STEEP SLOPE LOGGING RESEARCH AT OSU

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

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Research Team Acknowledgement

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Steep Slope Harvesting

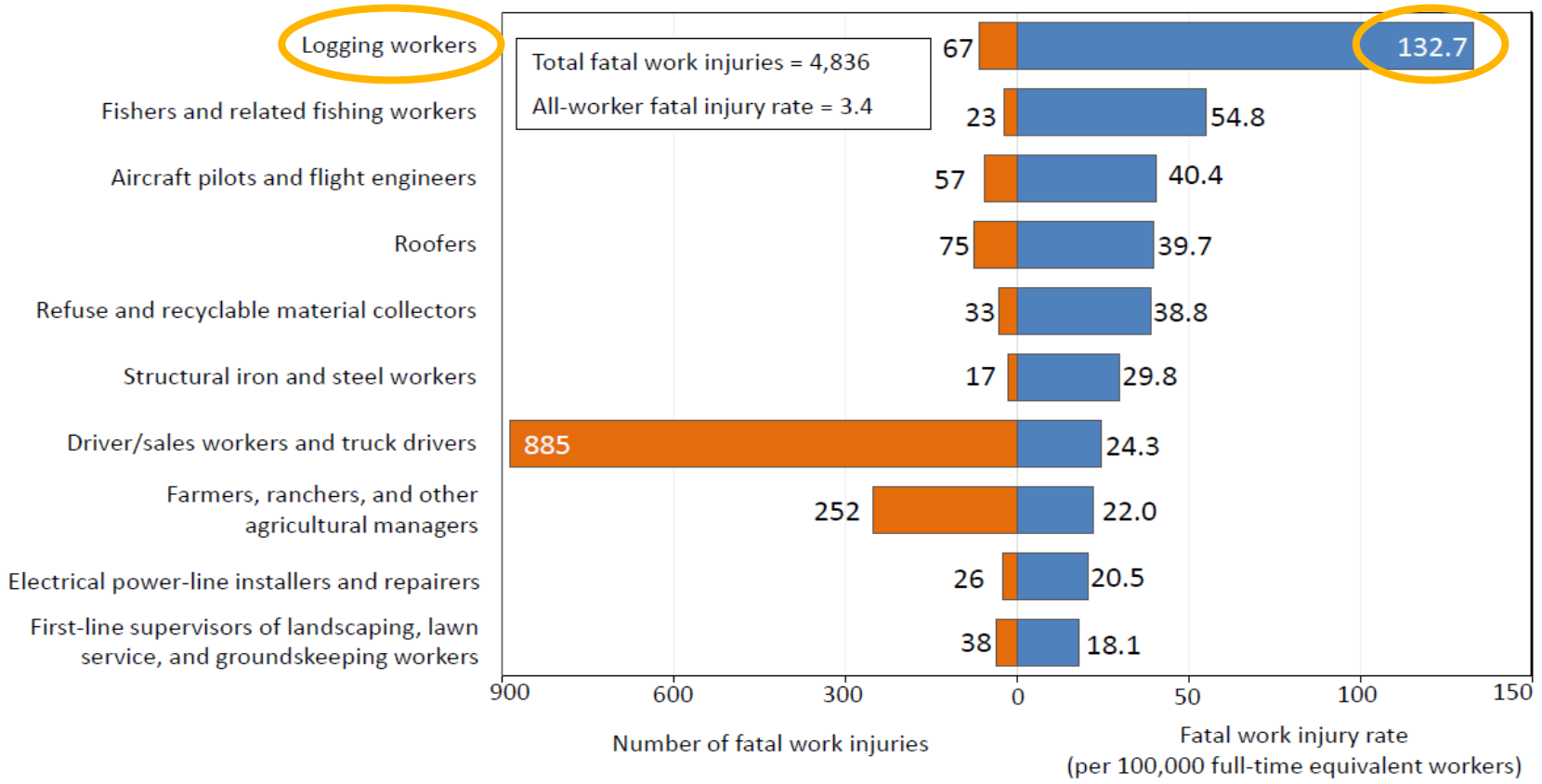
- Research Introduction
- Research Goals
- Methodology Overview
- Results to Date
- Future Plans

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.

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.

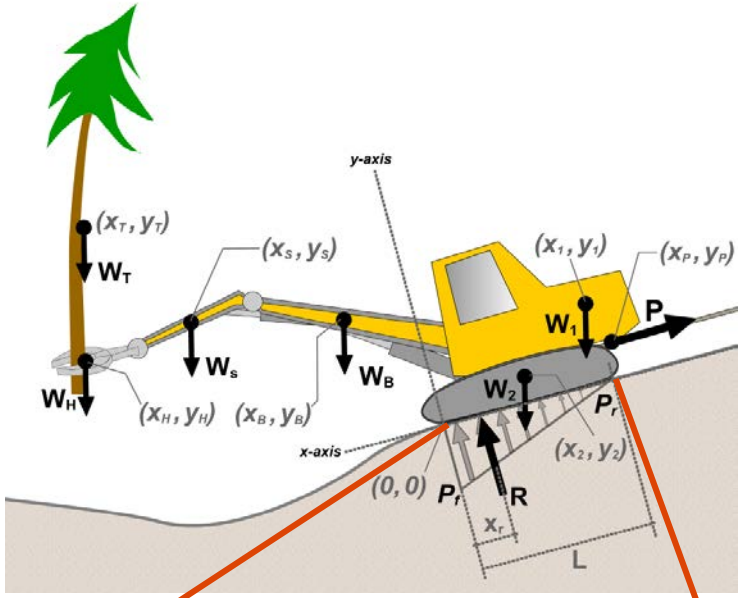
Other medical-grade devices similar to a Fitbit to track vital signs and galvanic skin responses.

Wired Operator

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.

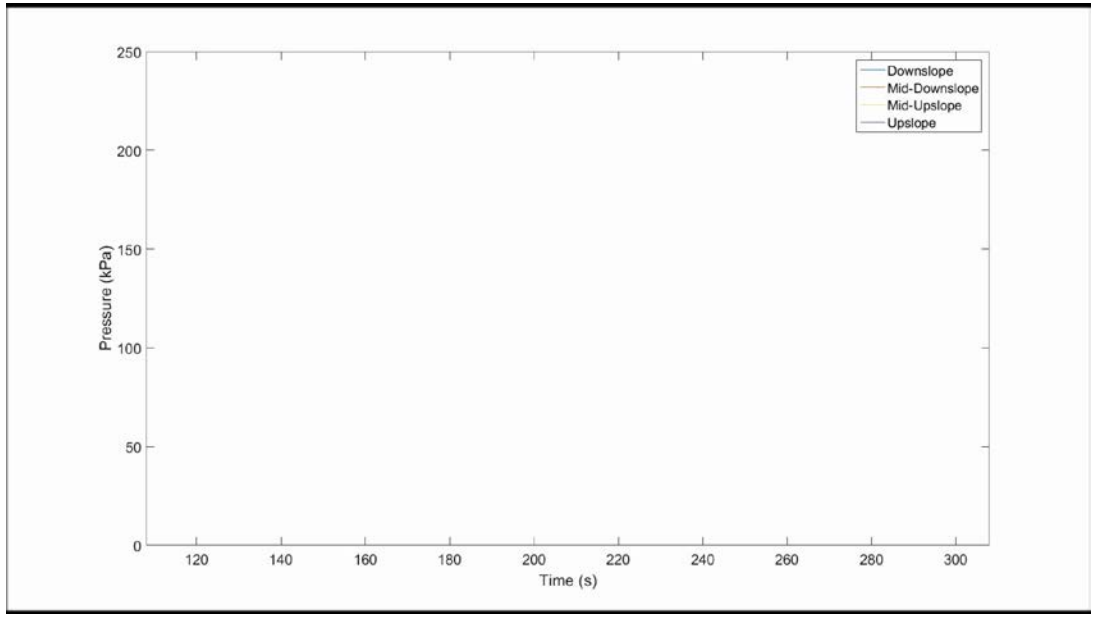
Field Testing

Results to Date

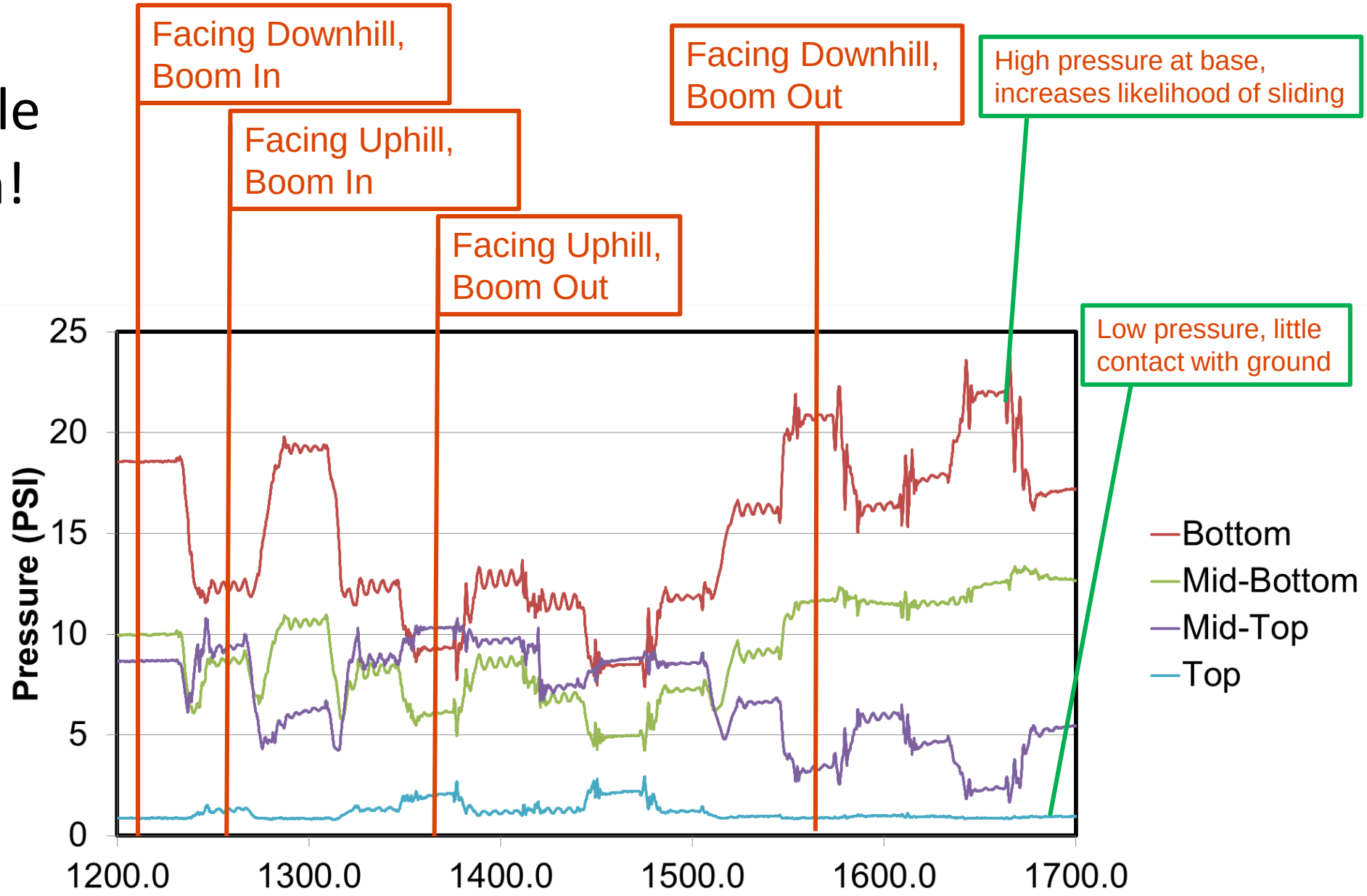
Practical & Physiological Response of Operator


14,000
SMI
SensoMotoric Instruments

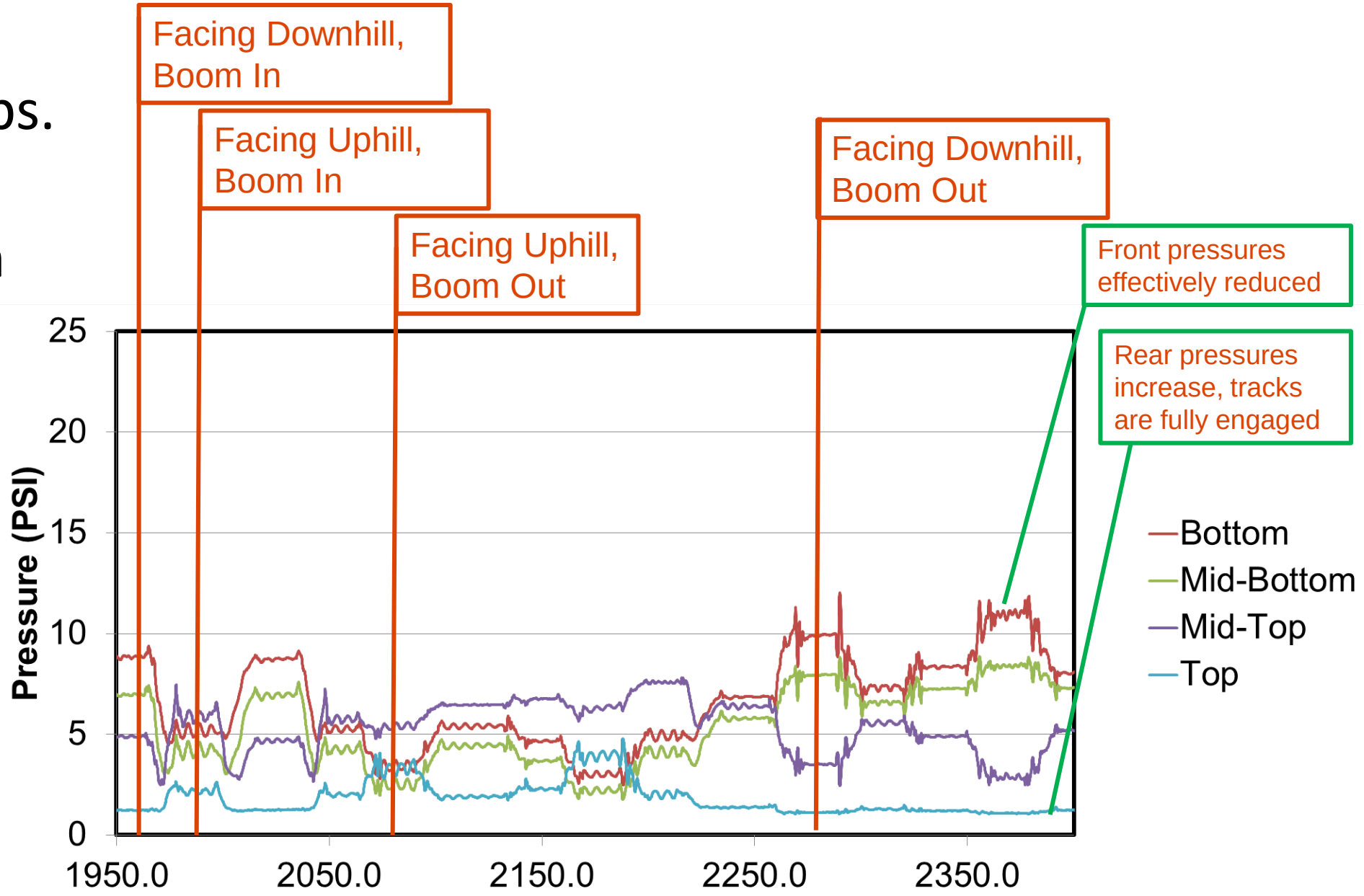
Environmental Impacts


250
200
150
100
50
0
Pressure (kPa)
120
140
160
180
200
220
240
260
280
300
Time (s)
Downslope
Mid-Downslope
Mid-Upslope
Upslope

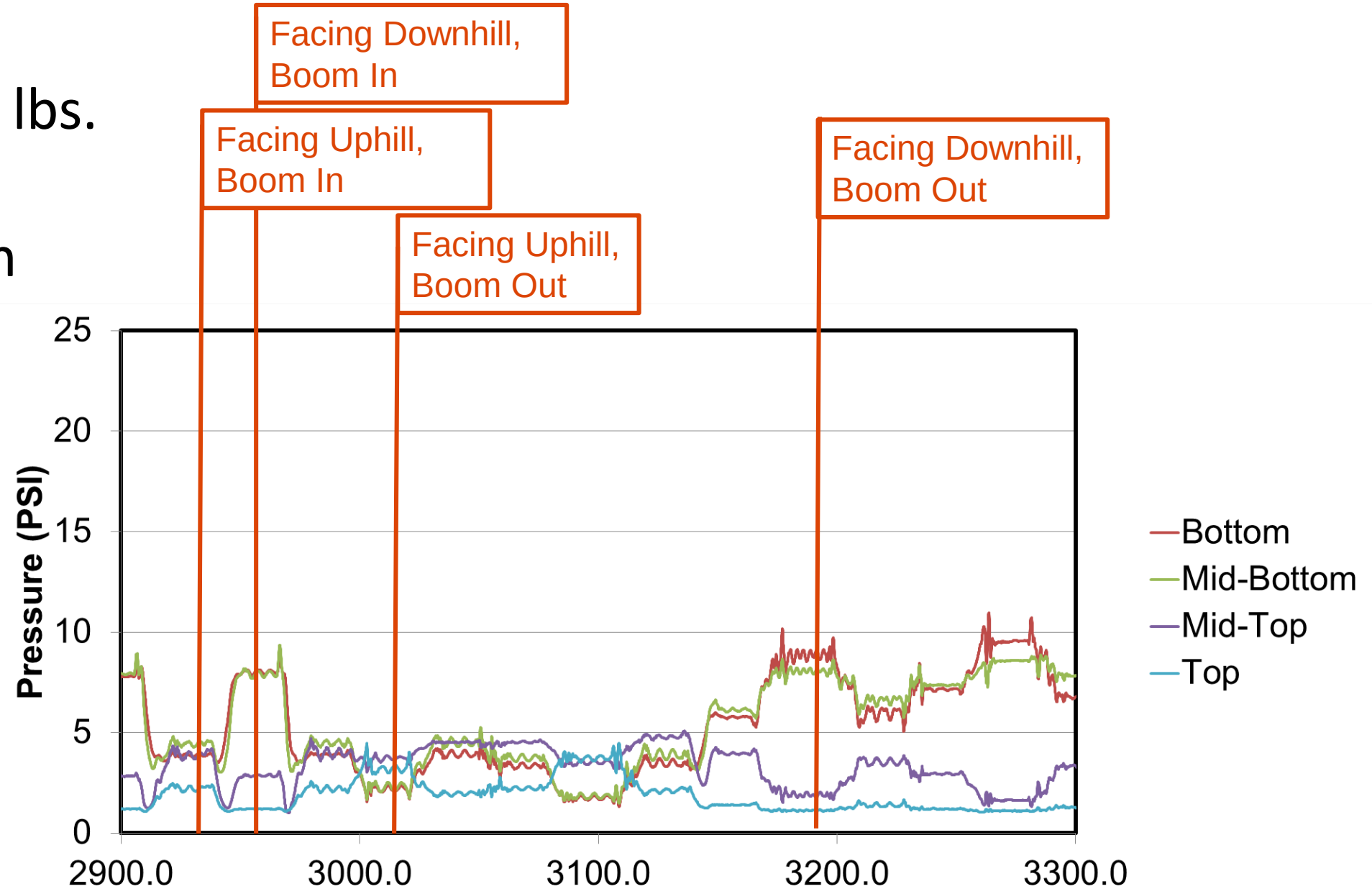
No Cable Tension!



9,000 lbs. Cable Tension



20,000 lbs. Cable Tension

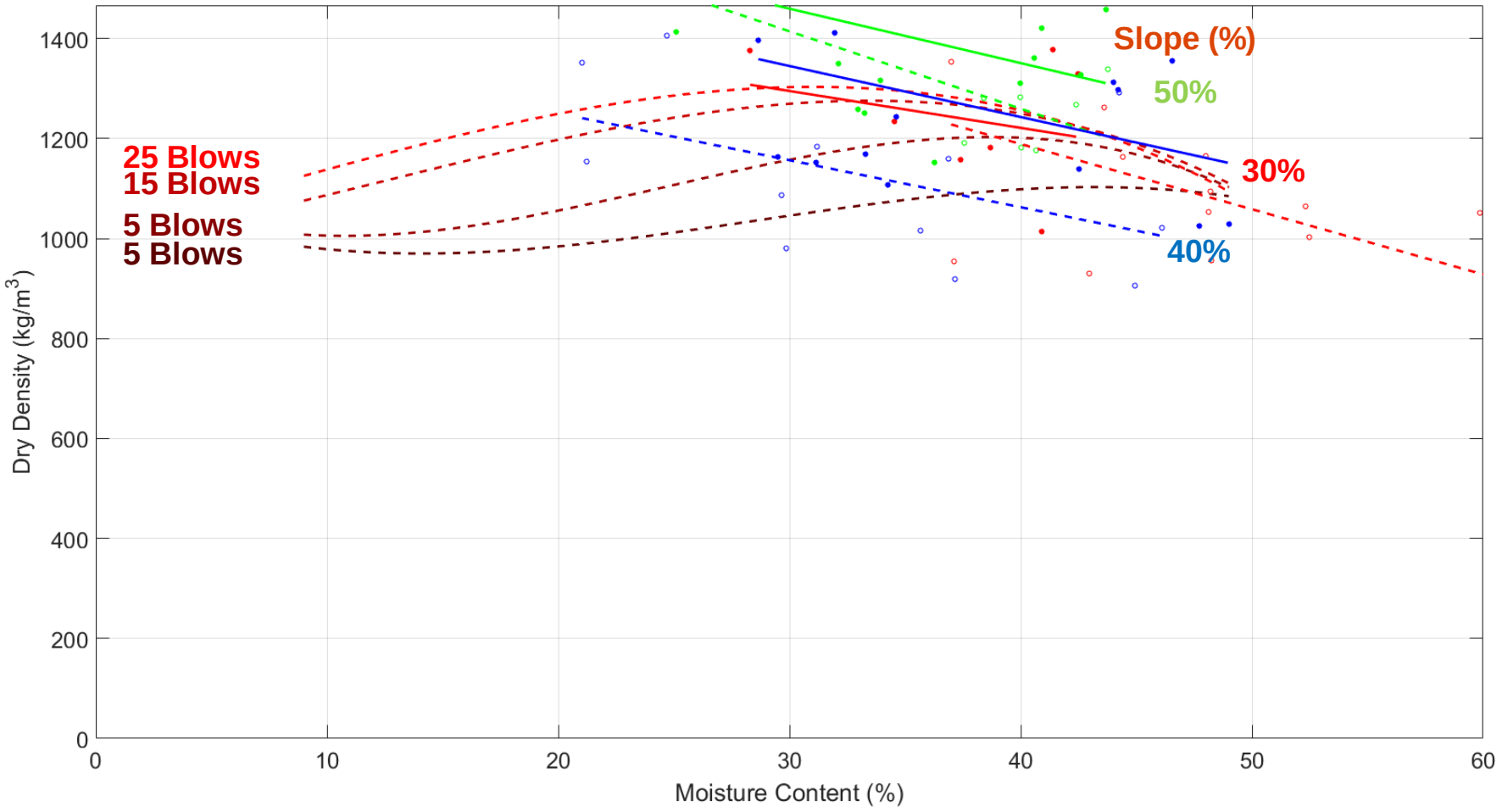


What does this mean?

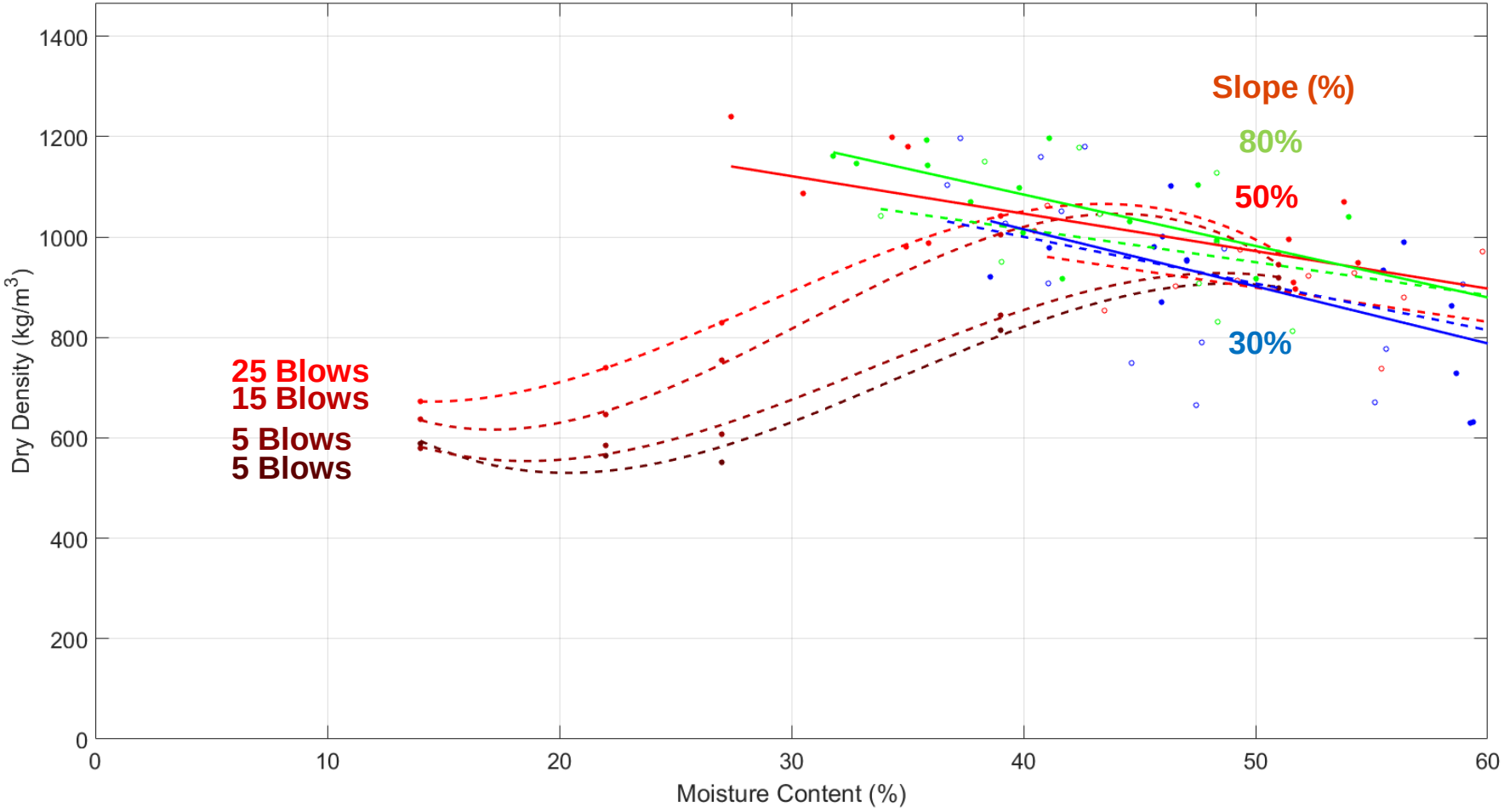
- Tracks are better engaged throughout their entire length due to cable tensions (better mobility)
- Ground pressure decrease (less soil disturbance, more stability)
- Downhill operation is improved by reducing maximum track pressures.
- Uphill operation is improved by better distribution of ground pressures.

What about compaction?

Harvester – No Tether Tension



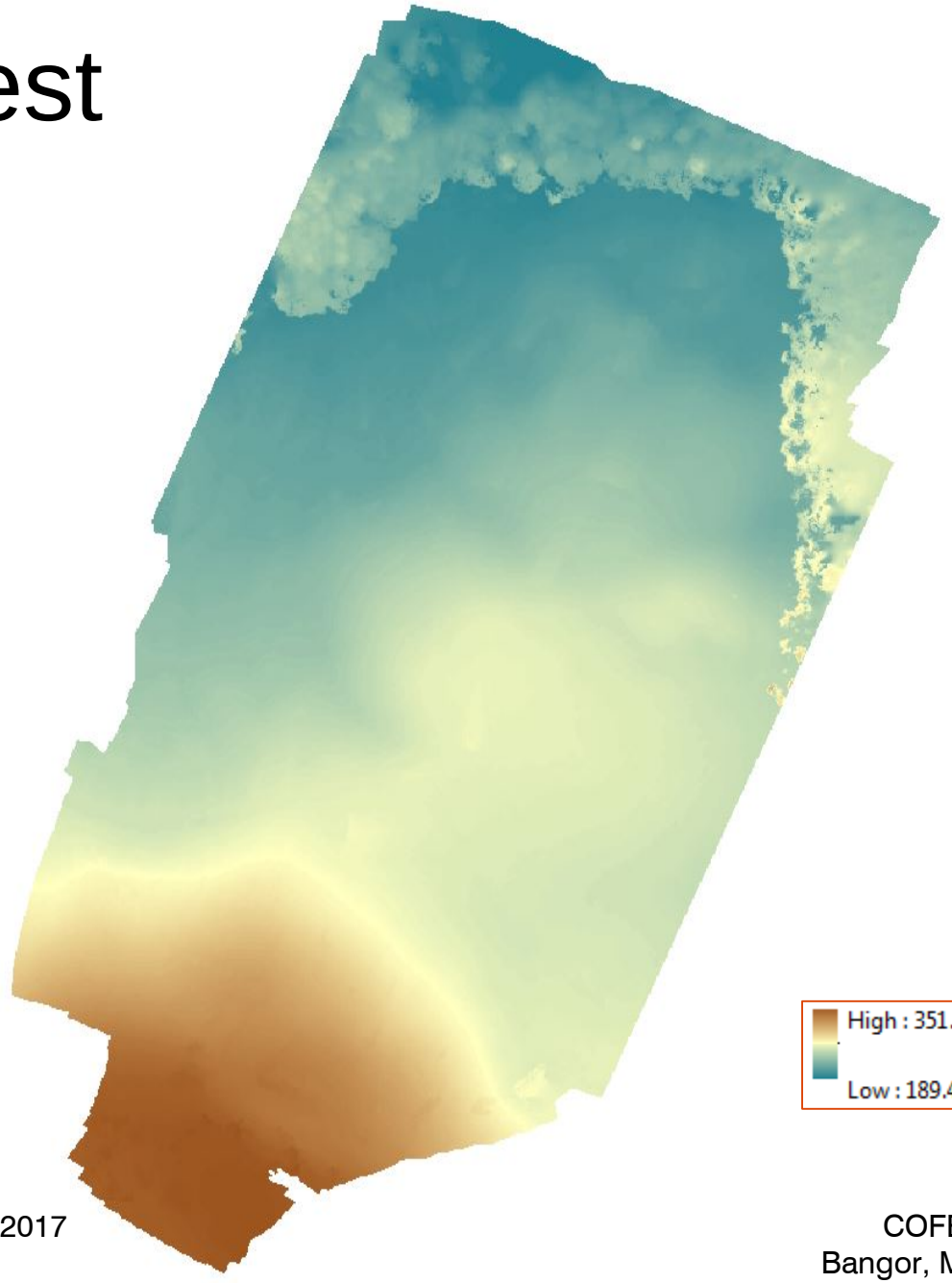
Harvester –Tension



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



Productivity and Cost Comparison

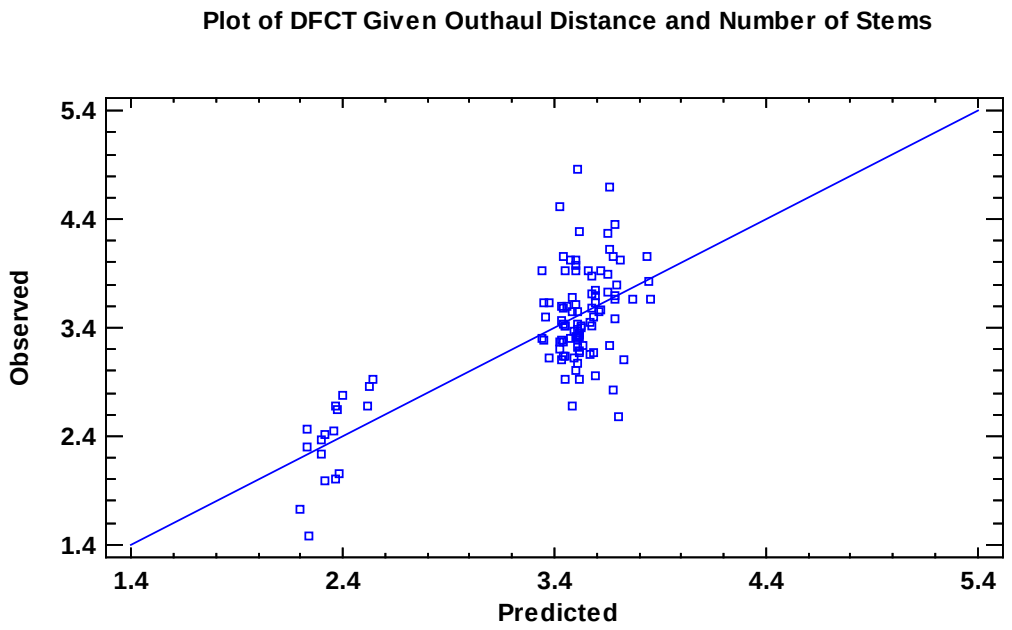
Cable Yarding

- 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

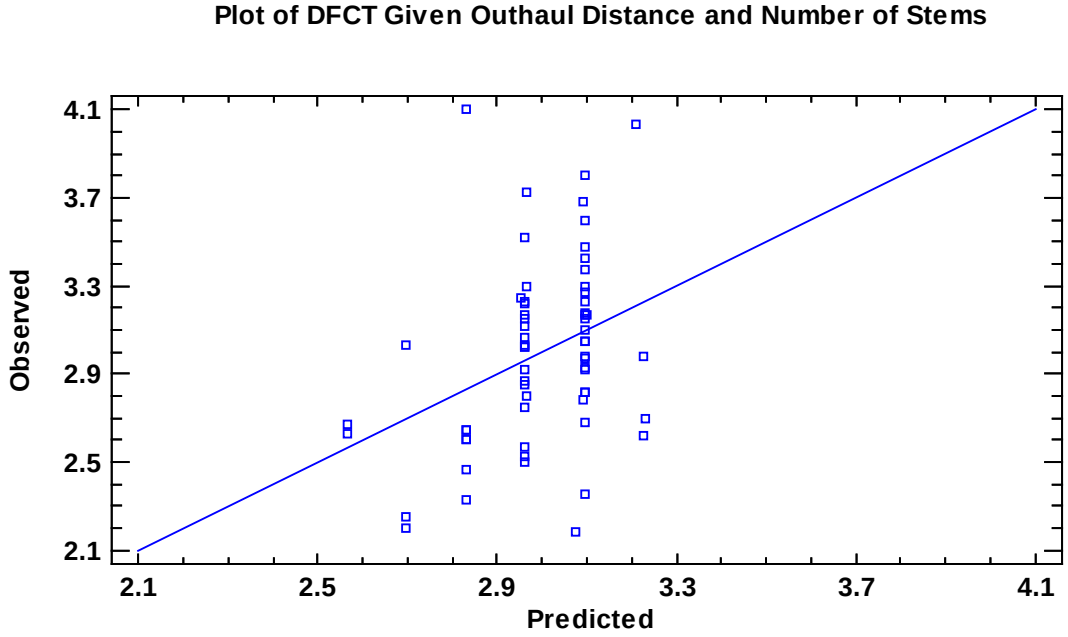
- AYD: 591 feet
- Without delay: 16.89 MBF/Hr.
- With delay: 13.98 MBF/Hr.
- Cost/SMH: $491.44
- Cost/PMH: $741.07

Cable Yarding vs. Grapple Yarding



DFCT (min.) = 1.94515 + 0.00104797*Outhaul_Distance + 0.0753253*#Stems

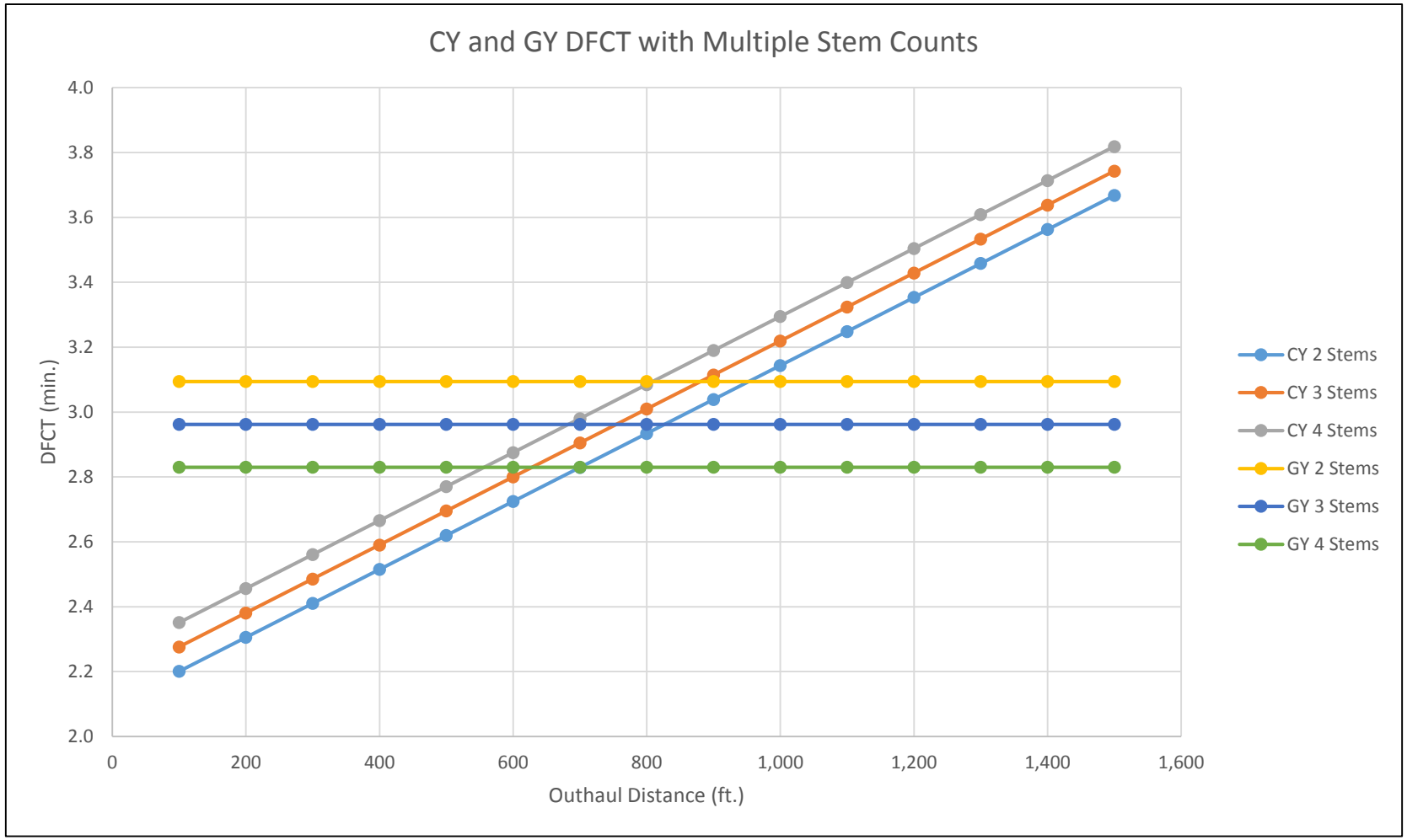
R-squared (adj. for d.f.) = 55.7425 %



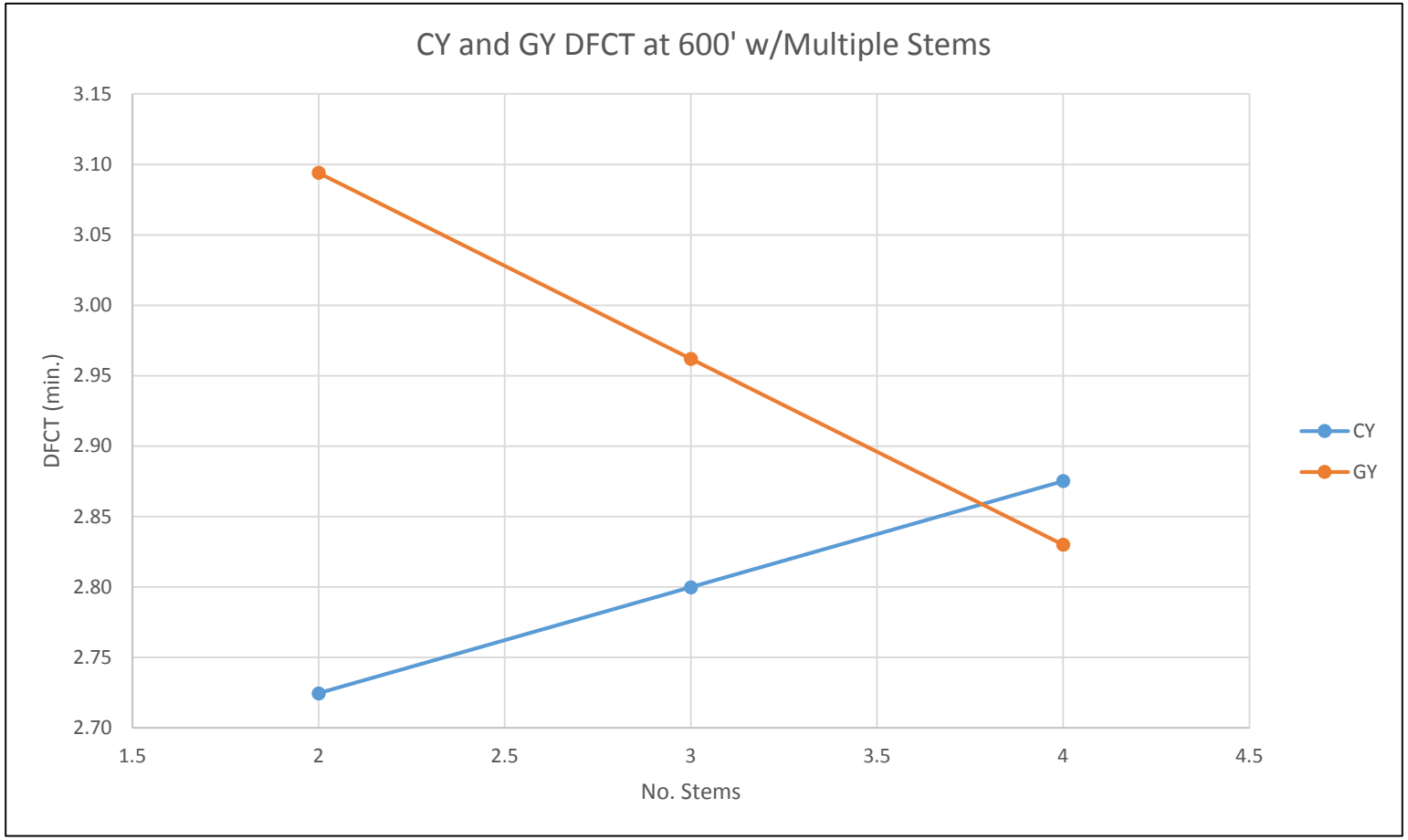
DFCT (min.) = 3.3581 - 0.132014*#Stems

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

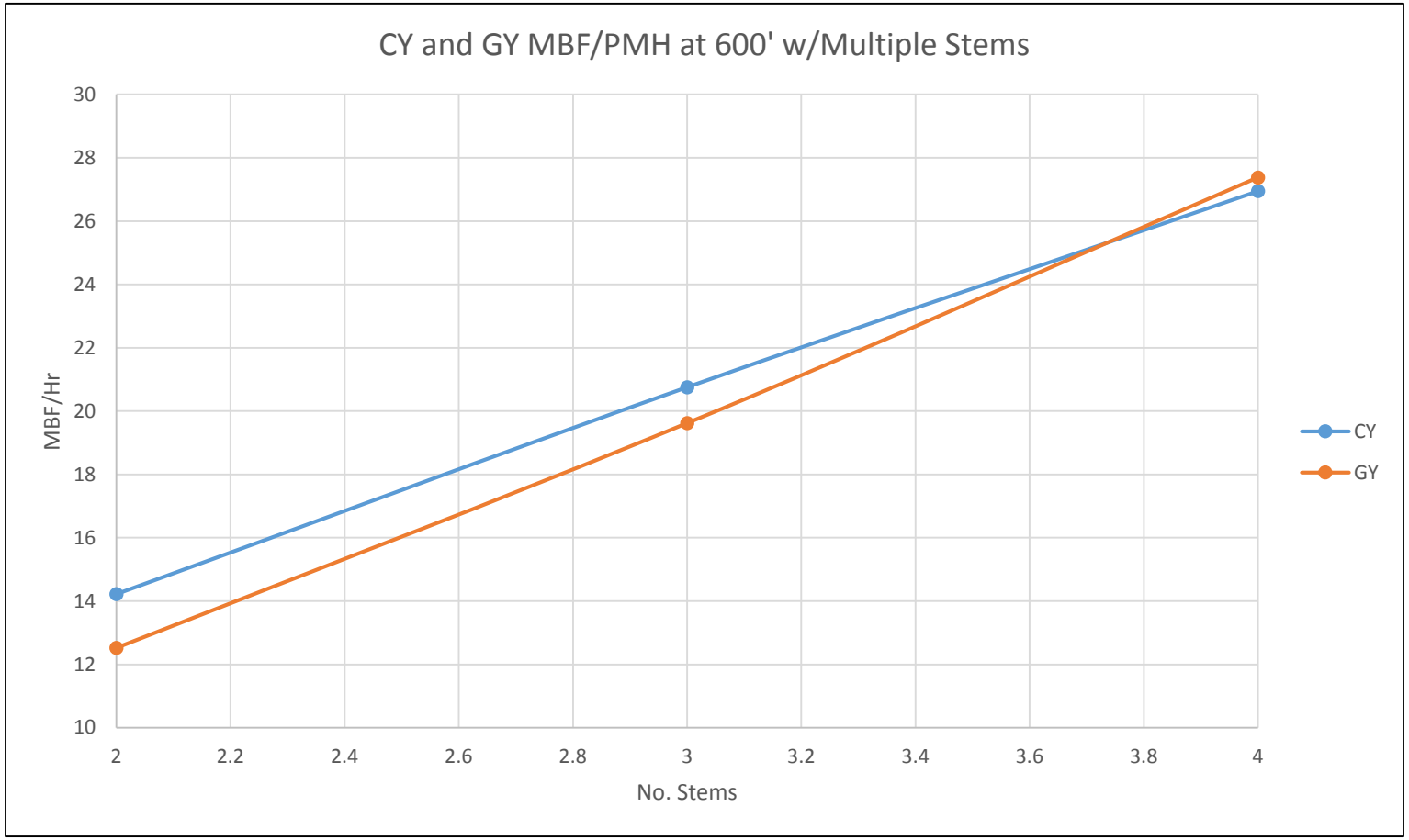
Cable Yarding vs. Grapple Yarding



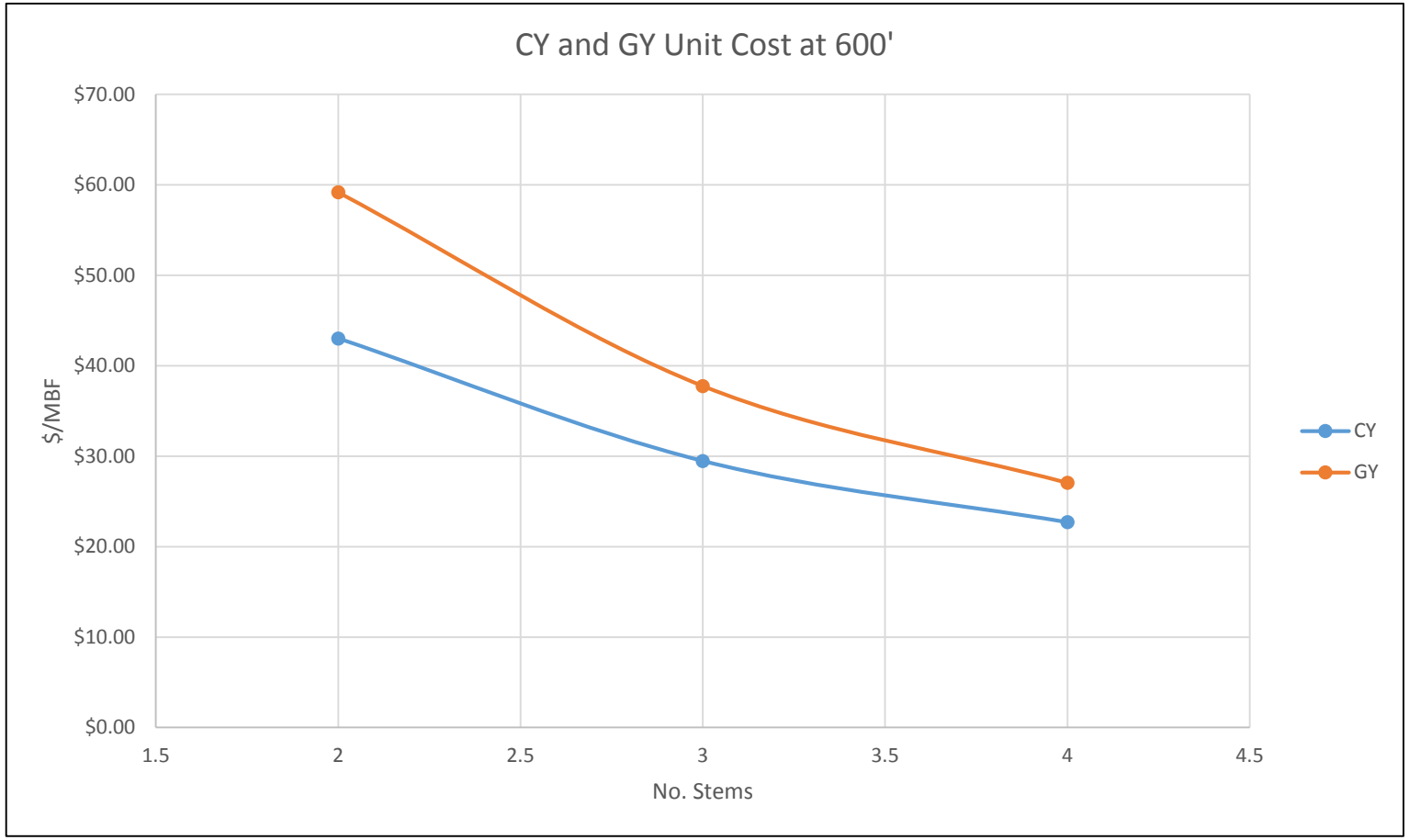
Productivity & Cost Comparison at 600’



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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