Predicting product performance: recent progress

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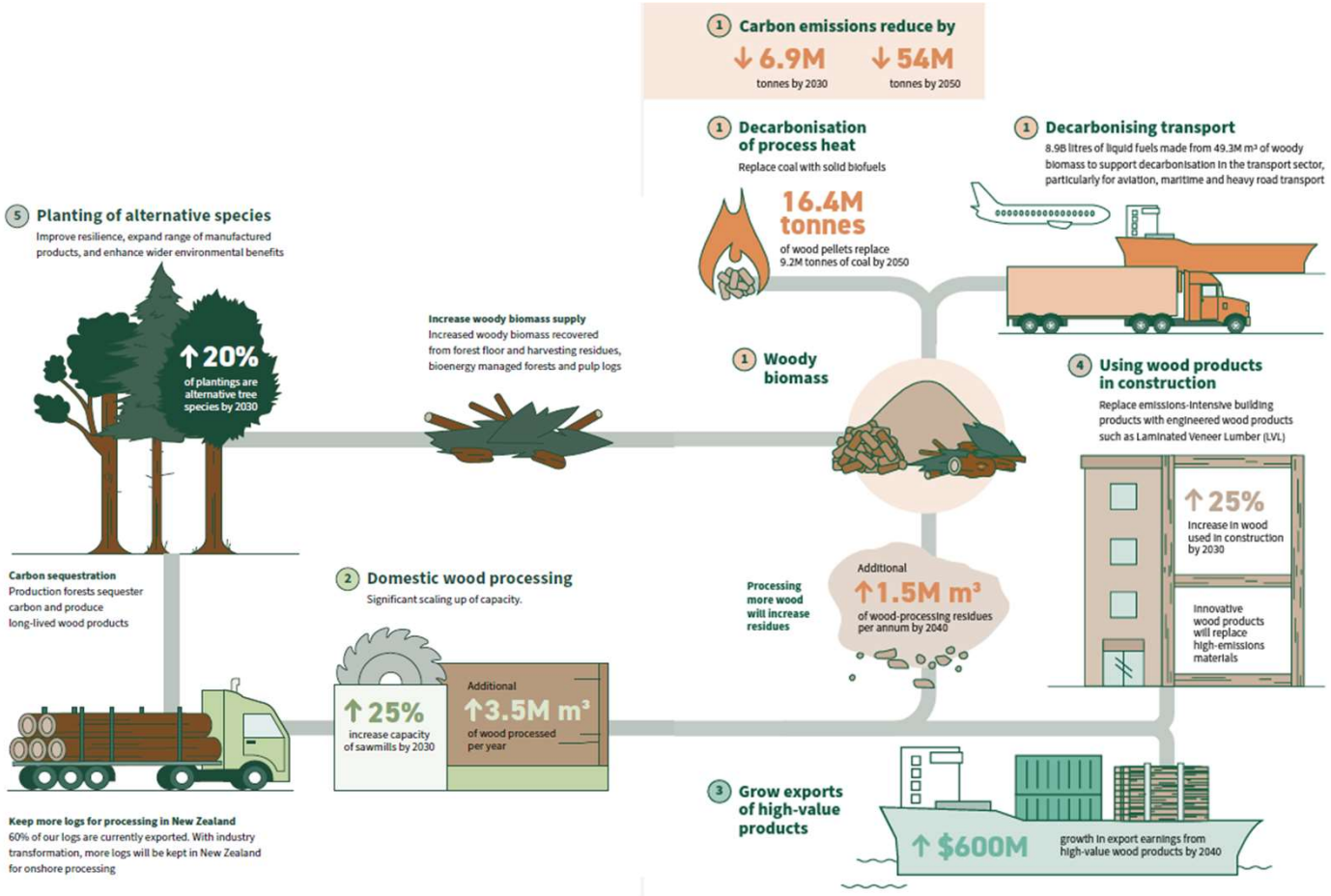
RESILIENT FORESTS
SCION
CONFERENCE 2023

FOREST GROWERS RESEARCH

Resilient Forests Research Programme

Change is eternal

- De-globalization
- Demographic shifts
- Climate change
- Onshore processing
- Automation

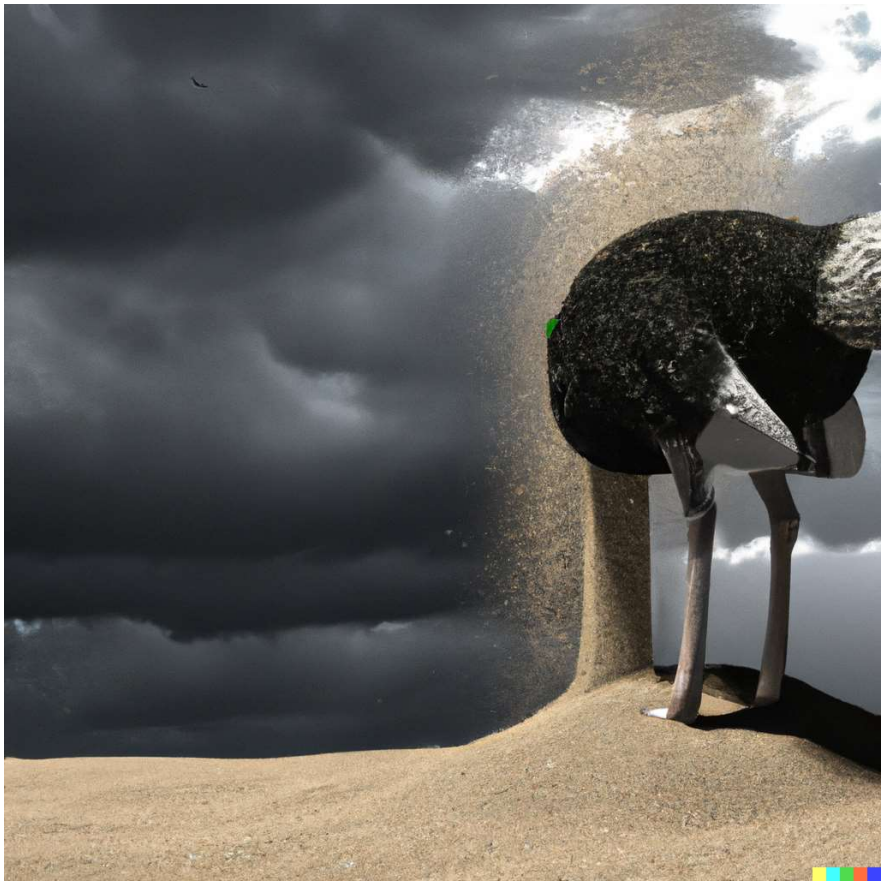


- Wider range of products
- More diverse feedstocks
- Reduced extraction costs
- Less waste

New things need doing – new things are risky

Do nothing approach

- KISS.
- Minimise overheads.
- Assuming no matter what you do there will be a (sufficiently) profitable outcome.



Risky business

- Who will want to work at whatever I need doing?
- How will I bring what I need in and transport what I make out?
- Will some bright spark in a different sector make my product obsolete?
- Will the vagaries of international finance tweak exchange rates in my favour or against?
- Will regulation overtake me? Domestically? Internationally?

All good questions, but not for today, sorry. However...

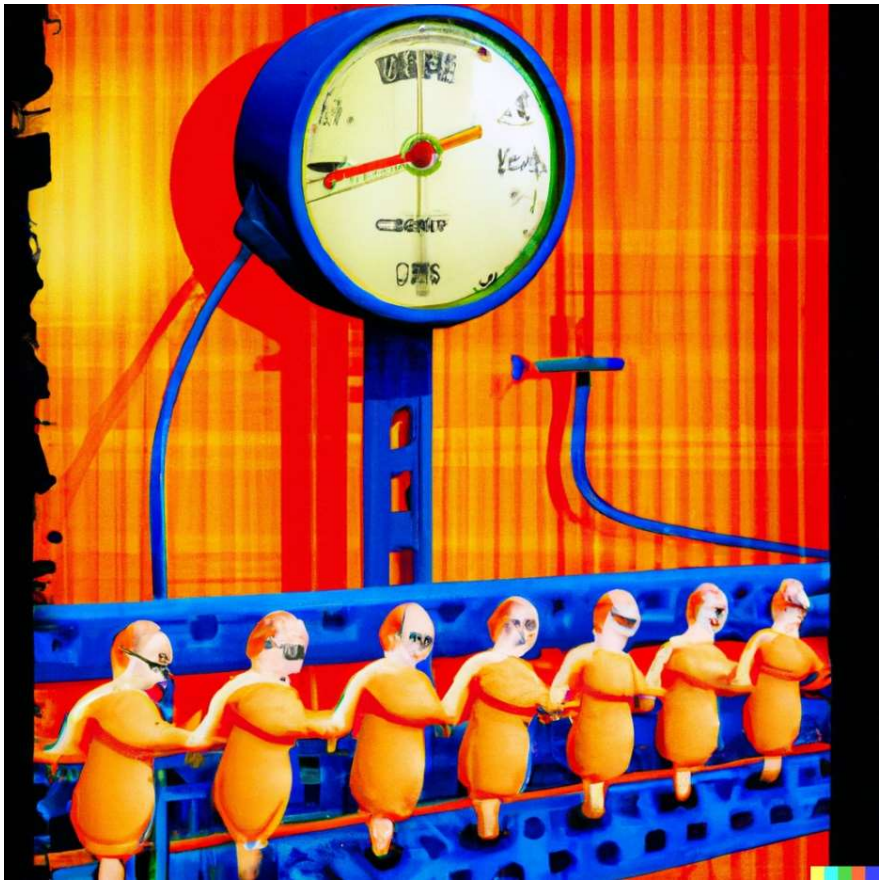
- **Will the products I make meet the needs of my customers?**

Opinion-based approach

- Expert opinion based on previous experience, knowledge, reasoning
  - Cheap & quick (per decision!).
  - Qualitative more than quantitative.
  - Experts in short supply.
  - Requires faith.

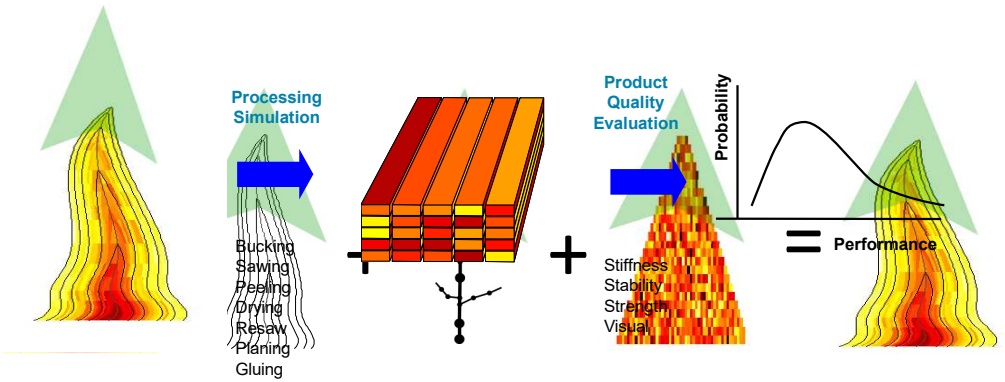
Empirical approach

- Empirical data
  - Try-and-see/Mill trials : if you have this, and do that, then you get this.
  - By far the most reliable if method if you're going to keep doing exactly what you've always done.
  - Difficult to extrapolate from directly.
  - Provides a basis for developing "expertise".



Simulation-based approach

- Simulation
  - Based around an explicit description (“digital twin”) of the product: tree, log, board, chip, veneer, etc.
    - Different levels of detail in description required for different products & processes.
  - Treat use whatever is known to constrain tree descriptions but otherwise operate on many random examples.
    - Coping with uncertainty baked-in.
  - Physical models for processes and performance evaluation.
  - Modular: the same components can be applied to diverse products, processes and performance metrics.



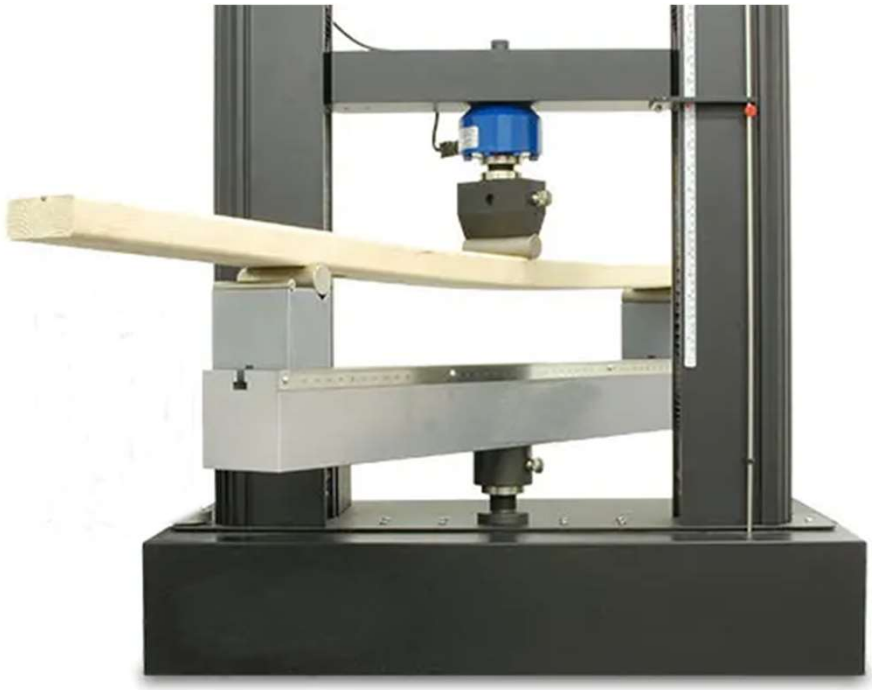
Simulation pros and cons

- Complex (but not complicated), non-traditional skill-set = high entry barrier.
  - Adoption by other industries means tools and skills increasingly available.
- Accuracy depends on analyst decisions and available data and effort.
- Flexible, can deal with novelty (silviculture, processing, products).
  - Applicable to future & green field operations, what-if studies.
- Less reliable than try-and-see.
- More effort required compared to expert opinion.
- Surrogate for (or a way to develop) expertise based on experience.
  - Great for helping to train ML.
- Expensive to develop, but
  - Costs can be shared by stakeholders all along the value chain.
  - Capability can be developed incrementally as value is demonstrated.

Stand level structural lumber stiffness prediction

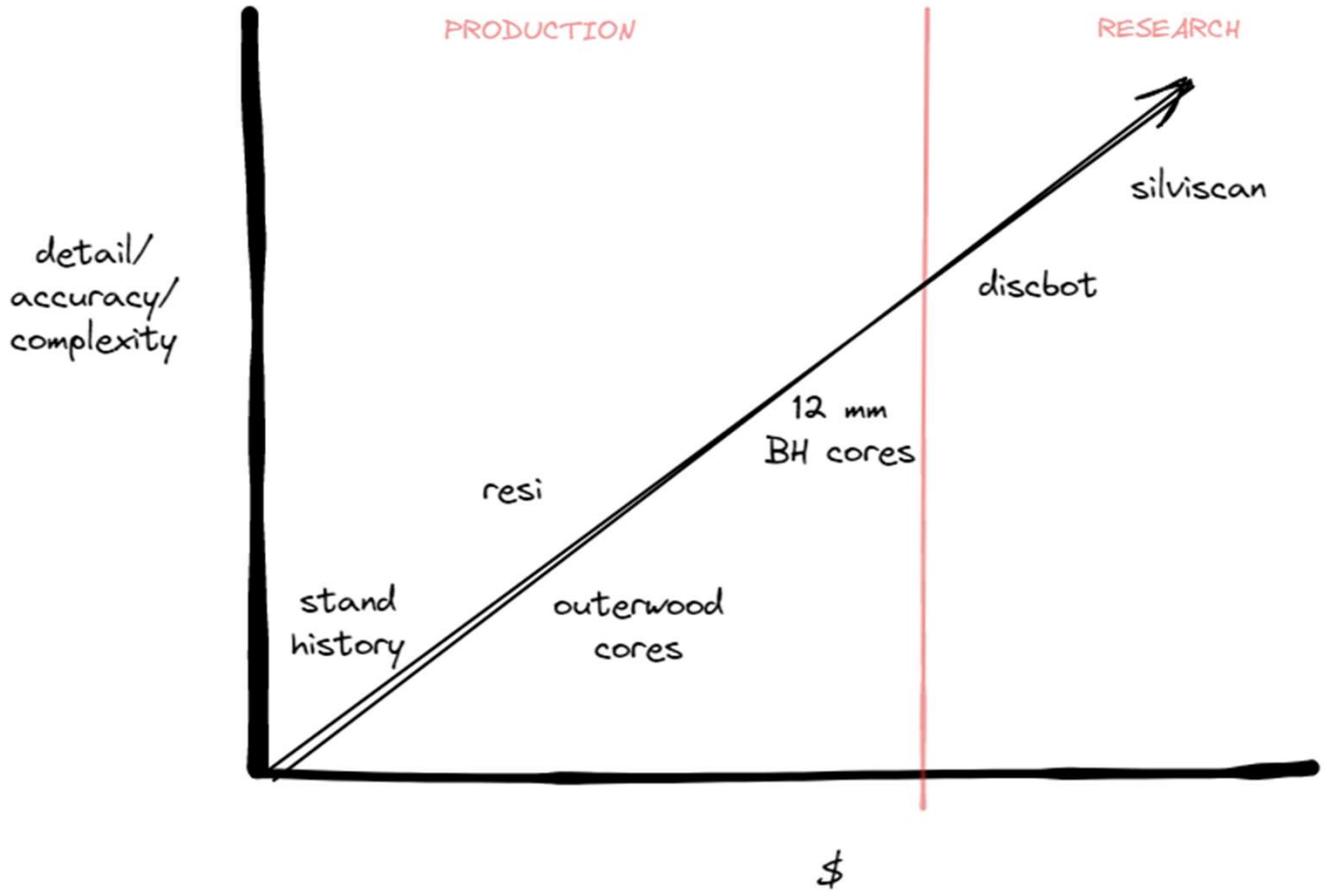
Stiffness, density, mfa, ...

- Wood stiffness along the grain (MoE) depends on
  - Basic density
  - Cell-wall microfibril orientation (“MFA”)
- Timber stiffness depends on
  - Wood stiffness
  - Grain angle
  - Knots, pith, etc
- Density, MFA, grain angle etc are ***variable***
  - Between trees
  - Within trees
- ***Variation*** is a result of **G**enotype x **E**nviroment x **S**ilviculture
- MoE tends to be controlled by
  - Density in older, outer wood
  - MFA in inner, core wood



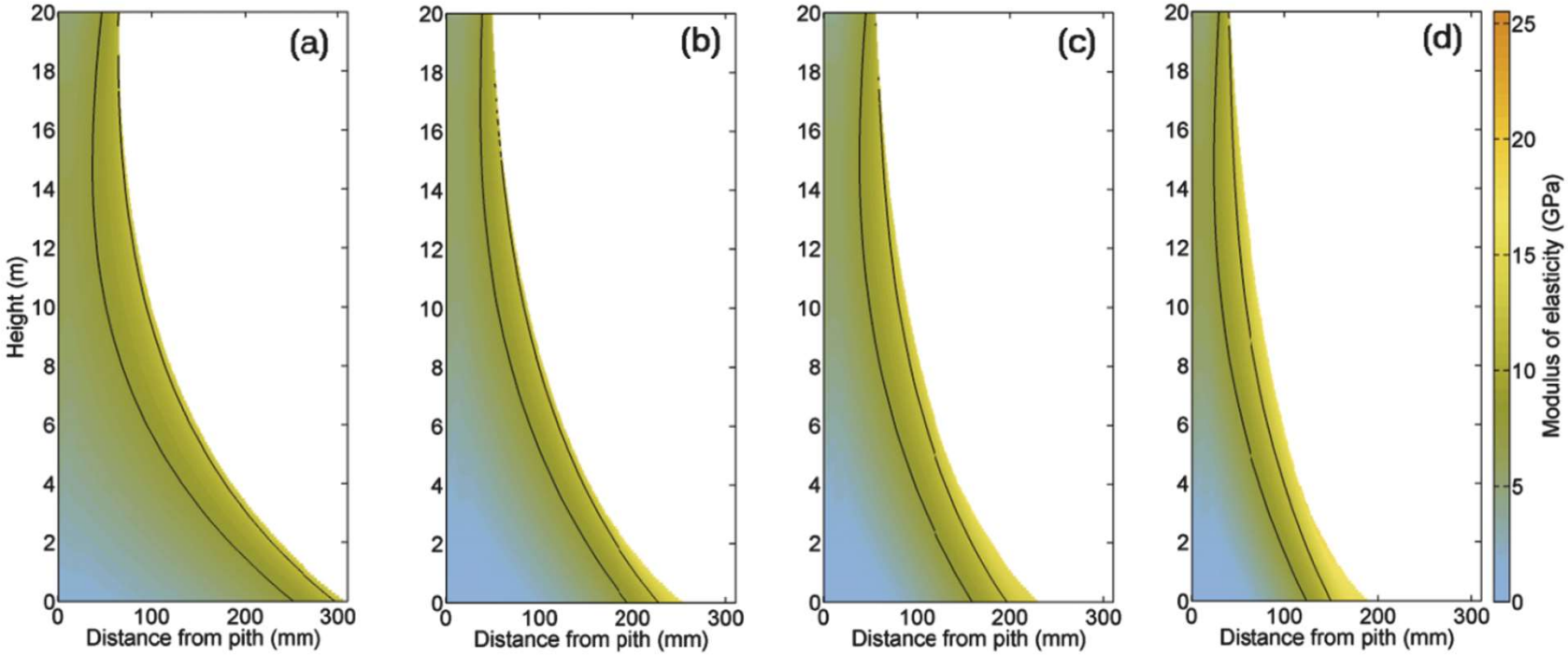
https://www.admet.com/testing-applications/testing-standards/iso-13910-timber-tests-of-structural-properties/

Data sources



Stand history

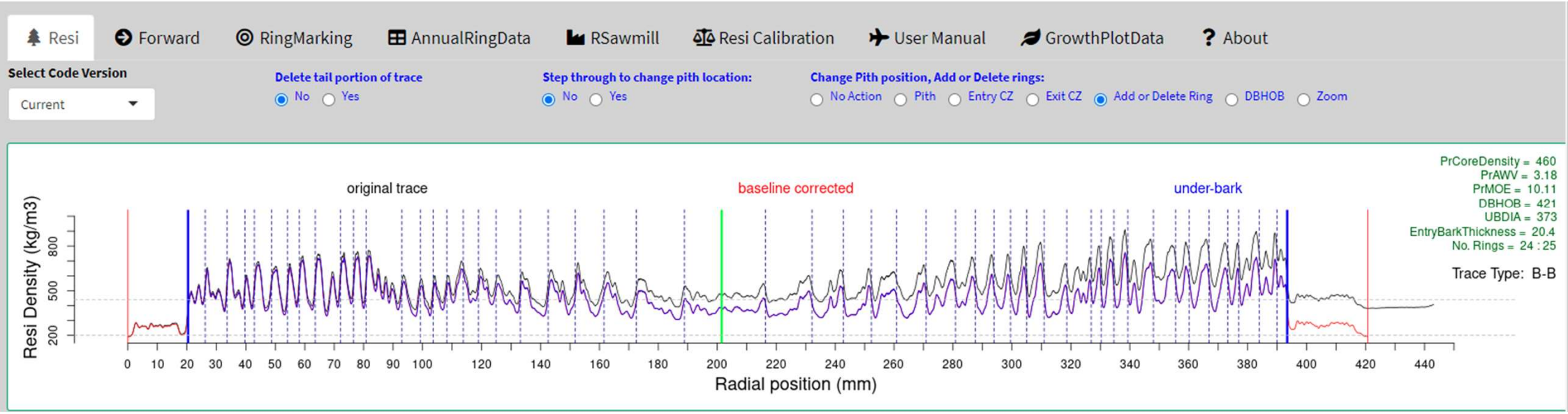
Fig. 5. Intratree patterns in MoE predicted by the model for trees growing at (*a*) 200, (*b*) 350, (*c*) 500, and (*d*) 1100 stems·ha^{-1} over the lower 20 m of the stem to a tree age of 21 years. The inner and outer black contour lines correspond to respective MoE values of 8 and 12 GPa. Note difference in units between *x* and *y* axes.



WattMichael S., ZoricBranislav, KimberleyMark O., and HarringtonJonathan. 2011. Influence of stocking on radial and longitudinal variation in modulus of elasticity, microfibril angle, and density in a 24-year-old Pinus radiata thinning trial. Canadian Journal of Forest Research. 41(7): 1422-1431. https://doi.org/10.1139/x11-070

Resi

https://www.iml-service.com/product/iml-powerdrill/

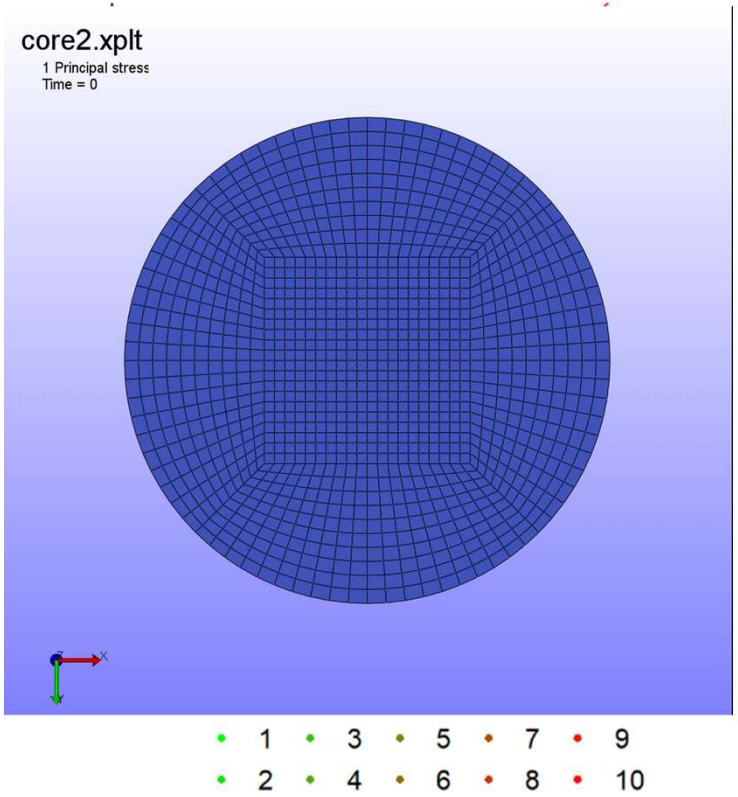


https://forestquality.shinyapps.io/FWPA-4 - geoff.downes@forestquality.com

Resi, MFA, USV

- Typically resi explains ~60% of variance MoE
- Resi predicts outer wood better than inner
- Why? can we do better?
- Yes resi sees density but misses MFA, ...
- How to measure MFA?
- It turns out that:

  Sound speed ~ MFA ~ specific stiffness
- Ultrasonic velocity (USV) is sound speed at high frequency
- Measured using time-of-flight
  - Same as ST300
  - Similar to hitman



Harrington, J, et. al. 2022. *Prediction of Green and Dry Board Properties from Pre-Harvest Inventory and Resi.* SWST 65th International Convention. Kingscliff, NSW, Australia.

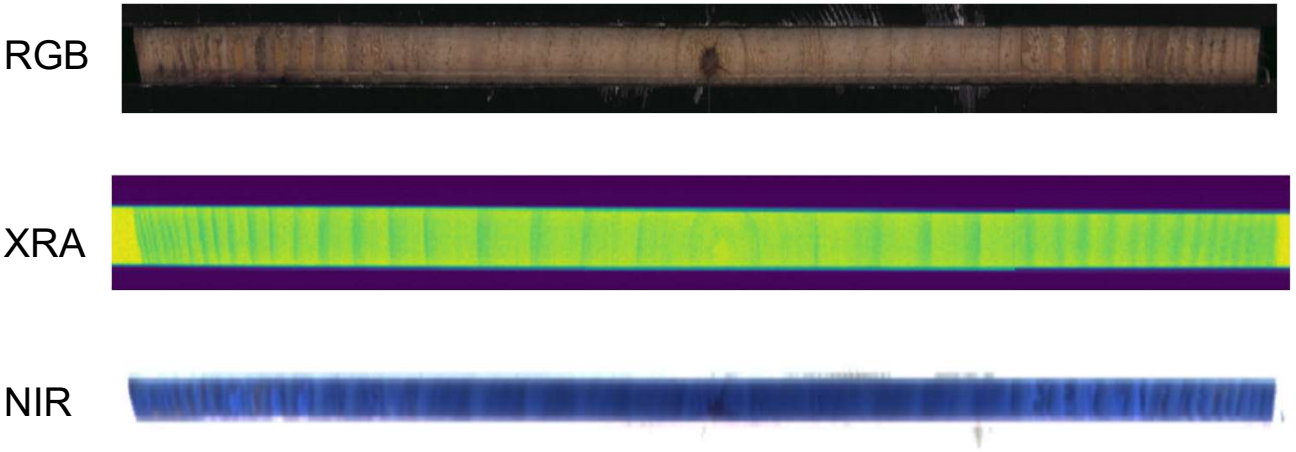
Pith-to-bark increment cores

- 10, 12, 16 mm diameter
- Typically collected
  - At breast height
  - From 10 to 100 trees/stand
- MoE prediction from density and USV demonstrated repeatedly
  - e.g. Weyco, Scion, UoC, ...
- Most recently in Southern Pines
- USV measured manually
- Density measured gravitmetrically
- 80% of variation in tree average MoE explained

Bailleres, H. et. al Improving returns from southern pine plantations through improved wood characterisation FWPRDC project number PNS361-1415 (2021) 78

Current corebot service

- Pulp screening tool
- Cheaper way to identify improved trees
- Leverage existing equipment
- Cores don’t require felling – well duh
- If MFA could be measured, then MoE could be predicted
- MFA can be estimated from USV
- So lets measure USV…

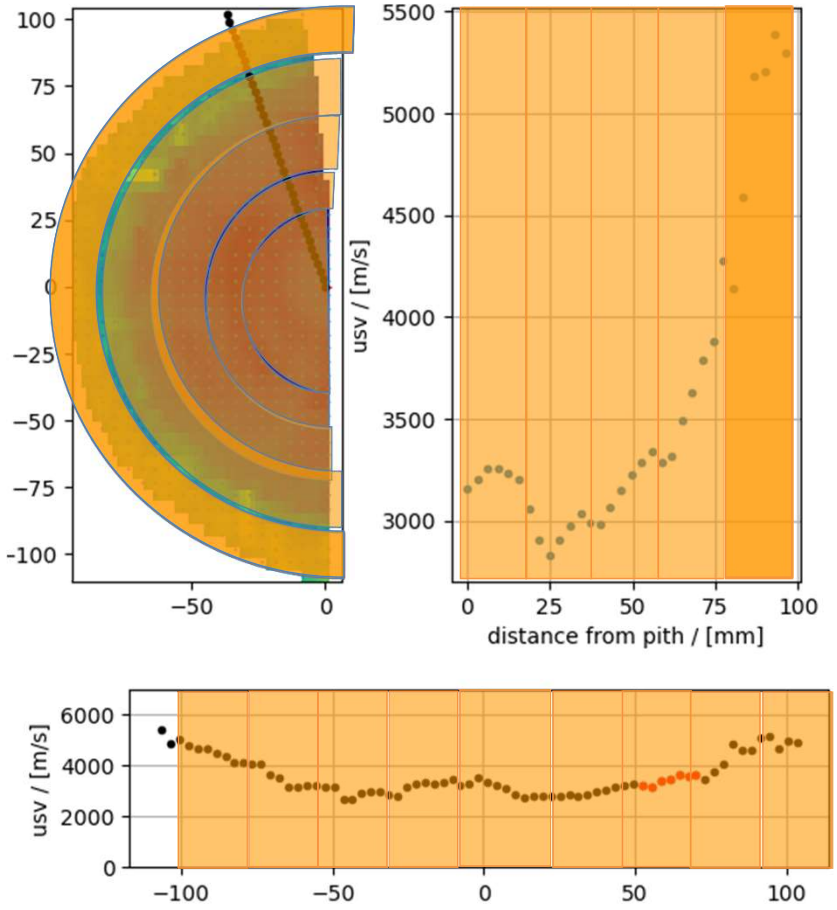


But...

- Cores are irregular
- Current core holder allows sound to sneak around the outside of the core
- Transducers optimized for 25 mm thick flat discs *not* 12 mm round cores
  - Rolling transducers
  - Low frequency
- High tech work-around to support cores
- Reprogram robot to step not roll
- Good enough to permit practical testing

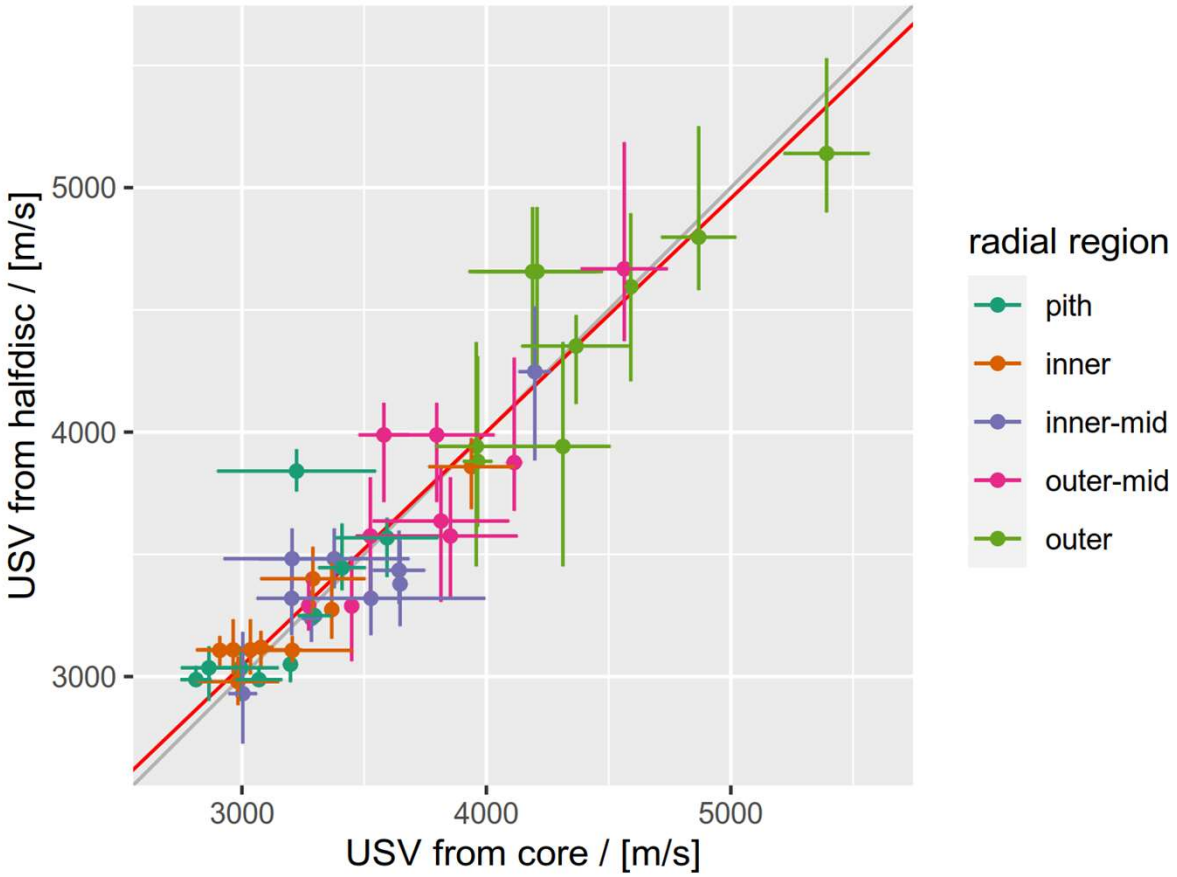
Test method

- Halfdiscs and cores from 7 trees
- Cores and halfdiscs from similar heights but no orientation info
- Partition disc USV results into 5 zones from pith to bark
- Partition core USV similarly
- Compare disc and core results



Test results

- Error bars include both measurement error and spatial variation
- USV from cores and discs differ by ~0.2 km/s
- Equates to an MoE difference of ~0.5 GPa
- Good enough to separate high and low stiffness stands from the rest
- Next steps
  - Beta-testing with client – each core has to be scanned twice
  - Investigating support solutions to get all sensors in one scan



Takeaways

- A changing world needs imaginative solutions
- The more imaginative the solution, the more benefit from *a priori* evaluation
- Product performance prediction has a role
  - Risk mitigation
  - Encourage investment
- Performance prediction via data-driven simulation is
  - Feasible
  - Flexible
  - Coming along nicely
- Want to know how profitably your forest might be processed in a structual mill?

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