

STEEP SLOPE LOGGING RESEARCH AT OSU

Eye movement tracking to grapple yarding, collaboration for a safer work environment.

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Oregon State
University

Research Team Acknowledgement

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Steep Slope Harvesting

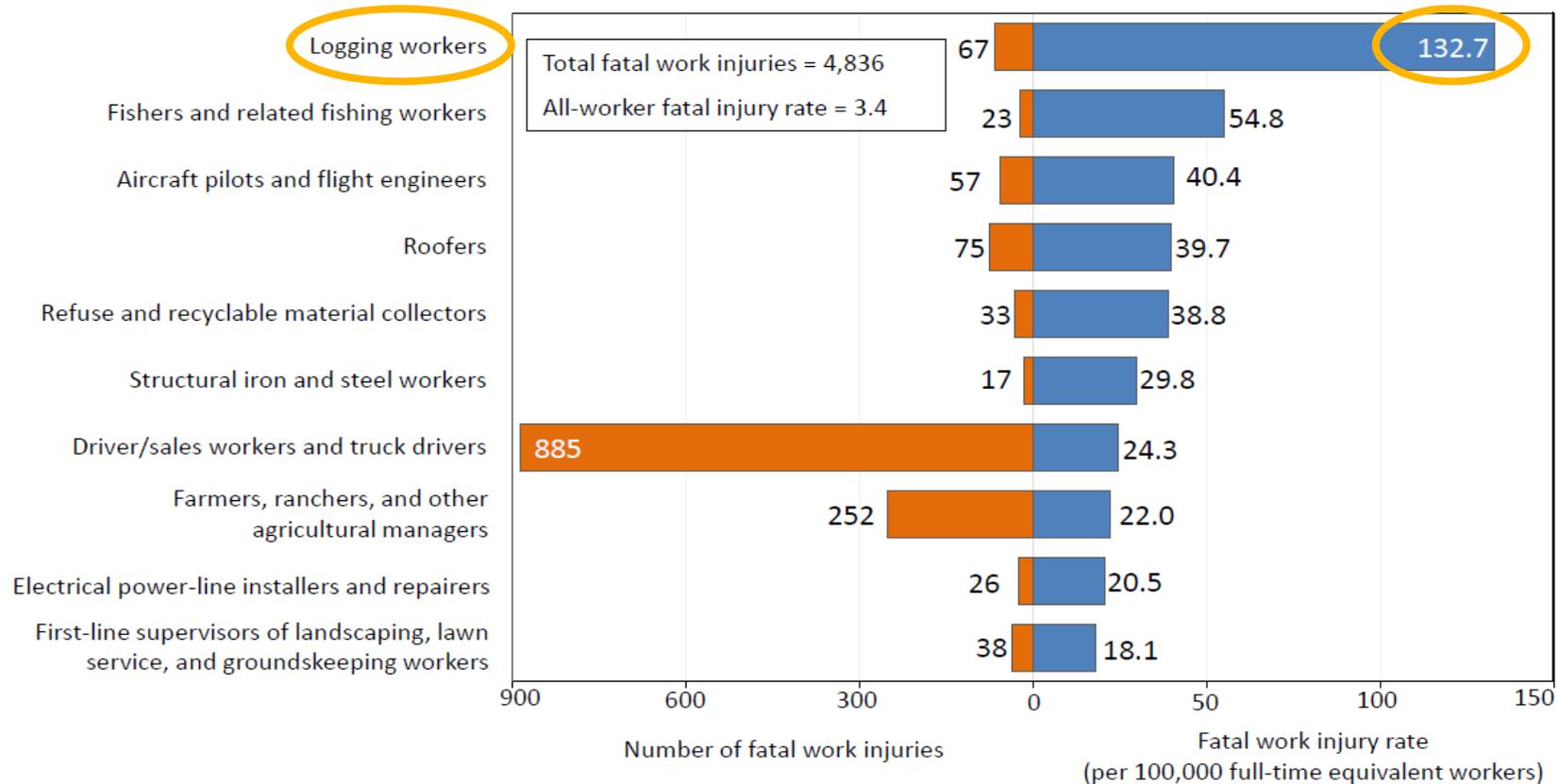
- Research Introduction
- Research Goals
- Methodology Overview
- Results to Date
- Future Plans

Research Introduction & Goals

- Motivations:
 - Logging is “difficult, dirty, dangerous, and declining” (Garland, 2012a)
 - Logging is the first step in an industry that generates over \$5.2 billion in revenue for Oregon alone (Rasmussen et al., 2012)
 - Workforce, mechanization, timber, political environment are all drivers of change
- Research Arms & Goals:
 - Assessing practical and physiological response of logging workers
 - Assessing environmental impacts of various steep-slope harvesting systems
 - Observe harvesting and yarding productivity to develop regression-based cost and productivity models

Motivations

Civilian occupations with high fatal work injury rates, 2015



In 2015, fatal work injury rates were high for logging workers and fishers and related fishing workers. Driver/sales workers and truck drivers incurred the greatest number of fatal injuries.

Motivations

- Logging generates billions in revenue for Oregon alone.
- Drivers of change:
 - Workforce: good employees harder to find, younger employees not looking for a career in the woods
 - Mechanization: other parts of the world are advancing in this area, big changes have been taking place
 - Timber: size (DBH) has decreased over time, requiring adaptations to logging systems to remain competitive

Methodology, Practical & Physiological Response of Operator

- Operators will be wired!
- Measurement of stress, fatigue, operator attentiveness through:
 - Heart rate monitor
 - Camera recording eye movements
 - Camera recording operator
 - Measurement of respiration (Fitbit-like device)
 - Periodic interviews in response to situations

Disclaimer

Mention or depiction of machines or trade names does not constitute endorsement by Oregon State University or any agency of the federal government.



NEW Natural Gaze™
Design

SMI Eye Tracking Glasses 2 Wireless

Mobile eye tracking made easy, robust, efficient and versatile



Wiring Operators

Camera watches and tracks the operators pupils, and relates that to what the operator sees in front of him. Camera watching pupils, camera looking forward.

Other medical-grade devices similar to a Fitbit to track vital signs and galvanic skin responses.

Wired Operator



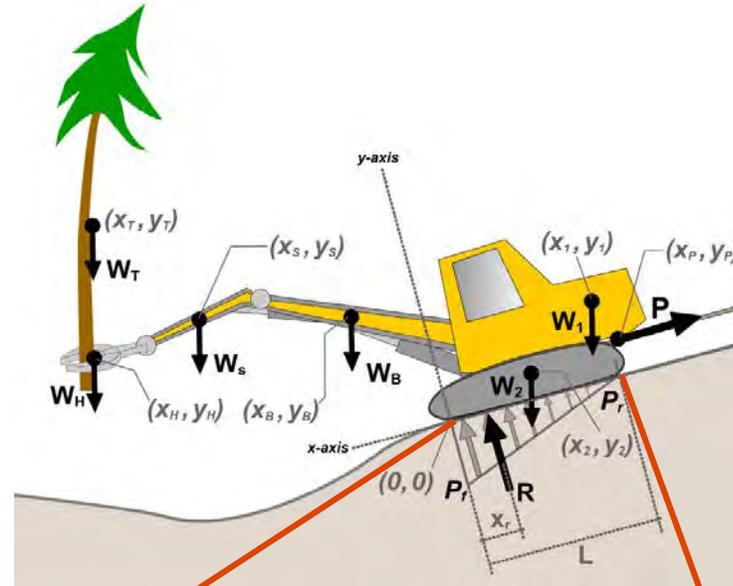
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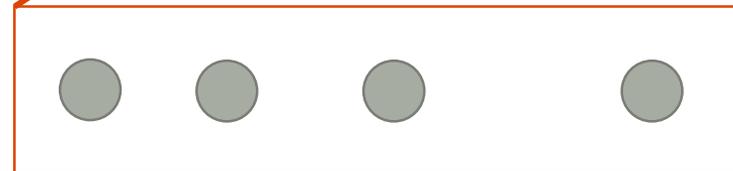
Methodology, Environmental Impacts

- Pressure monitors buried underneath tracks
 - Non-tethered tests with Tigercat 855 and CAT 552 at OSU on different slopes and boom positions
 - Tethered test with CAT 552 with C&C Logging in western Washington on different slopes, boom positions, and cable tension
- Accelerometers to measure movement of machine
- Bulk density to measure compaction
- Vane shear samples to measure undrained shear strength of soil
- Slash mat transects to capture effect of slash mat on compaction and rutting
- Rut depth
- Soil displacement (through ocular observation)

Field Testing



Pressure Cell Layout



Bottom Mid-Top
Mid-Bottom Top

Methodology, Harvesting & Yarding Productivity

- Detailed time study of cable-assisted harvester & forwarder, grapple yarding, conventional yarding (other systems planned for future research) via paper & stopwatch and video recording.
- GPS tracking of carriages to determine precise turn distances
- Data log from harvester head to capture tree size and detailed cutting log, done by measuring and pre-marking, otherwise.

Field Testing



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Results to Date



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Practical & Physiological Response of Operator



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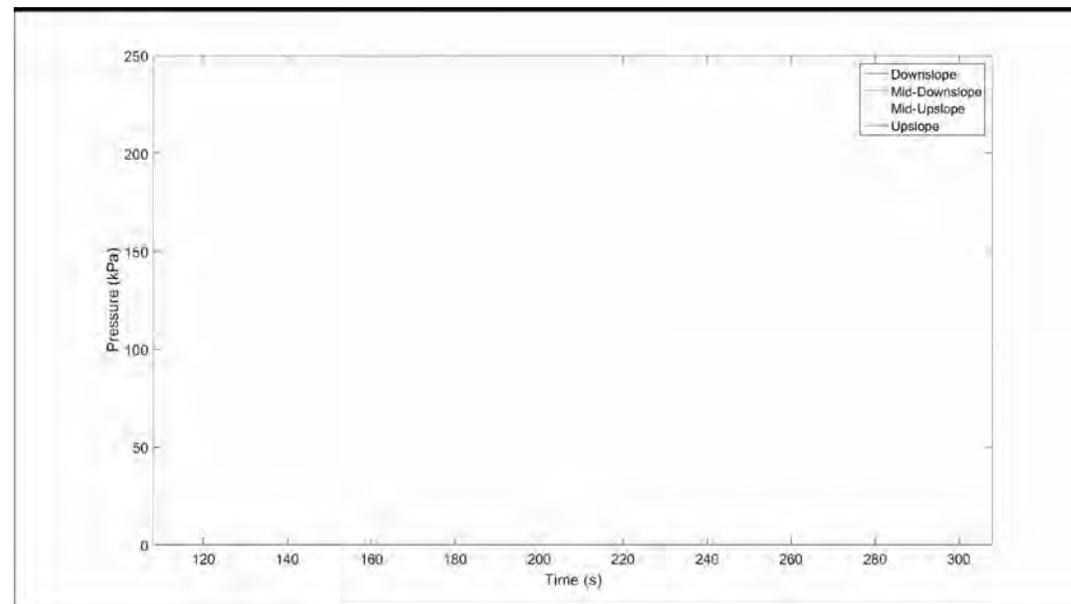
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Environmental Impacts

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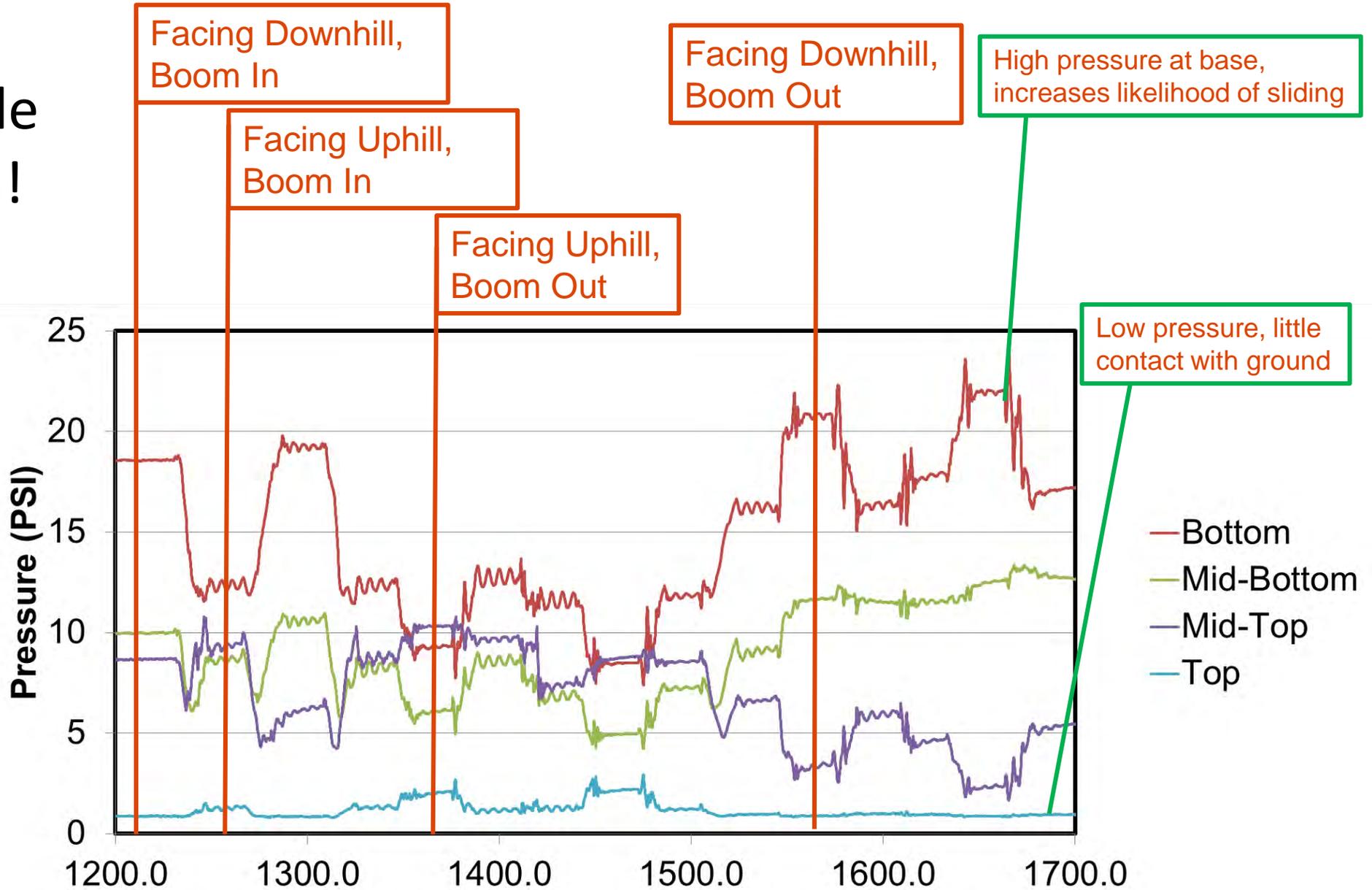
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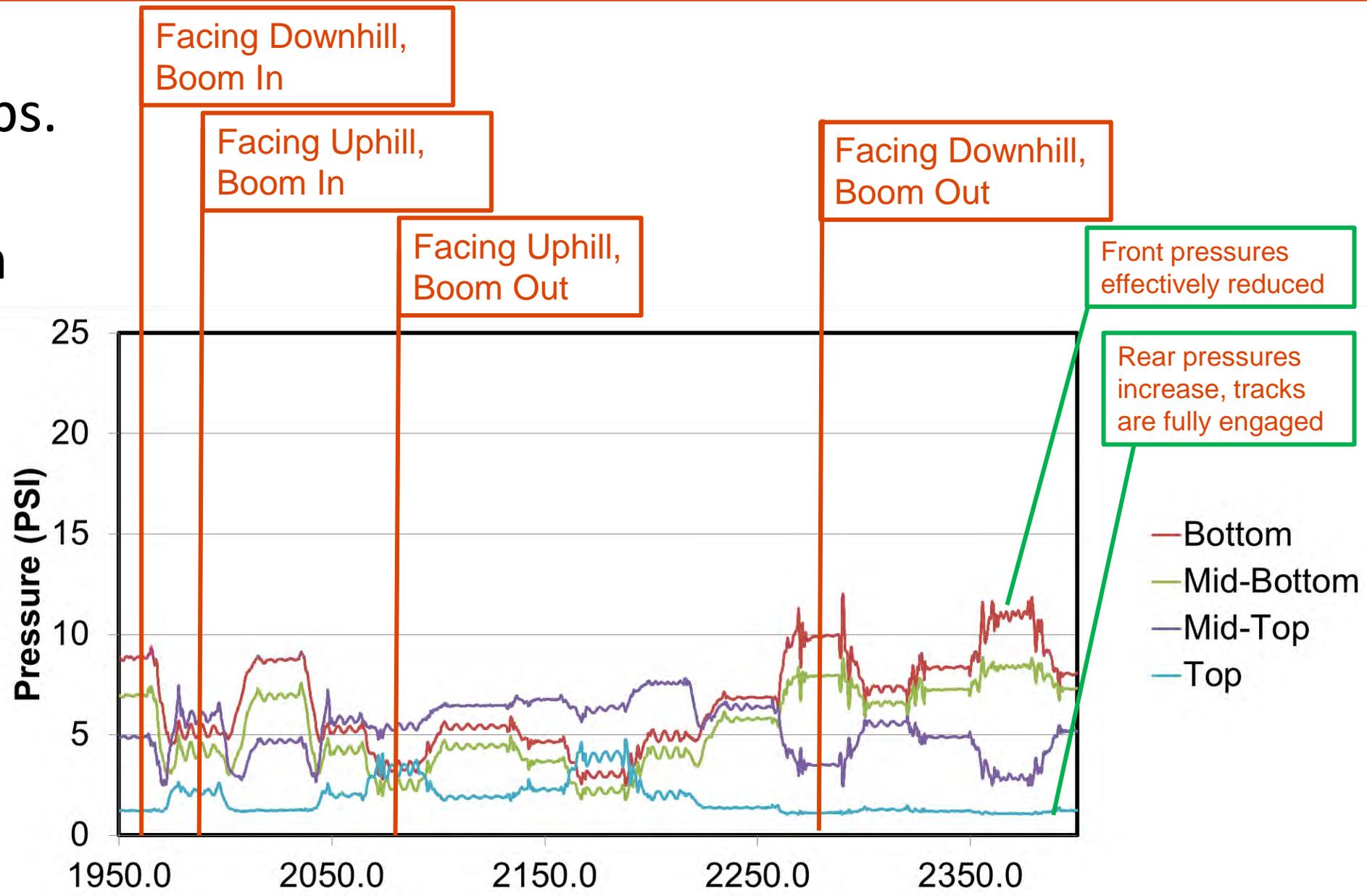
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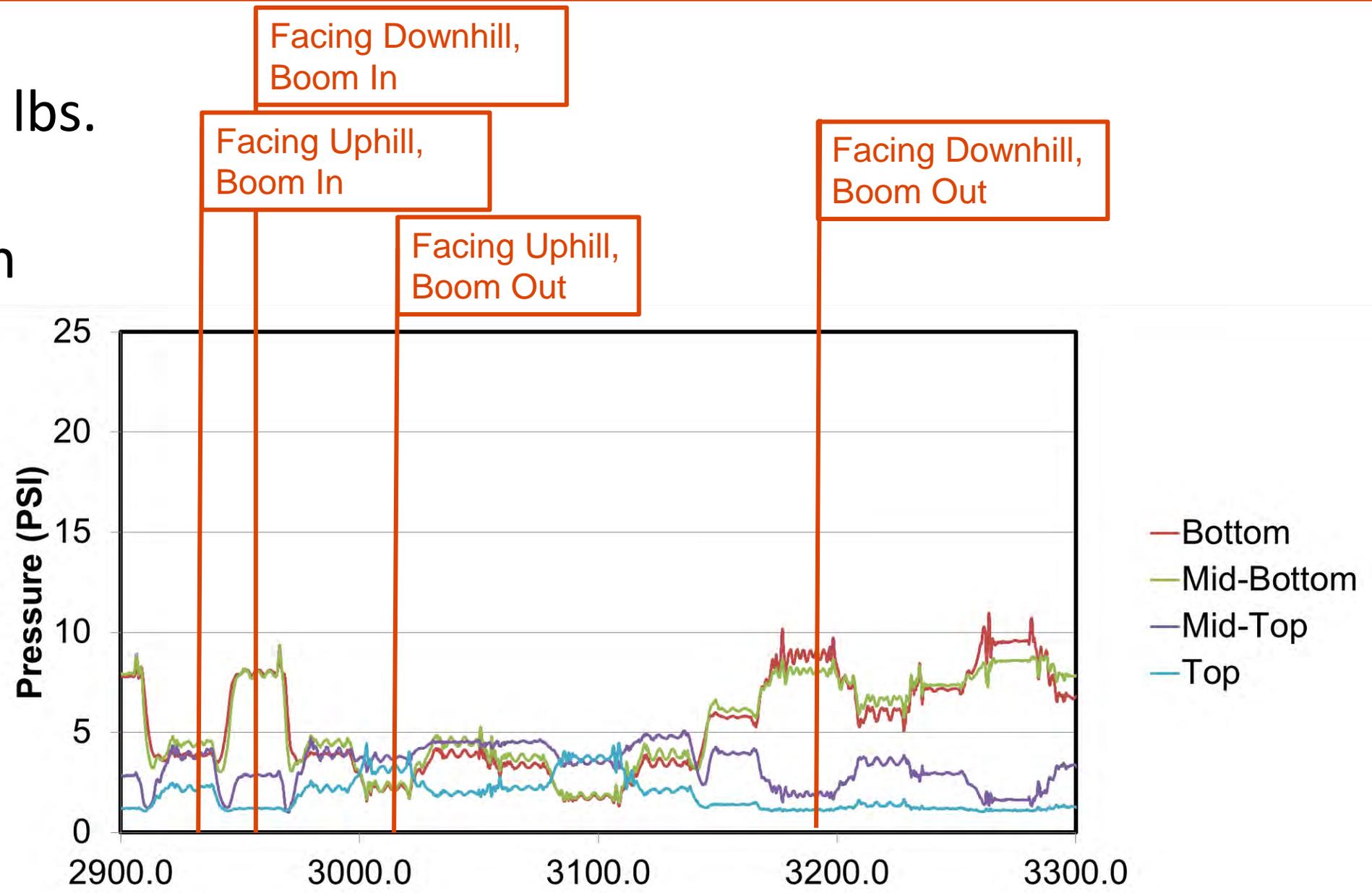
No Cable Tension!



9,000 lbs. Cable Tension



20,000 lbs. Cable Tension

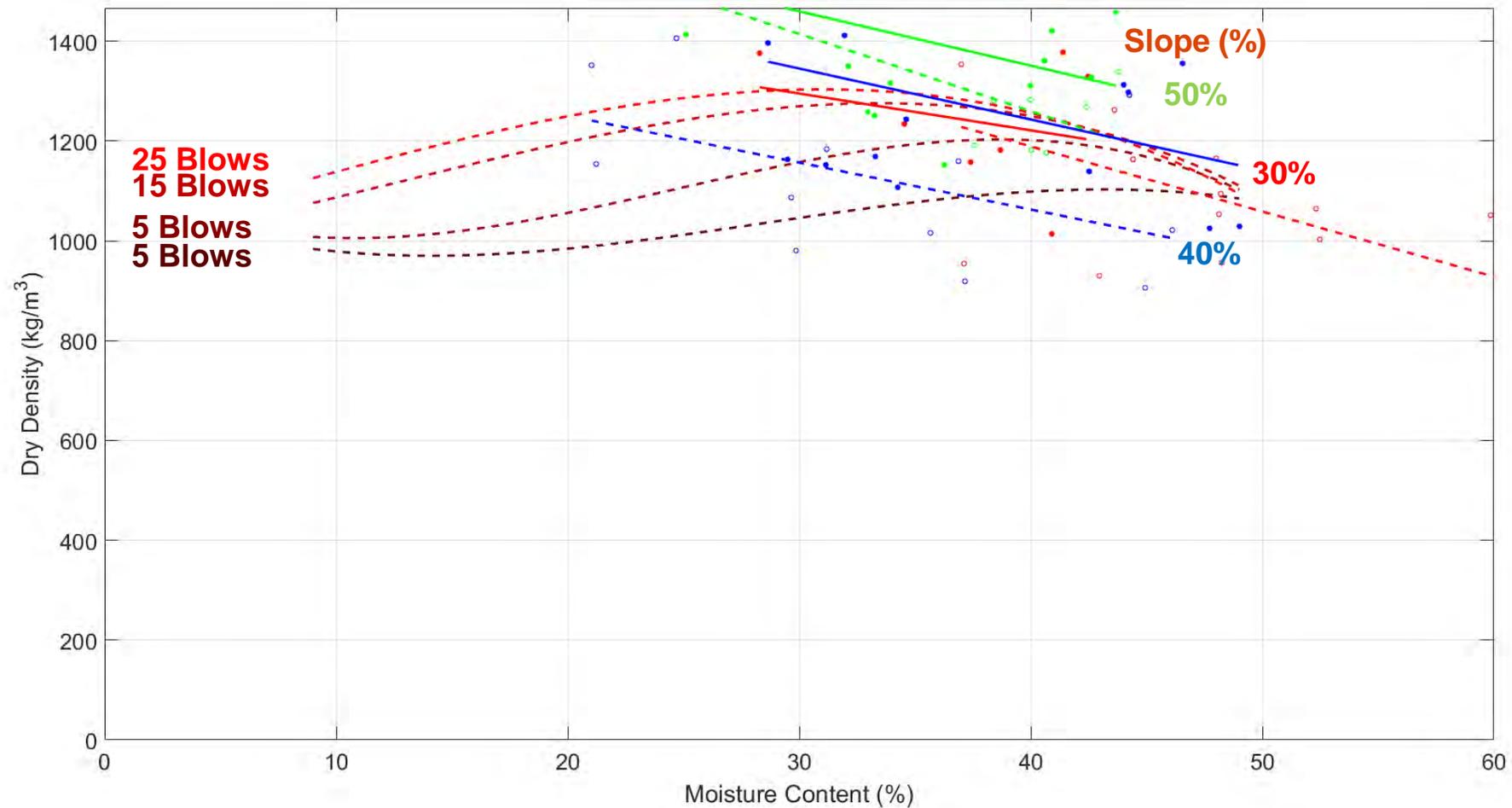


What does this mean?

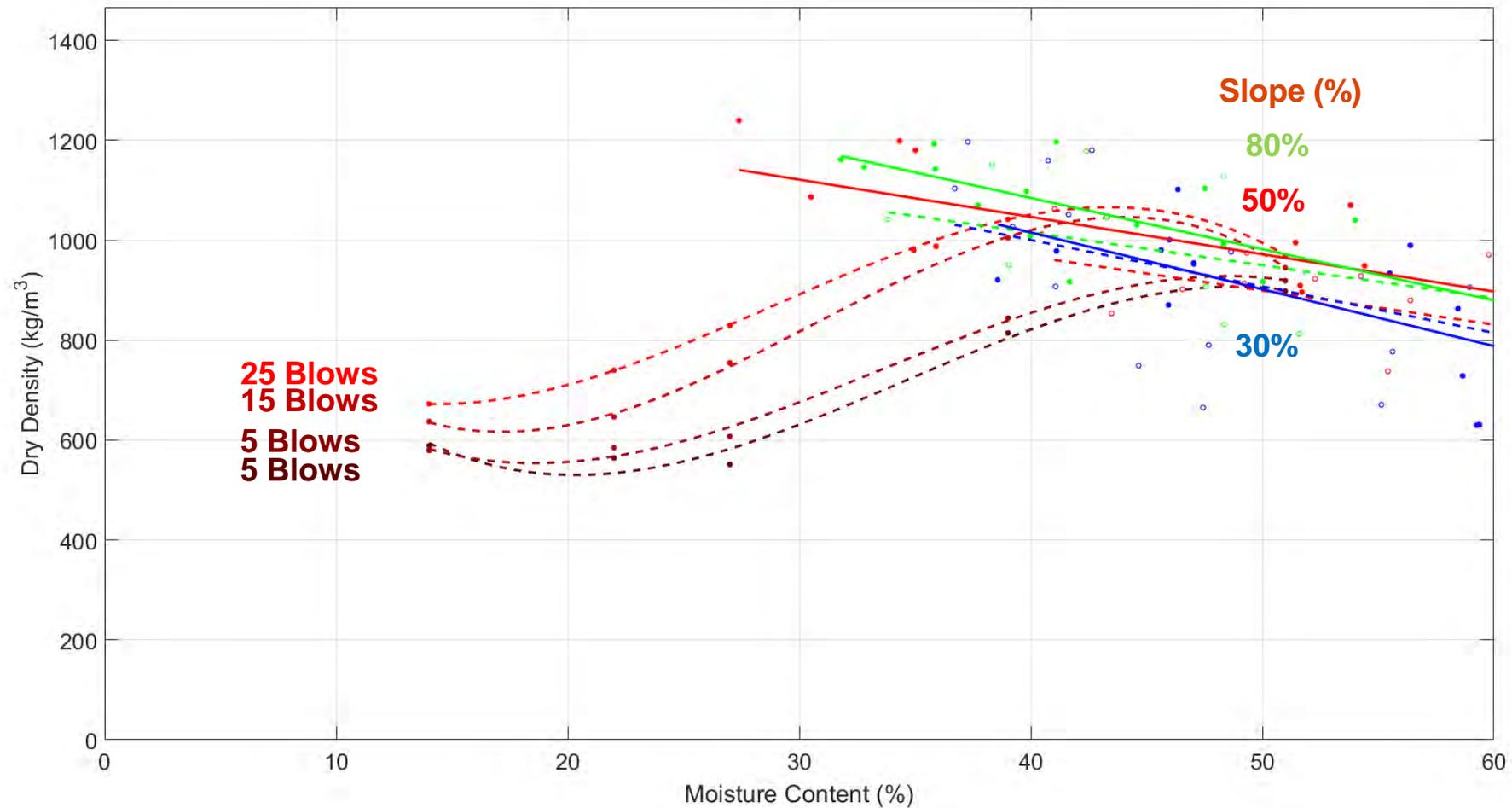
- Tracks are better engaged throughout their entire length due to cable tensions (better mobility)
- Ground pressure decrease (less soil disturbance, more stability)
- Downhill operation is improved by reducing maximum track pressures.
- Uphill operation is improved by better distribution of ground pressures.

What about compaction?

Harvester – No Tether Tension



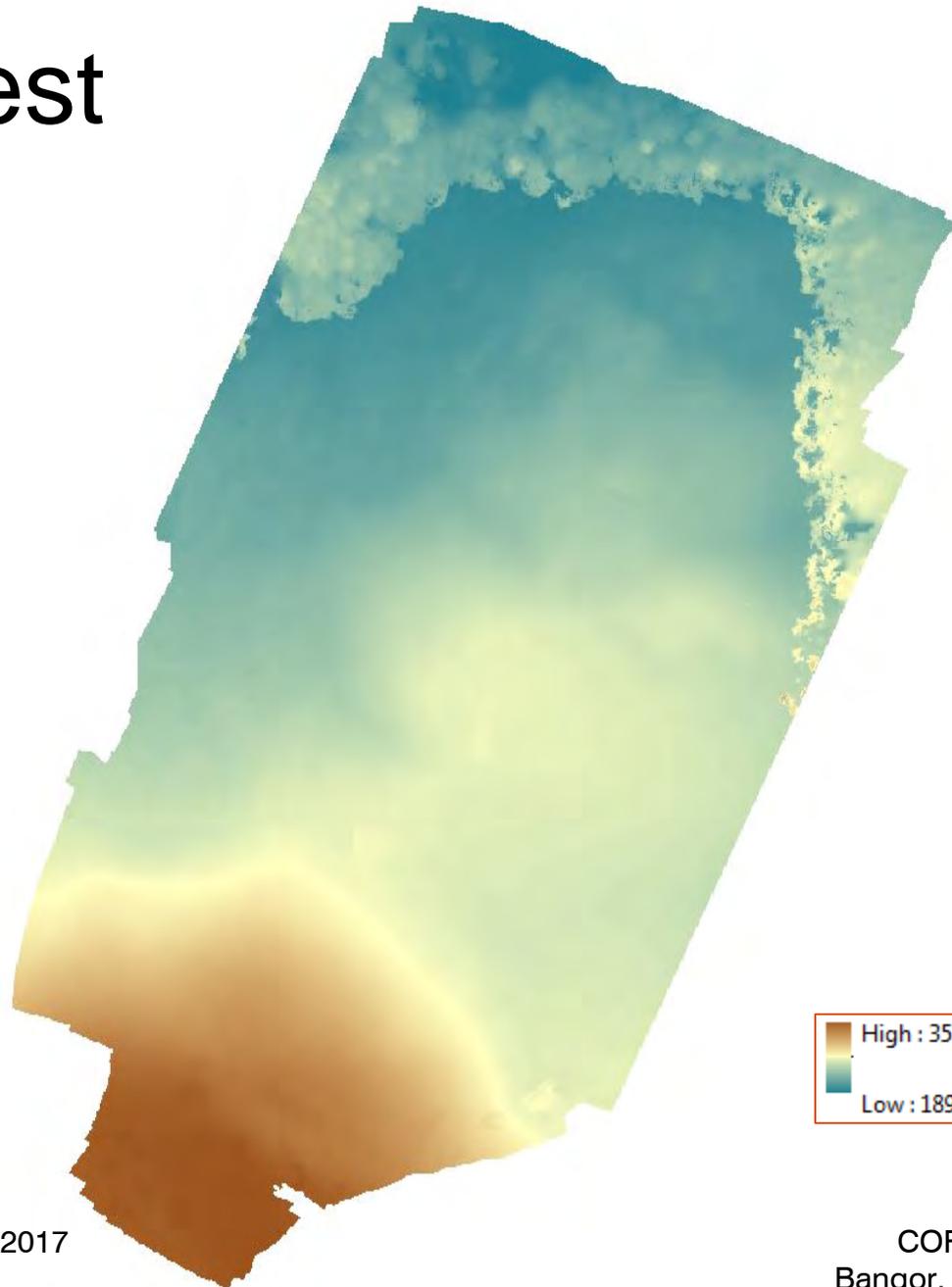
Harvester – Tension



Productivity & Cost

- Conventional yarding and grapple yarding on the same setting
- Madill 071 w/Boman Mark V carriage and Eagle Claw grapple
- Clearcut, Douglas fir age 50-55 (est.), 18.24" ave. DBH, 93.3' ave. height
- Yarding from pre-bunched decks of logs
- Independent variables:
 - Outhaul distance
 - Number of stems

Harvest Unit



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Productivity and Cost Comparison

Cable Yarding

- AYD: 1,129 feet
- Without delay: 17.38 MBF/Hr.
- With delay: 15.52 MBF/Hr.
- Cost/SMH: \$407.51
- Cost/PMH: \$611.95

Grapple Yarding

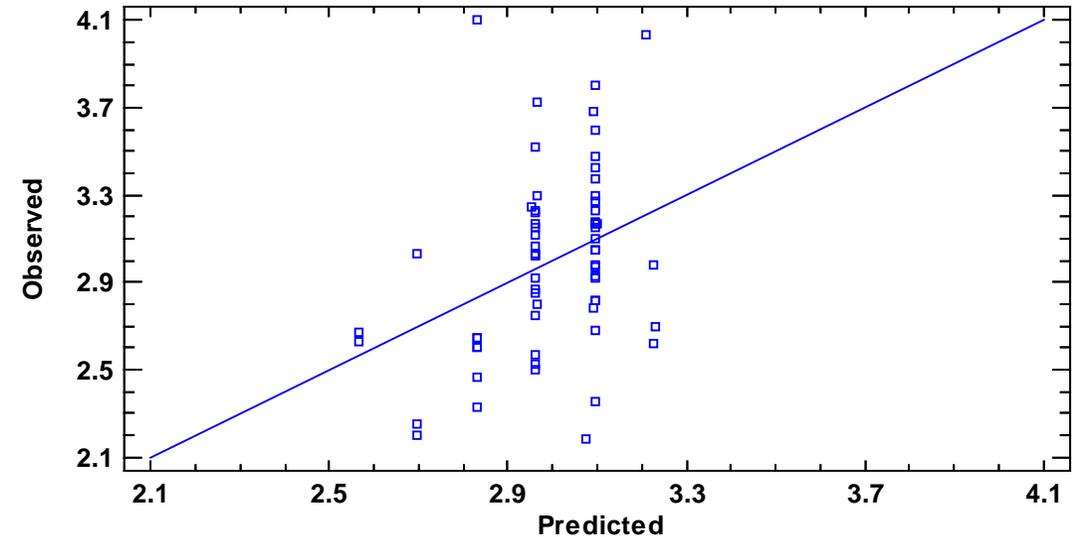
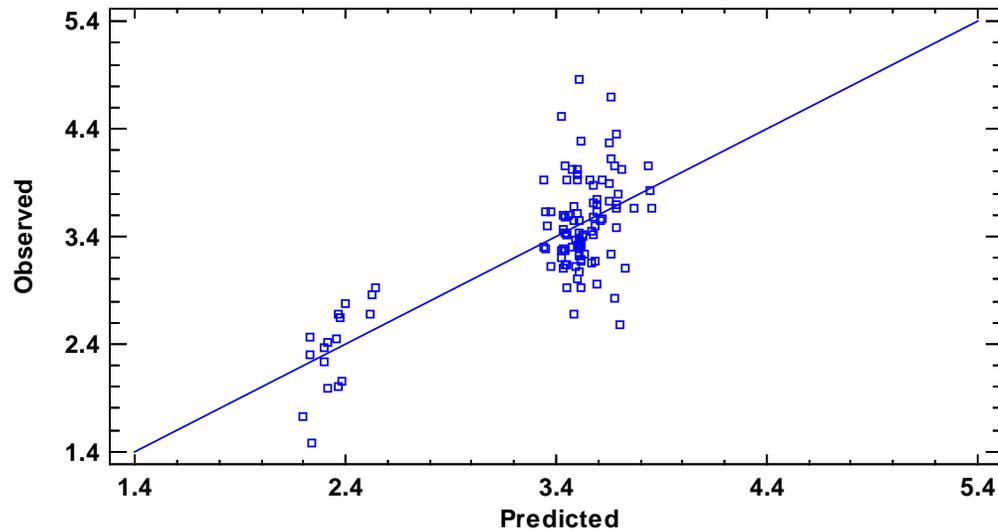
- AYD: 591 feet
- Without delay: 16.89 MBF/Hr.
- With delay: 13.98 MBF/Hr.
- Cost/SMH: \$491.44
- Cost/PMH: \$741.07

Cable Yarding

vs. Grapple Yarding

Plot of DFCT Given Outhaul Distance and Number of Stems

Plot of DFCT Given Outhaul Distance and Number of Stems



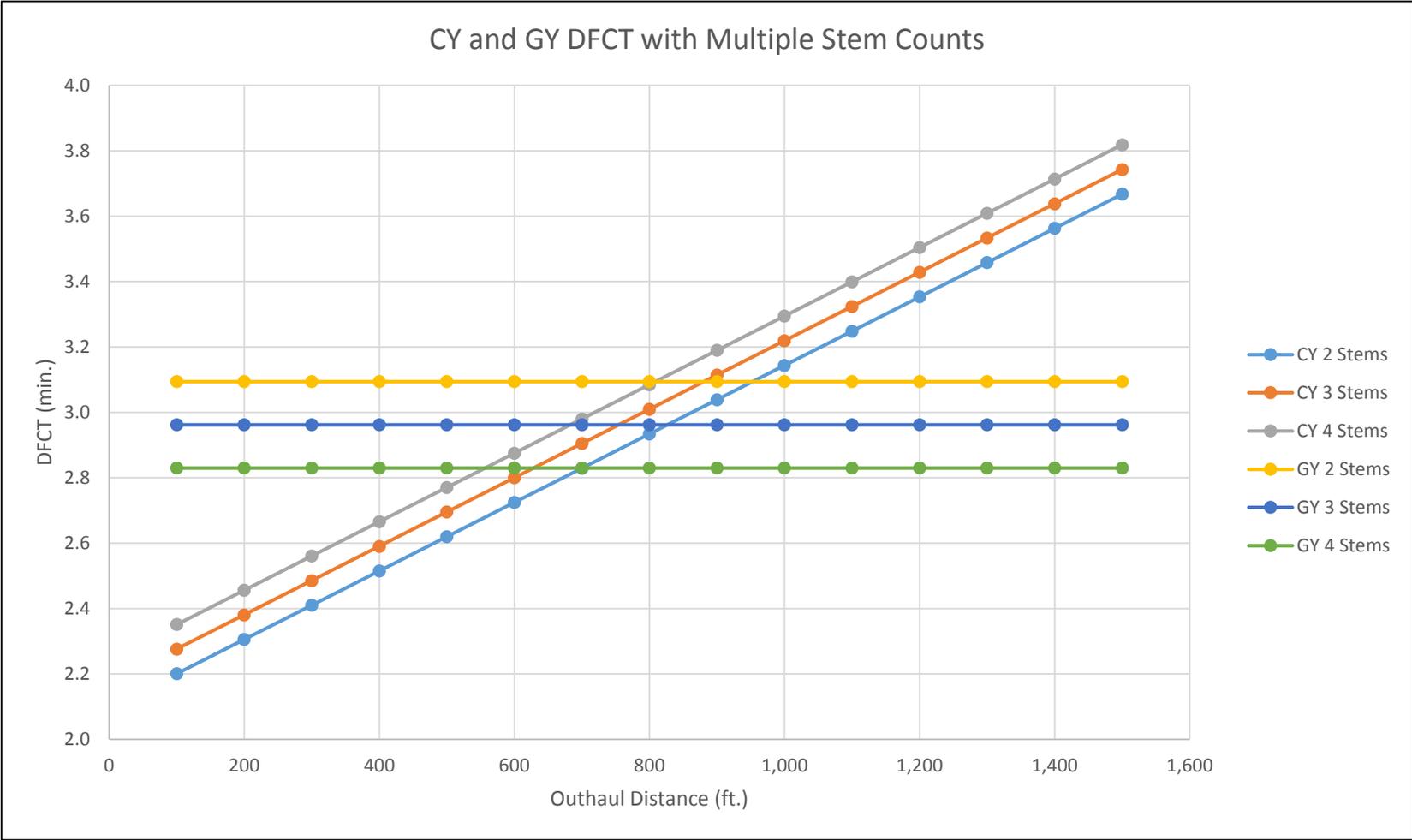
$$\text{DFCT (min.)} = 1.94515 + 0.00104797 * \text{Outhaul_Distance} + 0.0753253 * \#\text{Stems}$$

$$\text{DFCT (min.)} = 3.3581 - 0.132014 * \#\text{Stems}$$

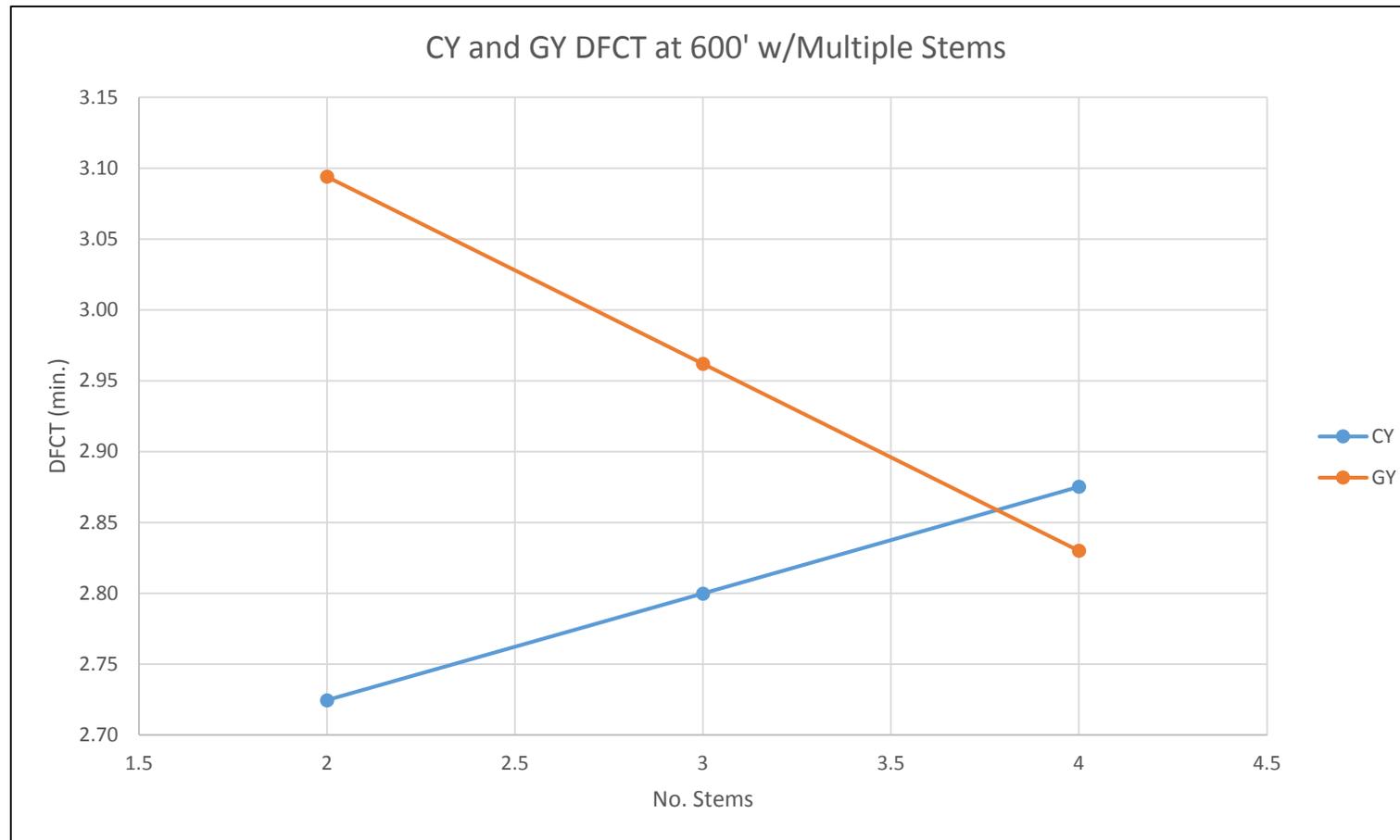
R-squared (adj. for d.f.) = 55.7425 %

R-squared (adj. for d.f.) = 10.6615 %

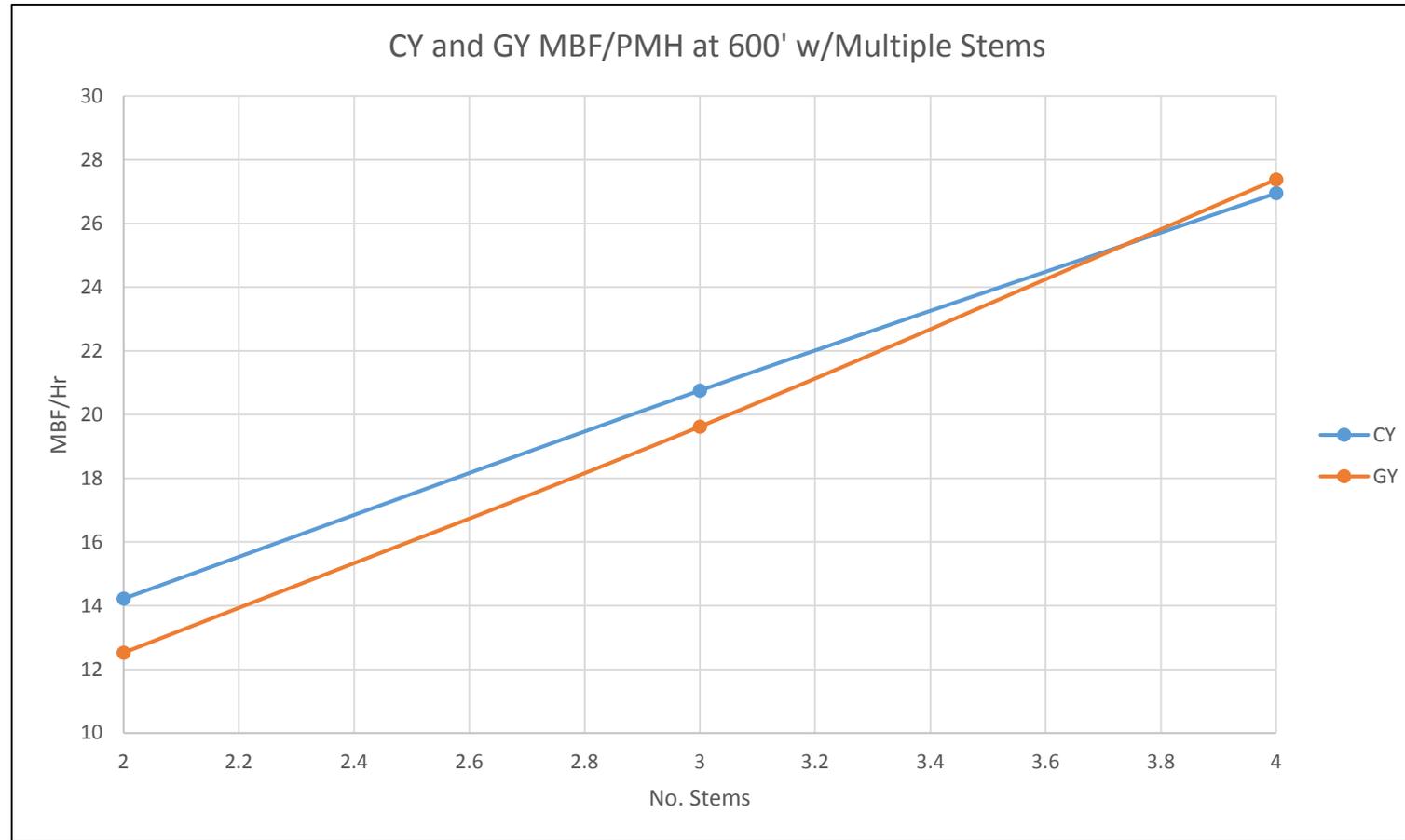
Cable Yarding vs. Grapple Yarding



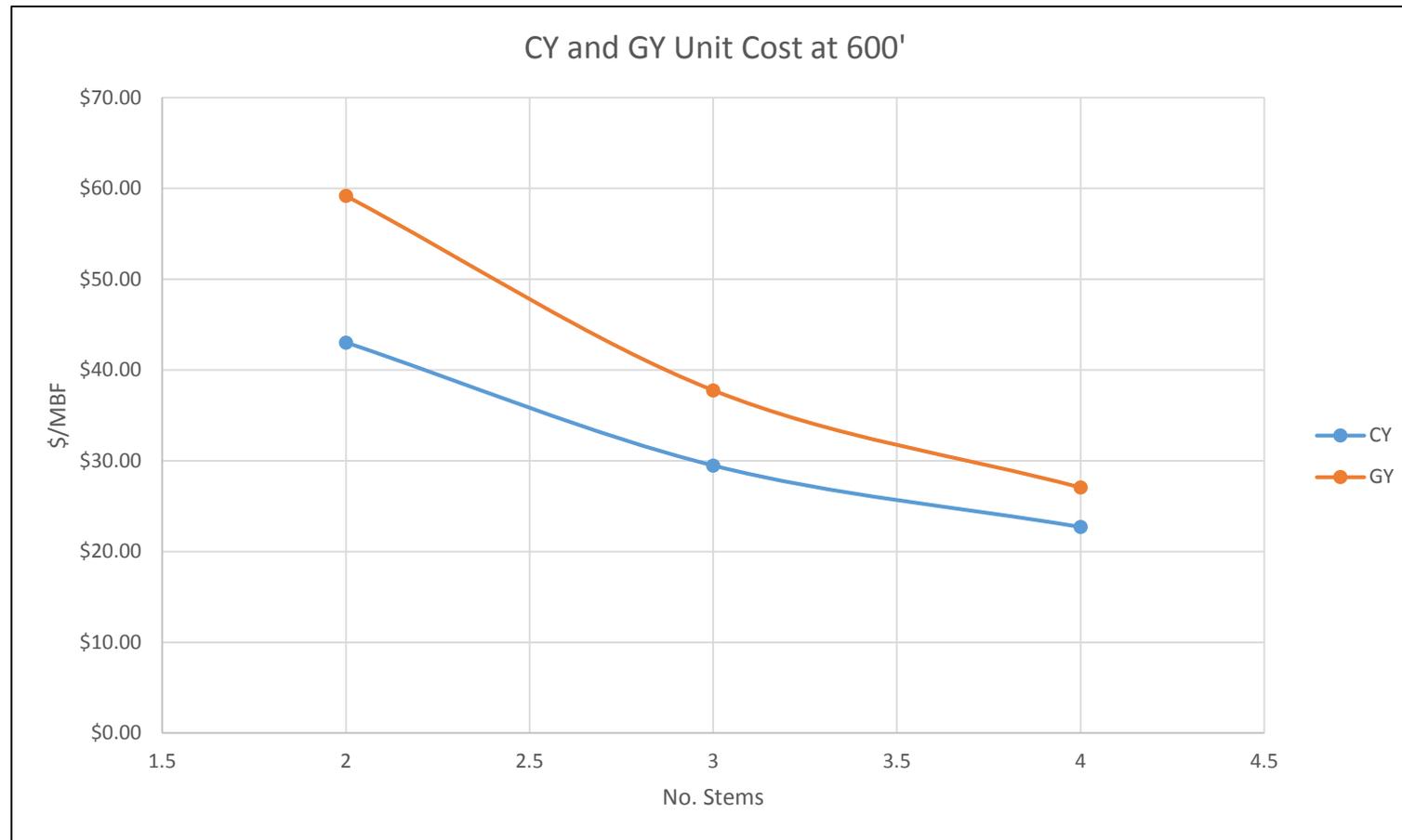
Productivity & Cost Comparison at 600'



Productivity & Cost Comparison at 600'



Productivity & Cost Comparison at 600'



What does this mean?

- More data needed for grapple yarding to determine better productivity estimates and 'sweet spots' for operating over traditional cable yarding
 - Hand cutting + cable yarding vs. tethered cutting + grapple yarding
- Worker hazard exposure
 - Different type and severity between the two, need to analyze and plan accordingly
- Grapple yarding has room for efficiency improvement
- If the systems are relatively similar in cost, how much is the added hazard reduction of removing chasers and chokersetters worth?

Take-Away Messages

- ***Soils are complex, site conditions are important!***
- Ground pressures affect machine stability and soil disturbance.
- Use of cable assistance (and slash mat?) enables reduced ground pressures which provides:
 - Less soil displacement (slip and rutting)
 - Access to steeper slopes
 - Improved mobility
 - Improved stability
- Uphill orientation may be beneficial from a soil perspective due to better distribution of ground pressures.

Future Plans

- Assess worker response during feller-buncher operations
- Continue to measure shift-level productivity of felling and yarding as part of worker risk exposure
 - Mechanized felling (feller-buncher, grapple saw)
 - Extraction (tethered skidder)
- Compaction sampling of different carriers and effects of uneven terrain (road edges, etc.) and their creation of erosion/runoff channels
- Cable tension monitoring during mechanized felling and extraction to further explore a correlation between compaction and cable tension
- Development of guidelines and design criteria for new logging systems
 - New risks! Sliding, roll-over, loss of anchoring support, equipment immobilization, fire, etc.

THANK YOU! QUESTIONS?

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Plenary Sessions

Tim McDonald	Big Data in Forestry Big Problems?	Presentation
Brian Roth	The Cooperative Forestry Research Unit	Presentation
Wendy Farrand	Loggers for the Future	Presentation
Joe Conrad	Review of Logging Business Characteristics: Comparisons across time and Between Regions	Presentation

Concurrent Sessions

Neila Cole	Analyzing Characteristics of Log Truck Accidents in the United States	Presentation
Jean-Francois Gingras	FPInnovations' Forest-2-User 4.0 Initiative	Presentation
Ryer M. Becker	Use of LiDAR and simulation modeling to characterize alternative steep slope harvest system options in the Inland Northwest	Presentation
Pat Sirois	Maine's Progress in Logger Training and BMP Administration	Presentation
Robert F. Keefe	Real-time location sharing for forest operations: where we've been and where we're going	Presentation
Han Sup Han	Productivity and Cost of Cut to Length Thinning in Northern California Redwood Forests	Presentation
Chandler L. Dangle	Analysis of Upgraded Forestry BMPs for Stream Crossings in Virginia	Presentation
Ben Matthews	Getting the Fish up the Stream in Maine: the TNC's fish Restoration Program	Presentation
Lloyd C. Irland	Value Engineering for Stream Protection and restoration: Challenges in the Maine woods	Presentation
Keith M. Coulter	Got Salmon? Harvesting old growth within a major Alaskan salmon fishery	Presentation
Han Sup Han	Impacts on soils and residual trees from cut to length thinning operations in California's Redwood forests.	Presentation
Anil Koirala	Improving Maine's forest products trucking enterprises: A qualitative study approach	Presentation
Jason D. Thompson	Alternative Trailer Configurations for Maximizing Payloads	Presentation
Marissa "Jo" Daniel	Utilization of Phone App Technology to Monitor Log Truck Movement	Presentation
Jon Lancaster	Whole Tree Transportation System for Timber Processing Depots	Presentation
Michel Soucy	Work productivity of using a clearing saw designed for top spacing in a delayed precommercial thinning context: a case study	Presentation Supplemental Info
Preston Green	"Steep-Slope Logging Research: Eye Movement Tracking to Grapple Yarding, Collaboration for a Safer Work Environment"	Presentation
John Klepac	Evaluation of a Tracked Feller-Buncher Harvesting Plantation Loblolly Pine	Presentation
Rafael Santiago	Coppicing Evaluation in the Southeast of the U.S. to Determine Harvesting Methods for Bioenergy Production	Presentation
Eunjai Lee	Production of sawdust-type wood chips from stem-wood residues	Presentation
Mathew Smidt	Biomass chipping for eastern redcedar control	Presentation
Dana Mitchell	Biomass Removal Study on the George Washington National Forest	Presentation
Beth Dodson	Forest Bioenergy and Biofuels Integration: Sustainability, Energy Balance and Emissions from Forest Restoration in the Southern Rocky Mountains	Presentation