 13 Height 7828cm Out of Bounds. Resetting Tree Height to 2523cm Estimated 1

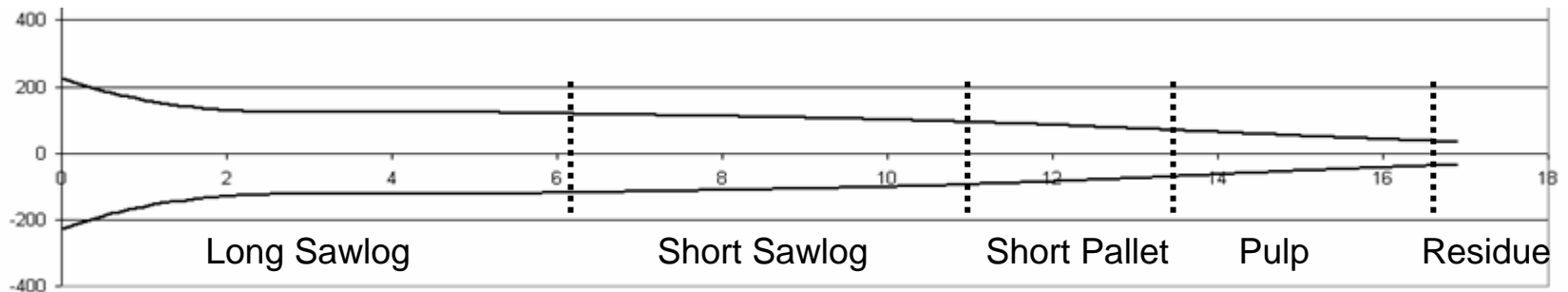
Species: Spruce Start height: 0
 Show Tapered Predictions Timber Height: 1030
 730 672 659 647 657 615 587 614 546 538 529 524 539 565 539 528 539 525 5:

APT Identity: UntitledID APT File Name: UntitledID.apr
 Site Number: 0 Compartment Number: 0 Lot Number: 0

Improving Value Recovery

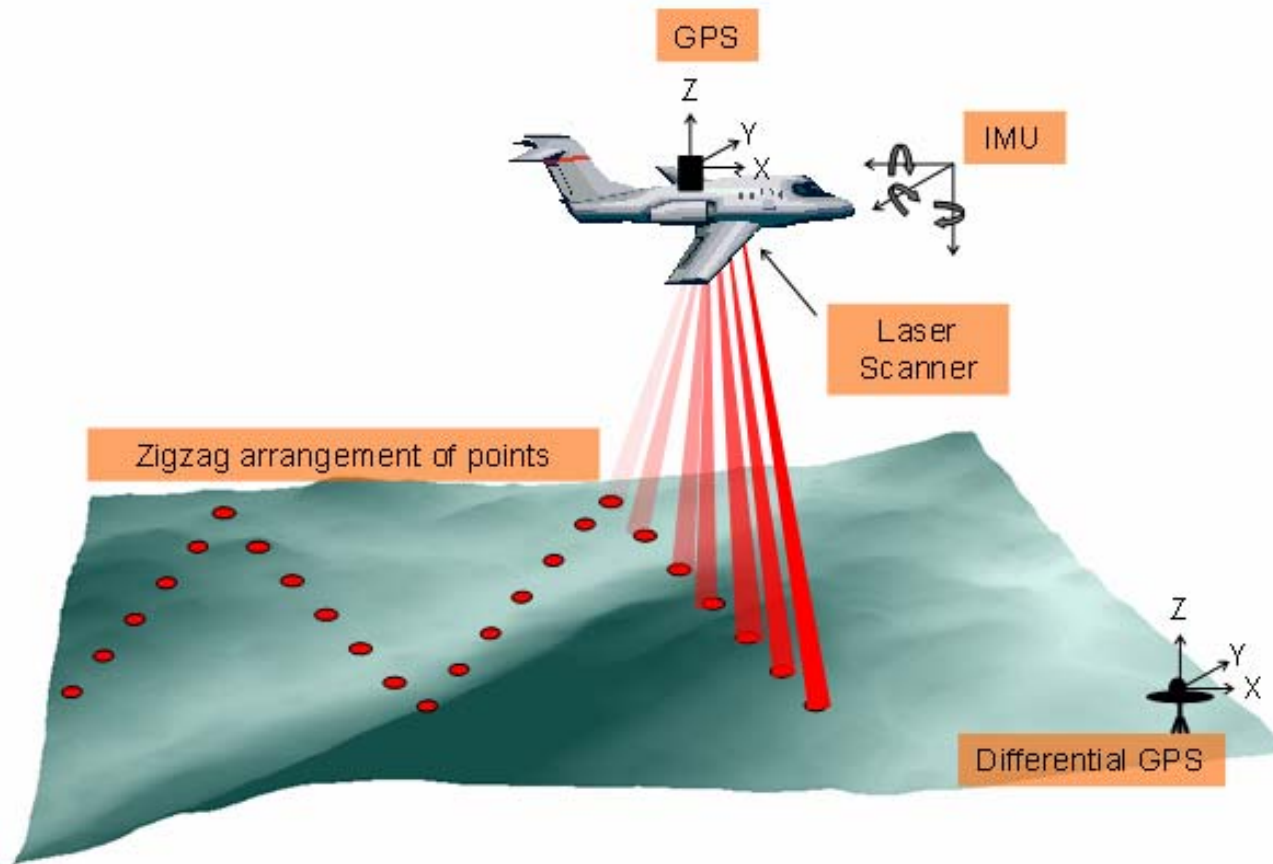


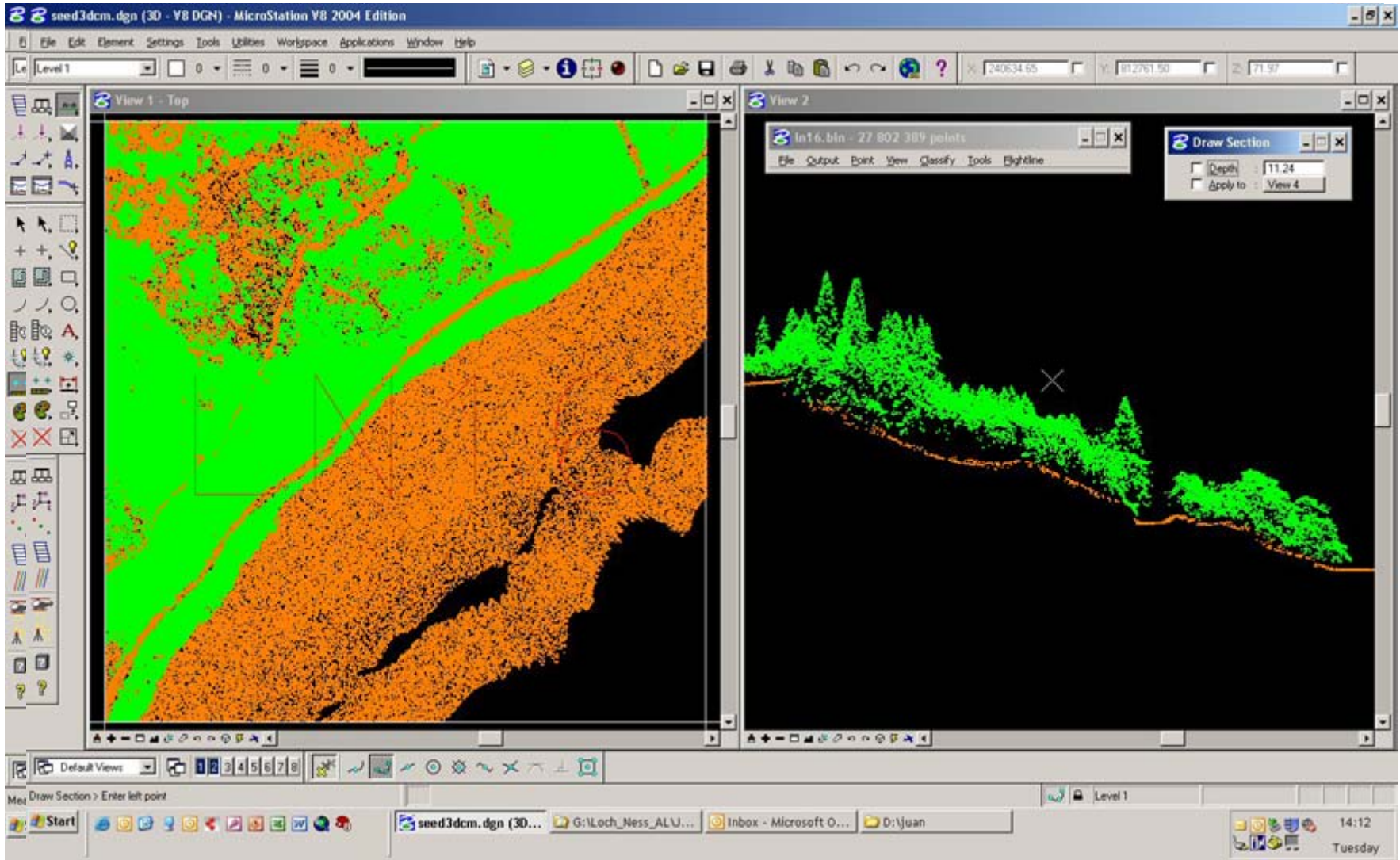
AutoStem Harvest Solution



Airborne LIDAR

Measured-range interpretation of tree canopies





Part 3: Mechanical Stiffness of Timber

- Tools for predicting recoverable volume tell us nothing about performance of final product
- Mechanical stiffness is best measure of final performance of sawn timber
- Acoustic tools allow non-destructive measurement of mechanical stiffness and grade outturn

Tools to Measure Mechanical Stiffness

- Standing Tree/Harvester Acoustic Tools
- Log Acoustic Tools
- In-line Acoustic Tools

Stand → Road side → Sawmill



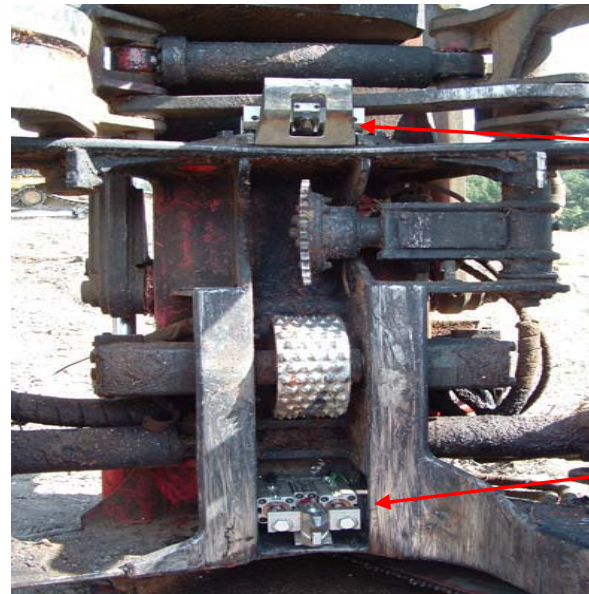
Tree level - ST300



Log level - HM200



- Prototype Acoustic Tool on Harvester Head (PH330)



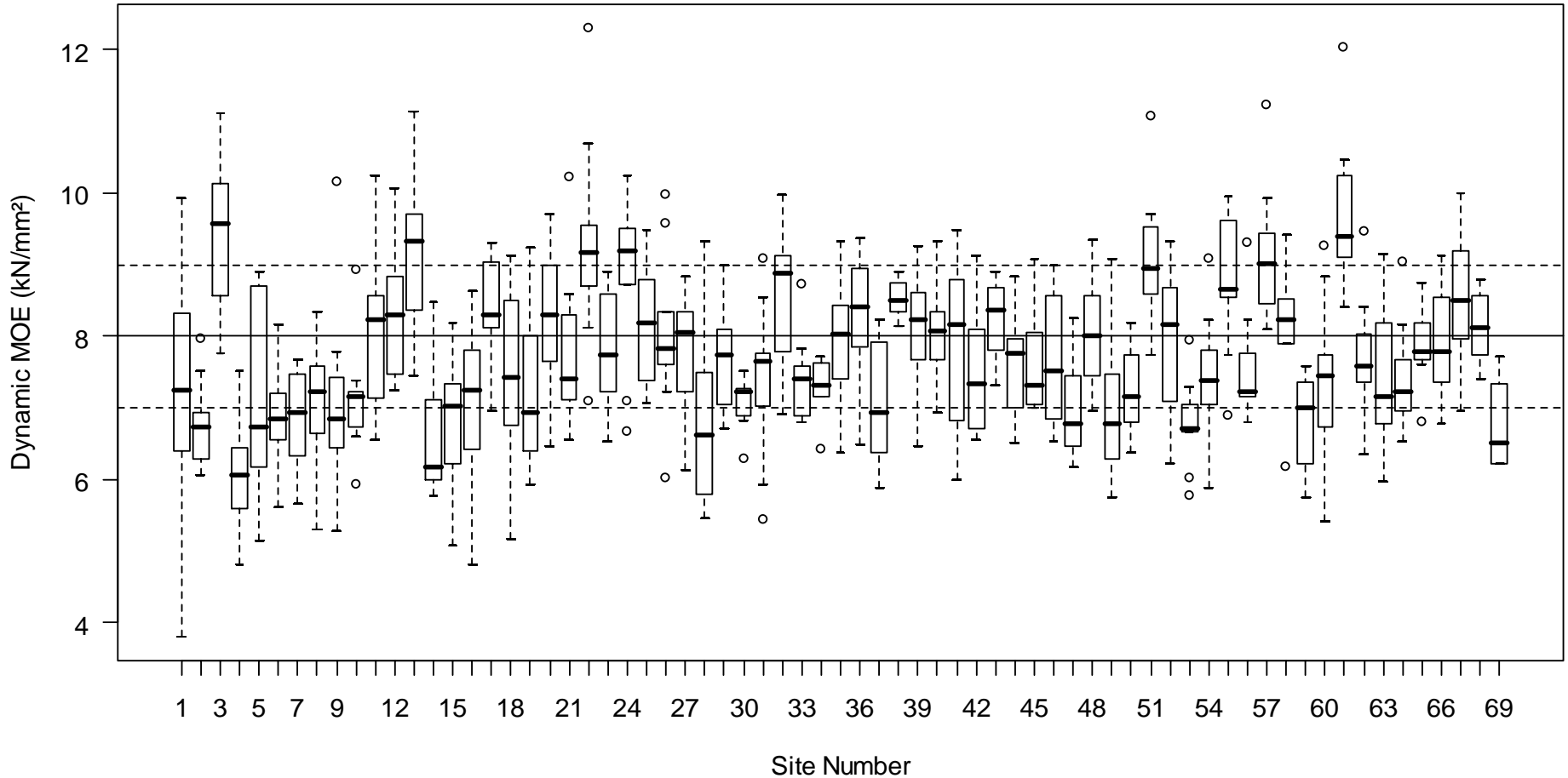
Rx probe assembly with delimb blade fitted

Tx probe assembly with integrated signal generator

- Operation Acoustic Tool on In-feed to Sawline (LM600)

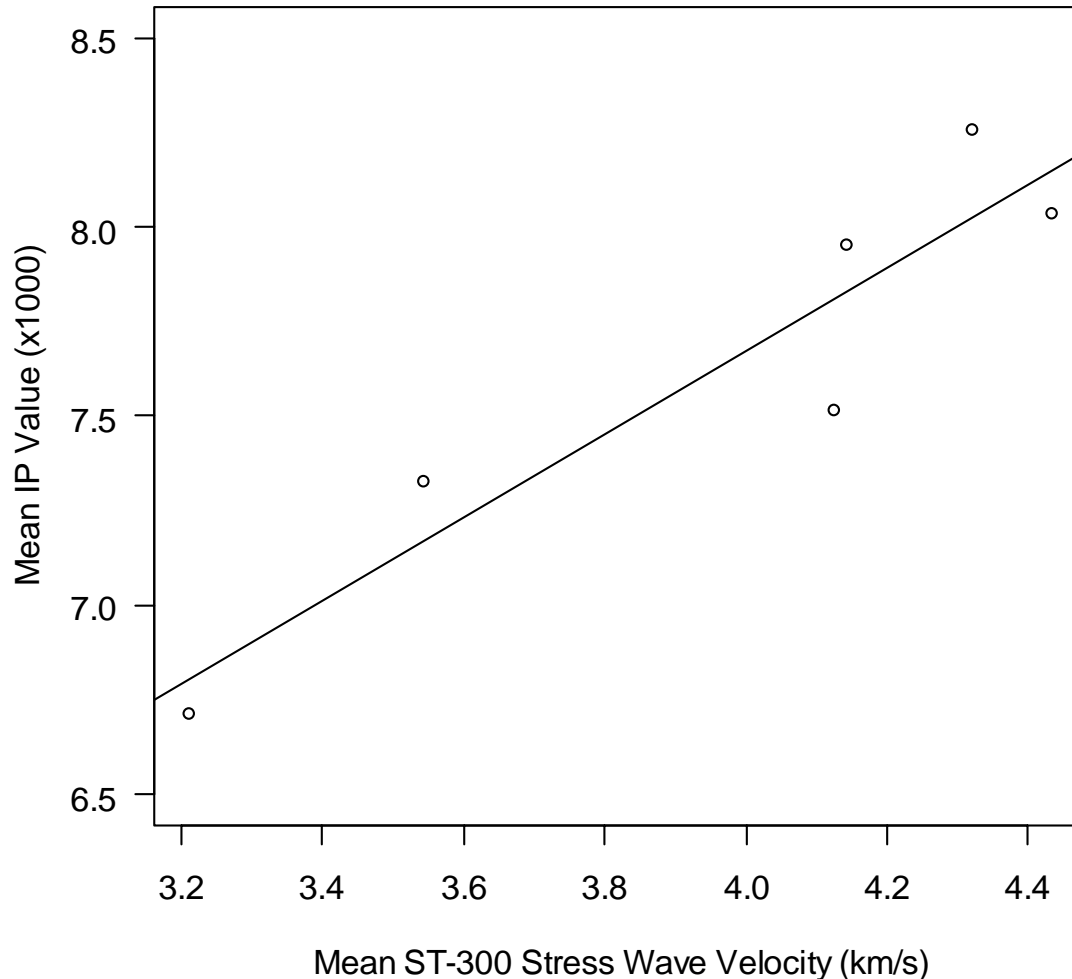


Variation in Dynamic MOE in Scotland and N. England *(courtesy Napier University)*



36% site-to-site, 55% tree-to-tree, 9% within tree

Correlation between ST-300 Acoustic Measurement and IP from Grading Machine

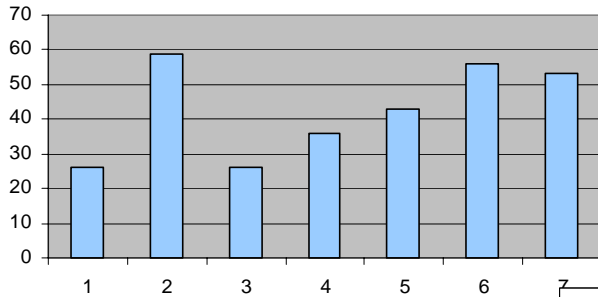


Part 4: Operational Use

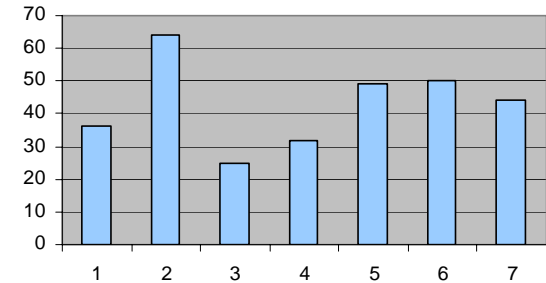
- Pre-harvest stem straightness assessment together with standard tariff measurements (60-100 trees). Allows assessment of product breakout.
- Acoustic velocities on trees prior to harvesting/logs at roadside/logs in sawmill (60-80 trees or logs). Allows assessment of probable sawn timber performance
- The earlier in the wood-chain the measurement the more flexibility in decision making but the weaker the correlation with final product performance

Variation in Stem Straightness

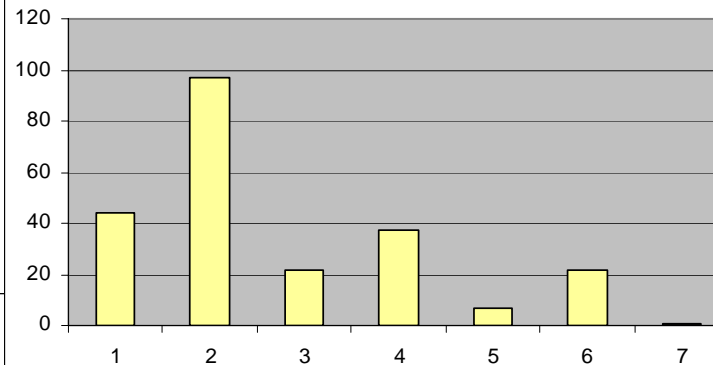
WAFD 18422



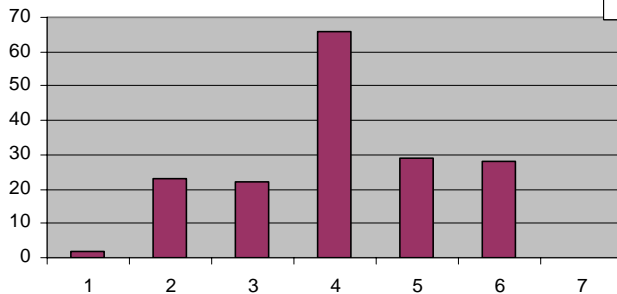
WAFD 18447



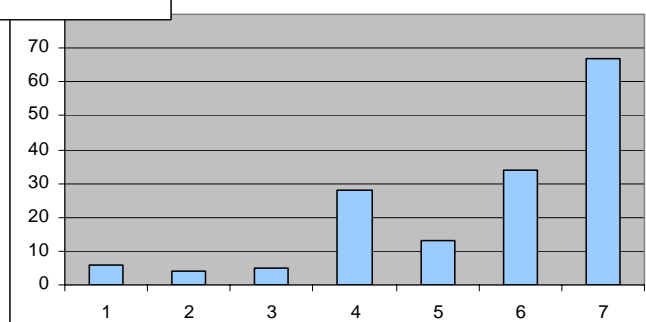
Galloway 1088



Moray - Culbin THIN



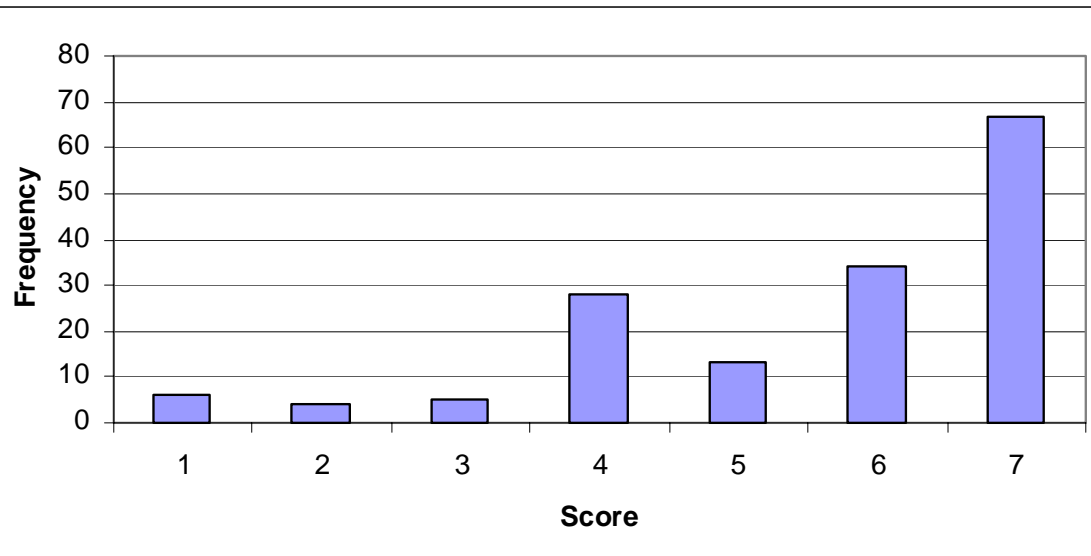
Lorne 13531



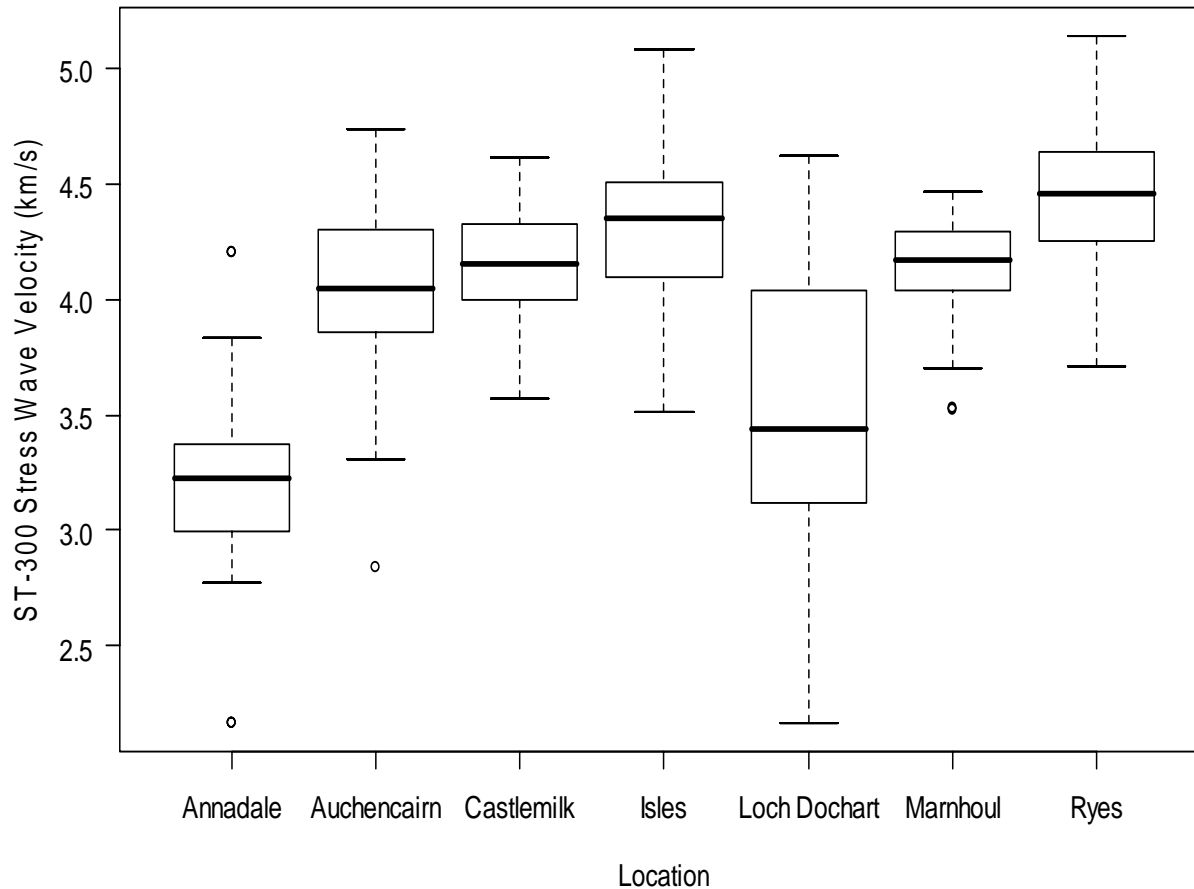
Log Breakout from Measured Stem Straightness

Log Valuation
Coupe: Ardmore 13531
Model : West Coast 2

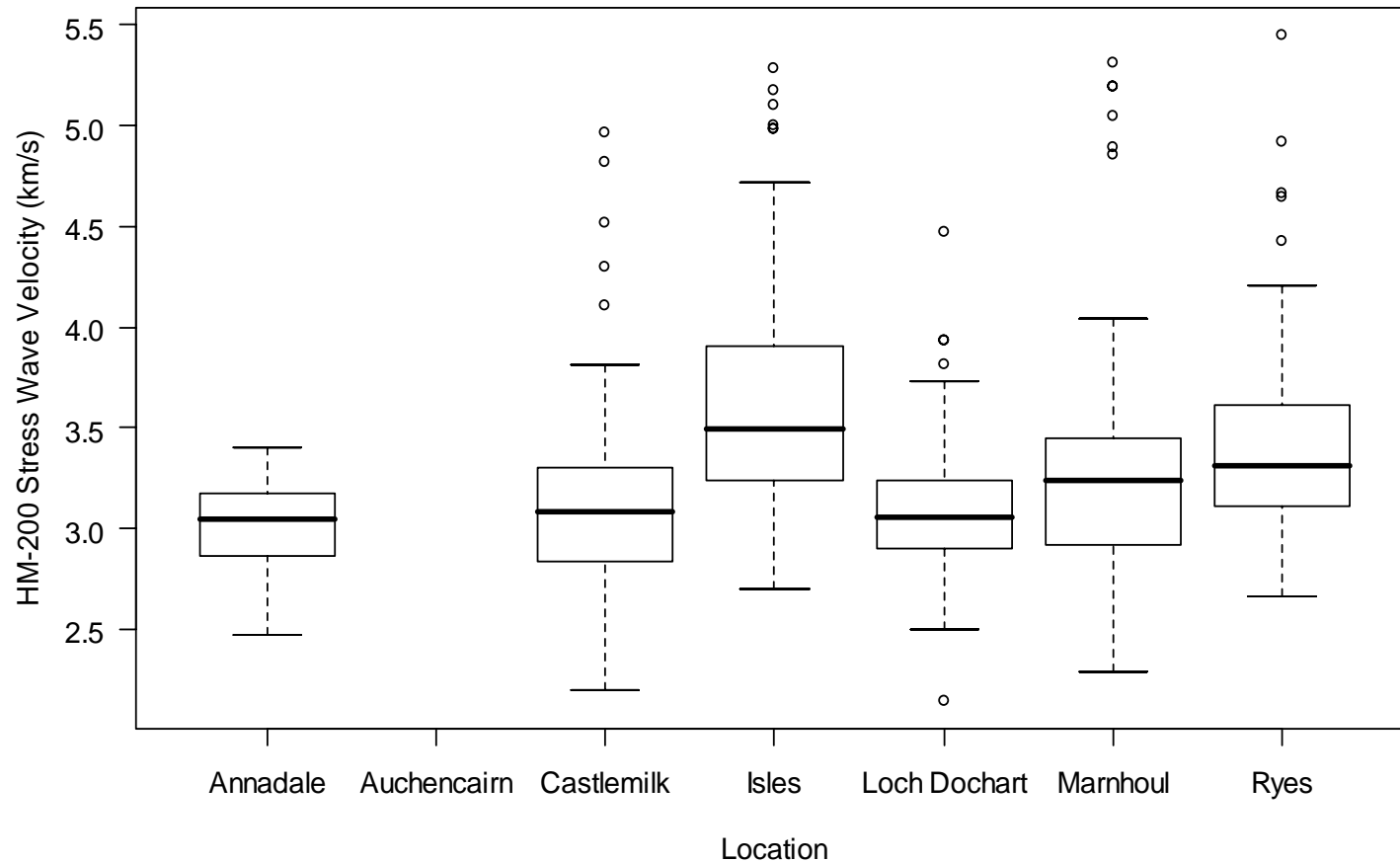
| Stem score | Cumulative score | % Score | Vol/score | Potential Log lengths | Product | Vol by length | Reject 3% | Actual Vol x 3% loss | Conversion loss x 10% | Av. Acoustic score | Acoustic Grade | Building Grade |
|--------------------|------------------|---------|-----------|-----------------------|------------|----------------|---------------|----------------------|-----------------------|--------------------|----------------|----------------|
| 1 | 6 | 3.82 | 390.04 | 0 | 0 | | 11.70 | 378.34 | 340.50 | | | |
| 2 | 4 | 2.55 | 260.03 | 2.5 | 2.5 | | | | | | | |
| 3 | 5 | 3.18 | 325.03 | 2.5 | 2.5 | 585.1 | 17.55 | 567.51 | 510.76 | | | |
| 4 | 28 | 17.83 | 1820.18 | 3.1 + 3.7 | 3.7 | 1820.2 | 54.61 | 1765.57 | 1589.02 | | | |
| 5 | 13 | 8.28 | 845.08 | 2.5 + 3.1 + 3.7 | 3.1 or 2.5 | 1195.1 | 35.85 | 1159.28 | 1043.35 | | | |
| 6 | 34 | 21.66 | 2210.22 | 4.2 + 4.8 | 4.8 | 2210.2 | 66.31 | 2143.91 | 1929.52 | 3.31 | 'green' | C16 to C22 |
| 7 | 67 | 42.68 | 4355.43 | 4.8 + 5.2 + 5.4 + 6.2 | 5.4 | 4355.4 | 130.66 | 4224.76 | 3802.29 | | | |
| Total stem: | 157 | | | | | 10166.0 | 304.98 | 9861.03 | 8874.93 | | | |
| Total m3 | 10,206 | | | | | | | | | | | |

Volume Total
9214


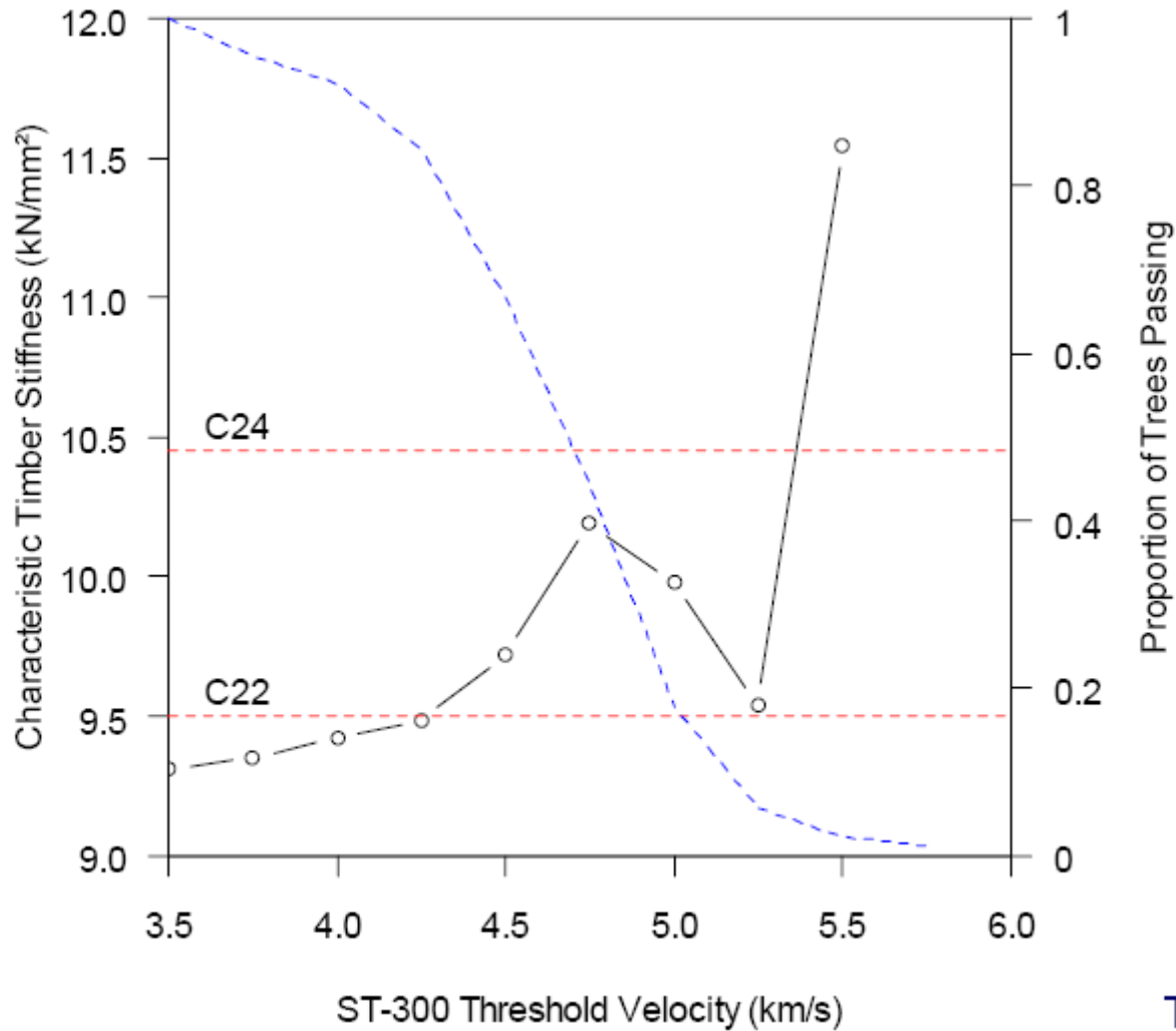
Variation in Tree Acoustic Velocities in South Scotland Sitka Spruce



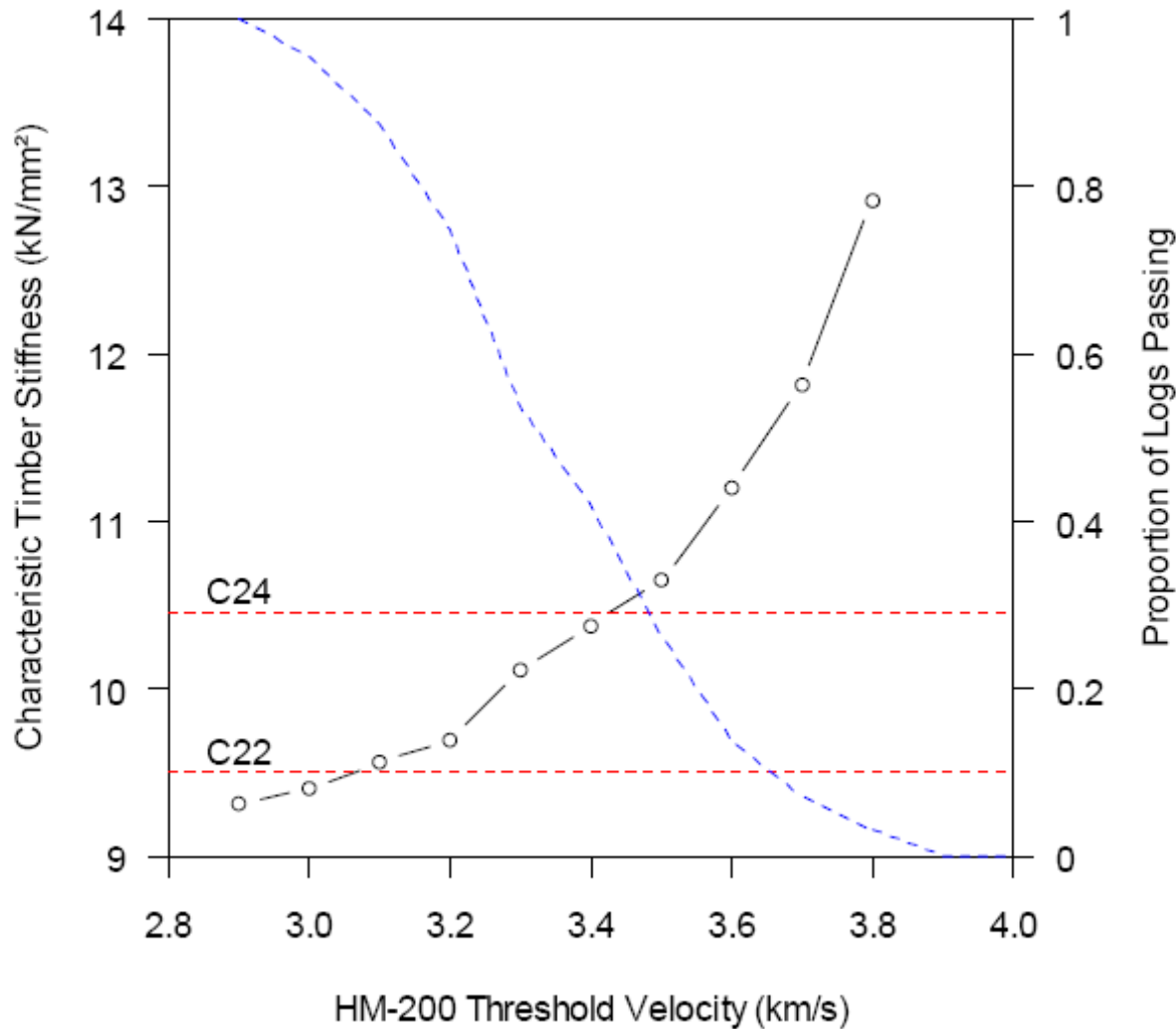
Variation in Log Acoustic Velocities in South Scotland Sitka Spruce

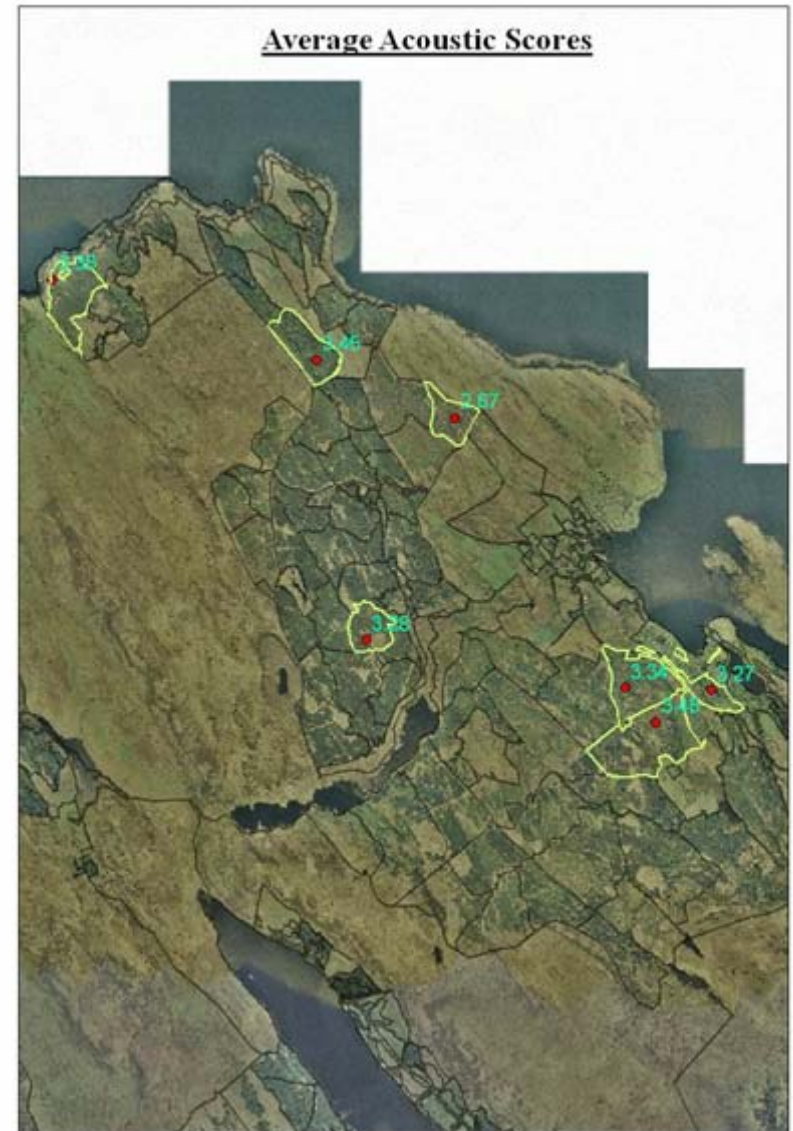


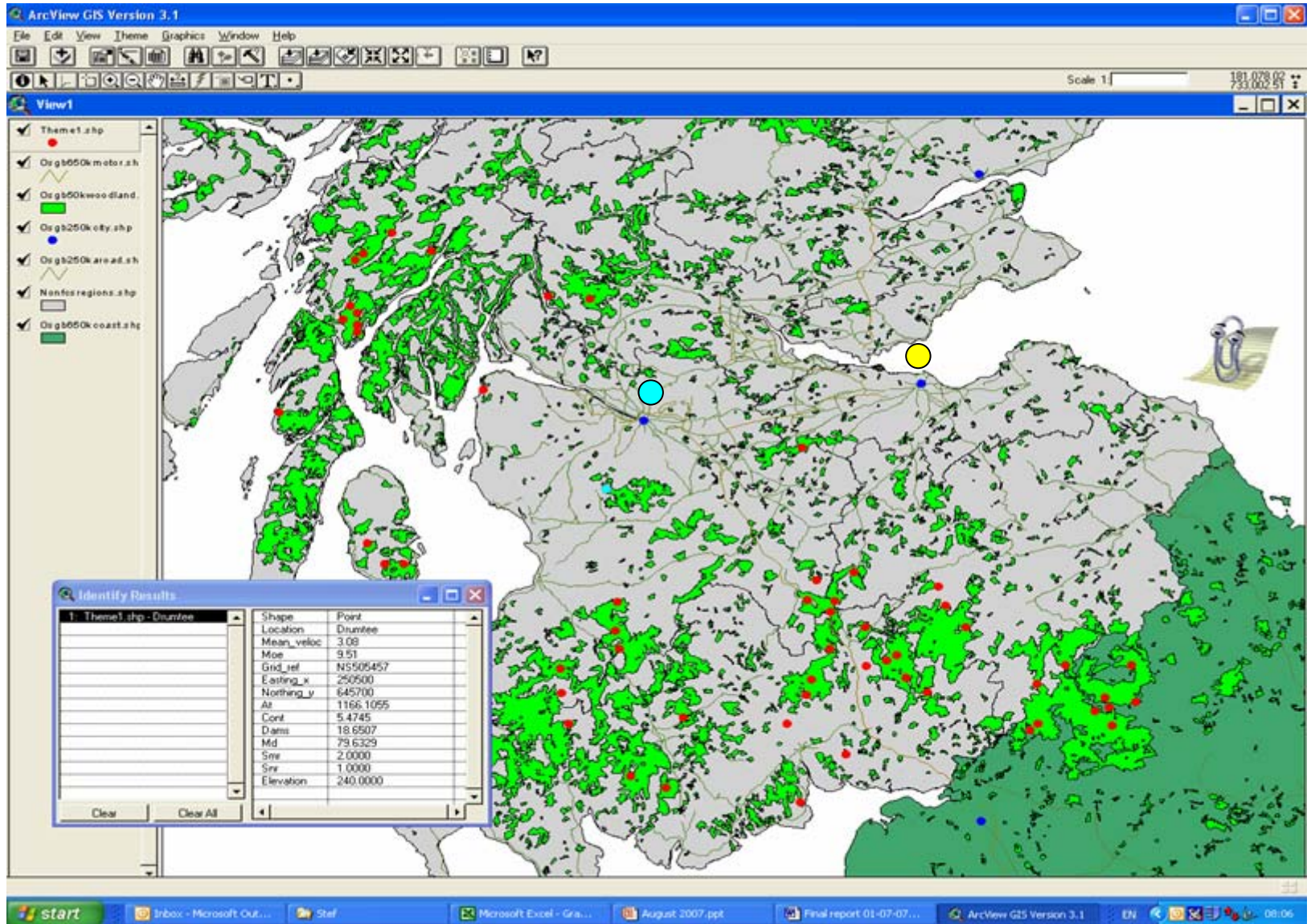
Segregating Trees in Scots Pine (courtesy Napier University)



Segregating Logs in Scots Pine (courtesy Napier University)







Trial sites:

- | | | |
|----|----------------------------|---------------------------------|
| 1. | Moray FD – Culbin | Stem Straightness and Acoustics |
| 2. | Lorne FD – Ardmore | Stem Straightness and Acoustics |
| 3. | Lochaber FD – Corrour | Stem Straightness and Acoustics |
| 4. | Aberfoyle FD | Stem Straightness and Acoustics |
| 5. | Tay FD | Stem Straightness and Acoustics |
| 6. | Wales 2-3 harvesting sites | Stem Straightness and Acoustics |

- Measure stem straightness before felling. 150 – 300 trees
- Measure acoustics on roadside logs c350 –500logs
- GIS mapping of results and input from Operations and Planning within FE.
- Compare harvesting data (stem files .stm) with straightness breakout model.

Costs:

- 10hours for 10,000m³ = 2 days @ £257/day = £514 or £0.05/m³

Savings:

- Can reduce costs by up to 7%

Summary

- Large variation in stem form within and between stands
- Large acoustic variation within stands and between stands
- Good relationship between stem form and height of lowest dead branch and green log percentage outturn
- Good relationship between tree and log acoustic values and the indicating properties used for grading
- Now have the ability to accurately measure stem shape and form in stands
- Now have tools for measuring stiffness in standing trees and logs

Future

- Build systems that utilise stem straightness and acoustics to more accurately predict product outturn and product performance.
- Use tools to determine optimum log cross-cutting, log allocation, tree/log selection, logistic solutions, and optimized wood-chain operations

References

- Macdonald, E. Mochan, S.J. and Connolly, T. 2001. *Protocol for Stem Straightness Assessment in Sitka Spruce*. Forestry Commission Information Note 39, Forestry Commission Edinburgh.
- Macdonald, E. Mochan, S.J. and Connolly, T. 2009. Development of a stem straightness scoring system for Sitka spruce (*Picea sitchensis* (Bong.) Carr.). Forestry, In Press.
- Mochan, S. Moore, J. and Connolly, T. 2009. *The Use of Acoustic Tools in the Forestry Wood Chain*. Forestry Commission Research Note. In Press, Forestry Commission Edinburgh.
- <http://www.forestresearch.gov.uk>

Thanks to: FC (CFS), FC Scotland, James Jones and Sons Ltd., FE Scotland, CTE Napier University, Fibre-Gen