Mechanised harvesting: a site perspective

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Introduction

- Mechanisation of plantation operations has, and will continue to increase, in SA.

- Mechanised operations in plantations lead to:
  - Soil compaction.
  - Soil disturbance.
  - Redistribution of surface plant residues.
  - Stump damage.

⇒ **Implications for soil environment and the growth of future rotations.**

- Resistance and recovery of soils dependent on:
  - Soil and site properties.
  - Magnitude of effect – characteristics of operation.
  - Ameliorative practices.

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Consequences of compaction

- Increased soil strength:

  → reduced ability of roots to penetrate soil.

  → lowered soil volume available for root exploration.

- Effect on soil water retention → generally decreases plant available water; exception: moderate compaction on sandy soils.

- Increased erosion risk.

- Decreased nutrient uptake due to reduced rooting volume and soil water.

- International literature points to differences in genus response to compaction: *Pinus* vs *Eucalyptus* vs *Acacia*?

- Variable effect on tree growth – site dependent.

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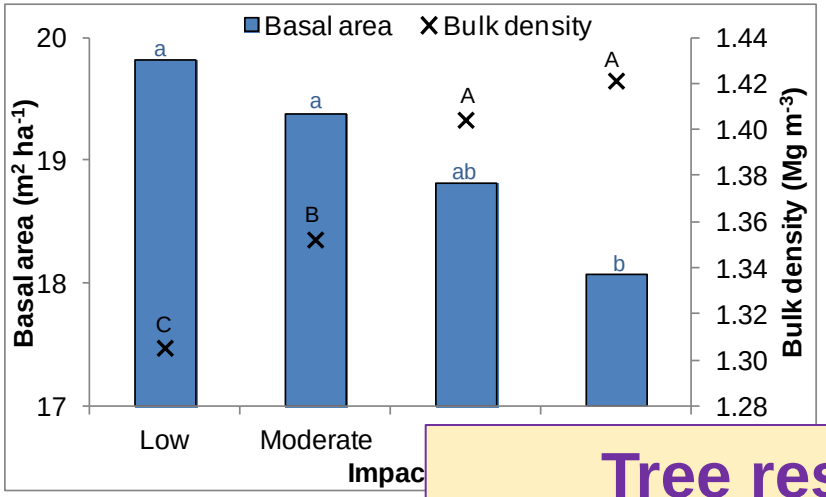
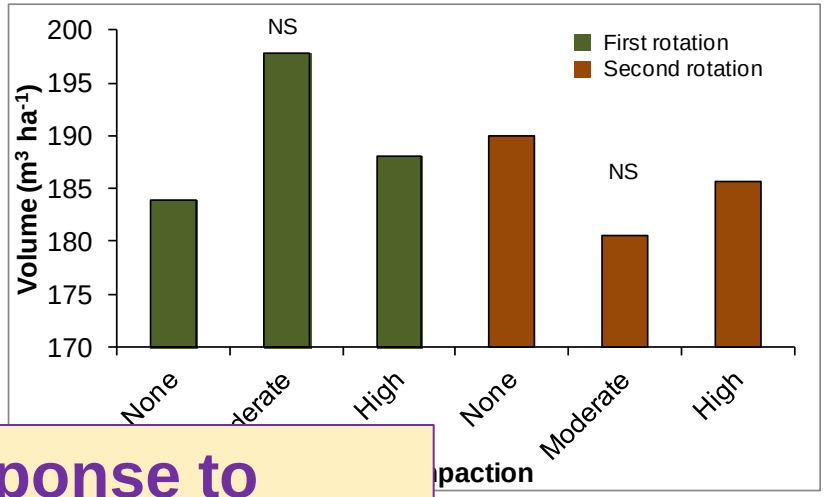
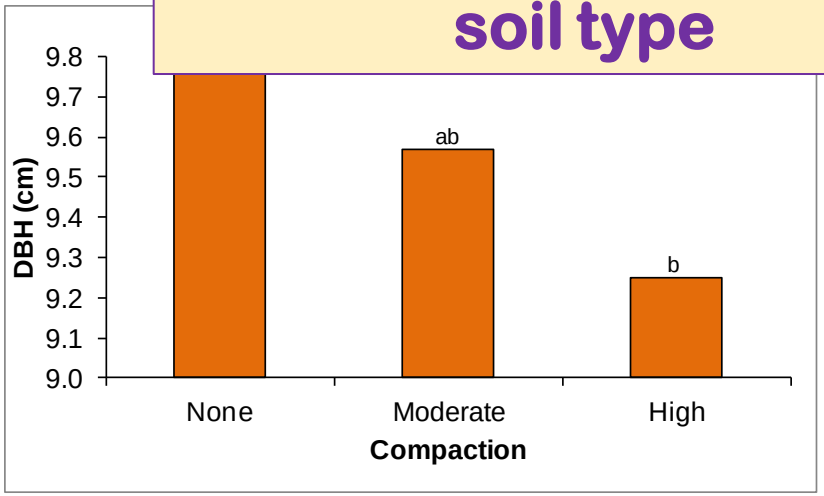
Consequences of compaction





P. patula (5.7 years old) – ears old) – Recent
Sandy clay loam soil il

Tree response to compaction dependent on soil type



E. grandis (2.5 years old)
Dolerite/Shale
Clay soil

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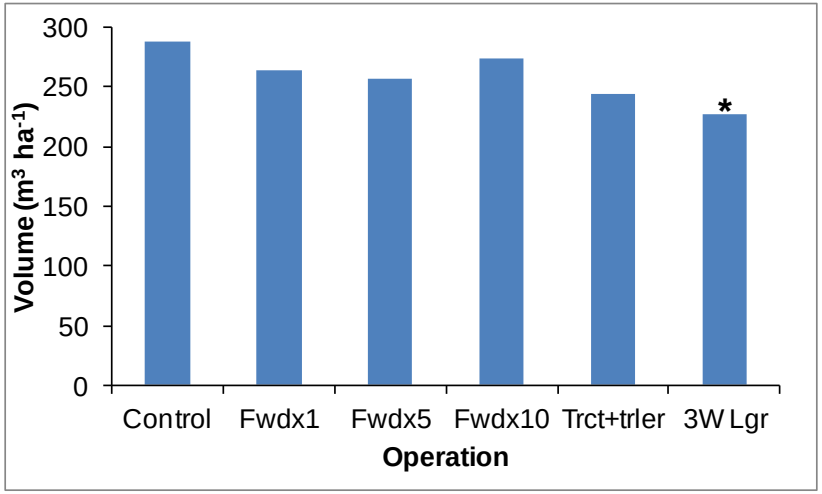
Consequences of disturbance

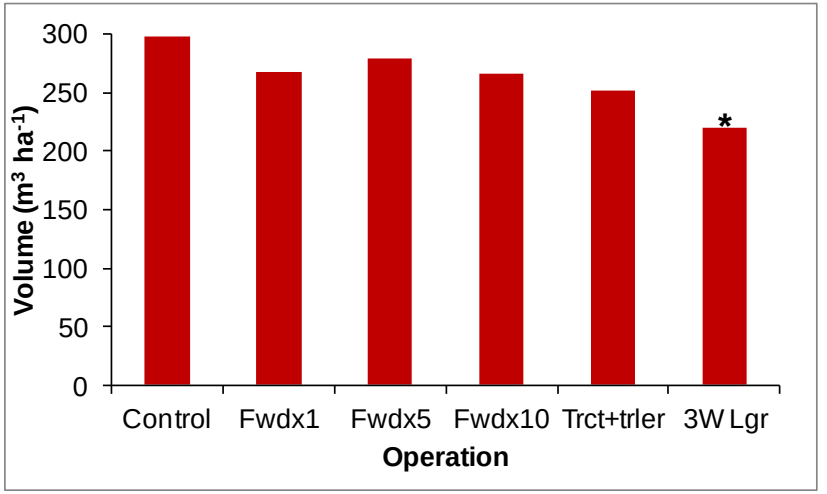
- Affects organic matter dynamics → adverse/beneficial effect on soil nutrient availability and soil organic matter content.

- Example: Rotation-end productivity of *E. grandis* on a dolerite/shale derived soil (clay soil - Shafton‡) and a dwyka tillite derived soil (loam/ clay loam soil - Highflats‡).

Shafton



Highflats



*** Indicates treatment is significantly different from control treatment ($p < 0.05$).**

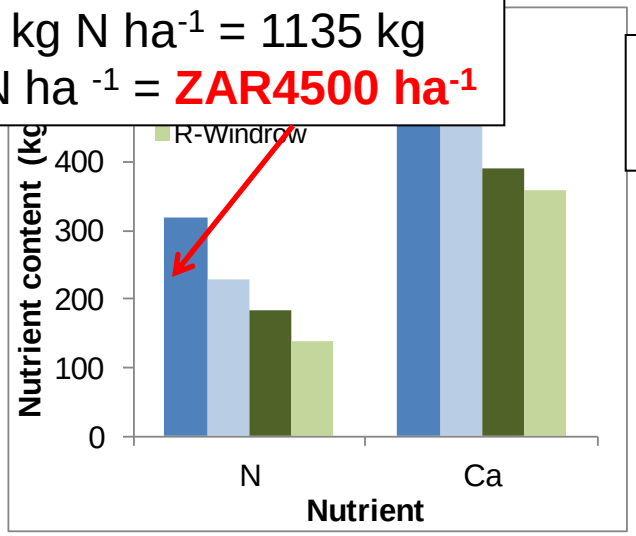
‡ Smith, CW. 2006. ICFR Bulletin Series 15/2006

Consequences of residue redistribution

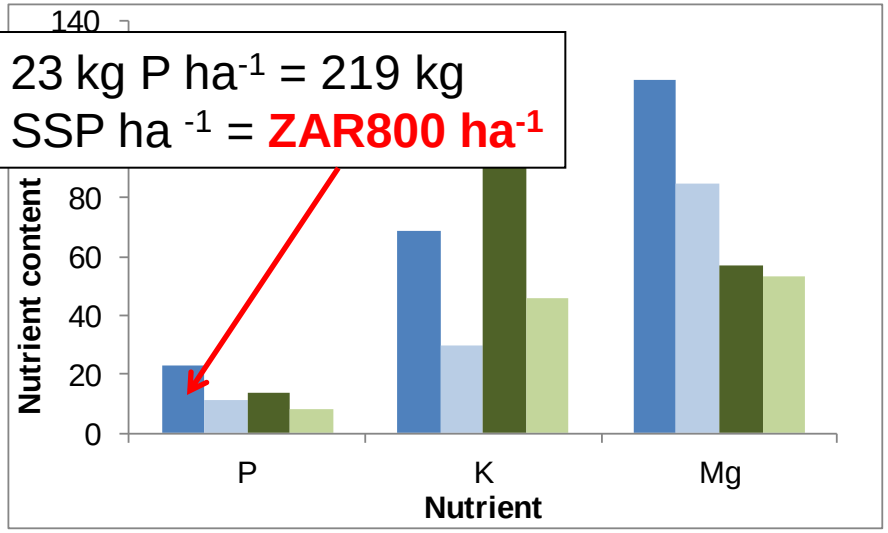
- Mixing of residues into top soil → organic matter and nutrient dynamics.
- Nutrient distribution across the site.
- Soil water and temperature.
- Removal increases erosion risk.
- Large influence on harvest residue management.
- Example: Two sites:

  E. grandis harvest residues sampled 9 months after felling (S).
  E. grandis x *camaldulensis* harvest residues sampled 2 weeks after felling (R).
  Both sites residues were either broadcast, windrowed, or removed (swept off site).

318 kg N ha^{-1} = 1135 kg
LAN ha $^{-1}$ = **ZAR4500 ha^{-1}**



23 kg P ha^{-1} = 219 kg
SSP ha $^{-1}$ = **ZAR800 ha^{-1}**



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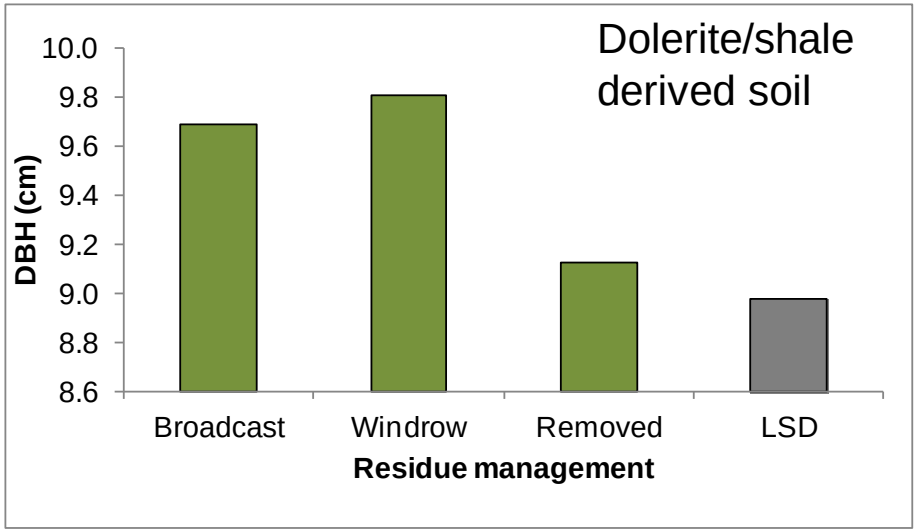
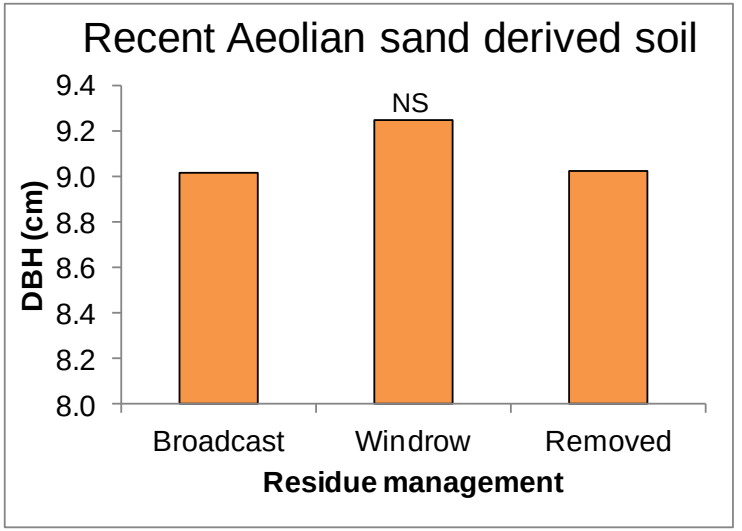
Consequences of residue redistribution

E. grandis - 2.5 years old



Significant negative effect of residue management on tree growth from 12 months of age



Responses are site dependent.

NOTE: Early results – may not indicate long-term effects over several rotations

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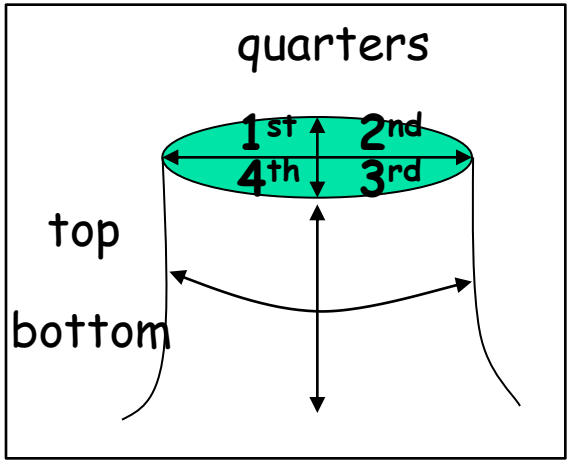
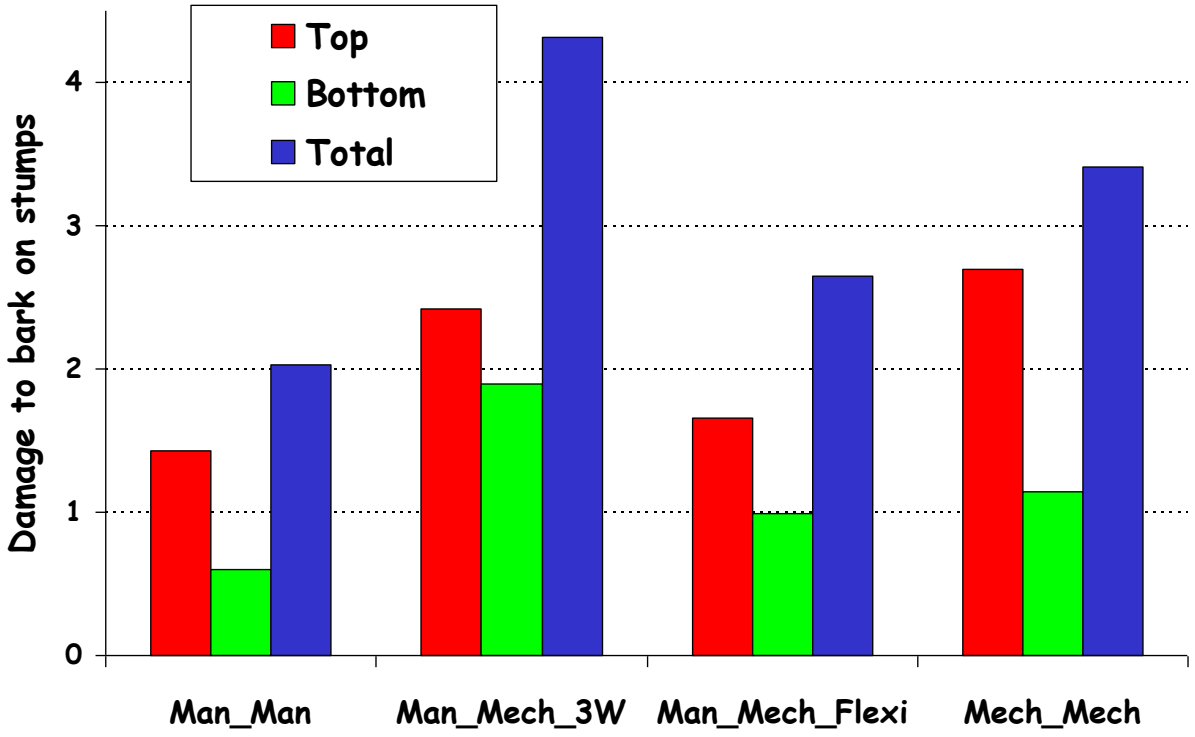
Stump damage - coppice

Little, KM. 2010





High bark separation = reduced budding for coppice. Occurs in mechanised operations both during felli and extraction.

Felling:	manual	manual	manual	mechanical
Debarking:	manual	mechanical (3W)	mechanical	mechanical
Cross-cutting:	manual	manual	manual	mechanical
Stacking:	manual	manual	manual	mechanical
Loading+ Extraction:	3W logger + tractor&trailer	3W logger + tractor&trailer	Flexiloader + tractor&trailer	Flexiloader + forwarder

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Site resistance and recovery

- Soil and site properties (self-amelioration by sites).
- Magnitude of effect – characteristics of operation.
- Ameliorative practices.

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Soil properties affecting resistance and recovery

- Soil uniformity:
  - Uniform = compaction transmitted deeply.
  - Layered = compaction concentrated above hardpan.
- Soil texture:
  - Sandy clay loam and finer – compaction and erosion risk.
  - Implications for traction and flotation.
- Clay type and quantity (dependent on lithology).
  - Shrink-swell types (self-amelioration) not under commercial forestry in SA.
- Organic matter content:
  - Climate, soil type and organic matter input and dynamics.
- Soil moisture content – wet:
  - Increased susceptibility to compaction.
  - Implications for traction and flotation.
- Initial bulk density.
- Level of soil erosion.

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Site properties affecting resistance and recovery

- Topography – steep slopes result in greater traction required by ground–based machinery.
- Plant residues:
  - Vertical (within soil profile) residue distribution.
  - Horizontal (across site) residue distribution.

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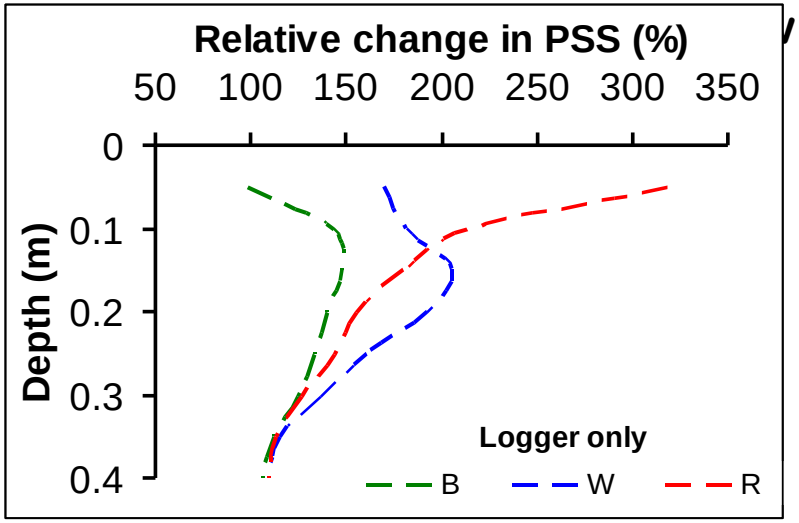
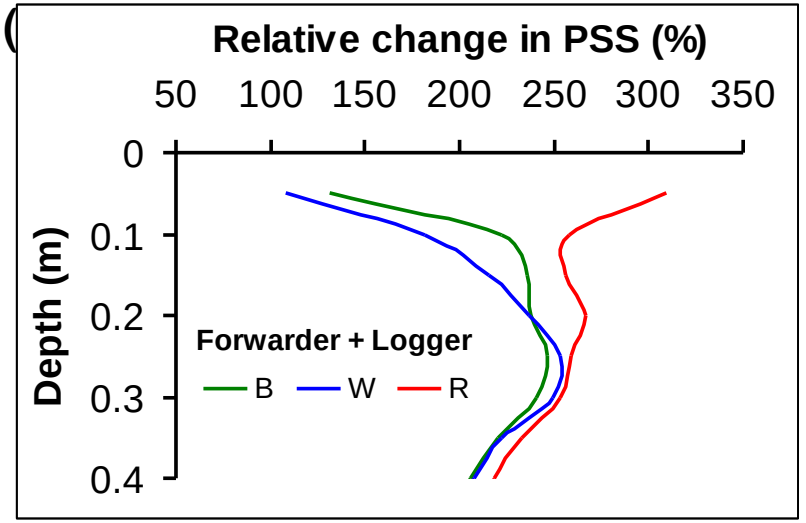
Residue retention effects on resistance and recovery

Example: Zululand, Aeolian sand lithology (sandy), *E G x C* harvest residues:





Similar results:
KZN Midlands, Dolerite/shale lithology (silty clay), *E. grandis* harvest residues:

Broadcast (62.0 t ha^{-1}) **Windrow (37.7 t ha^{-1})** **Removed (0 t ha^{-1})**

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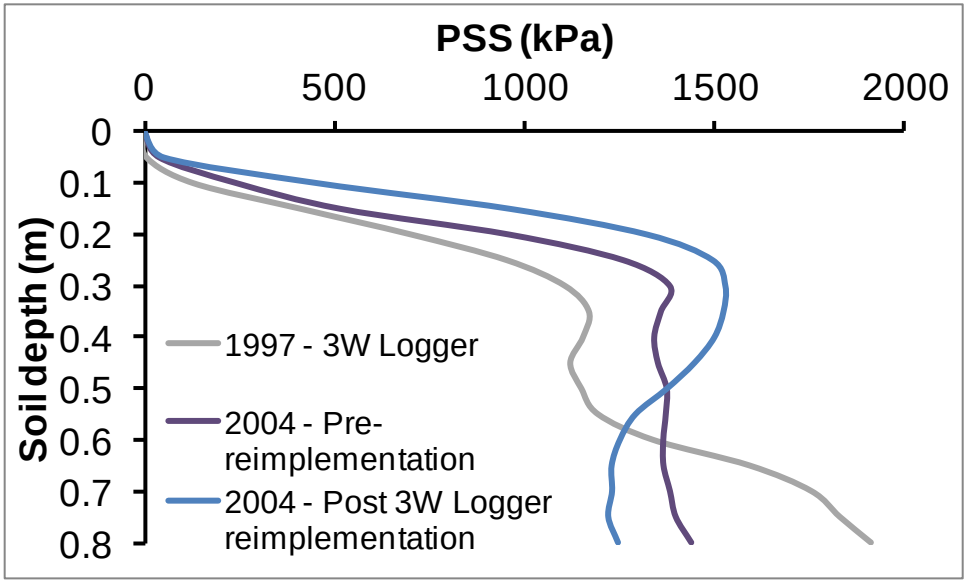
Site properties affecting resistance and recovery

- Freeze-thaw processes (self-amelioration) not present in SA.

No self – amelioration of compaction → Effects are cumulative.



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Magnitude of effect – characteristics of operation

- **Tyre design: Bias > Tracks ≥ Radial**
  - **Tracks: better floatation and trafficability; cause less compaction when tyre pressure is high (i.e. using bias tyres), BUT cause greater compaction when tyre pressure is low (i.e. using radial tyres).***
  - **Tracks better on wet/loose soils or steep sites and less overall ground disturbance (churning and rutting).**
  - **Tracks problematic on sites requiring manoeverability.**
- **Surface soil compaction related to ground contact pressure only.**
  - **Tyre size: larger tyre = lower psi.**
  - **Tyre inflation: over inflated (directly related to compaction) versus under inflated (rolling resistance).**
- **Wheel alignment – front and rear wheels and horse and trailer.**
- **Vibration.**

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* Cavers, C. Preventing and dealing with soil compaction – a toolbox approach. http://umanitoba.ca/afs/agronomists_conf/Proceedings/2010/Curtis_Cavers.pdf

Characteristics of operation cont.

Machinery mass (+ load):

- Directly related to depth and severity of compaction.
- Upper sub-soil compaction related to ground contact pressure AND axle load.
  - Axle loads < 10 t surface compaction (top 20 cm); > 10 t compaction as deep as 1m → Increase axles.
- Large machines – less traffic?
  - Up to 80 % of compaction by a machine occurs in the first pass → Less passes.
- Uncontrolled traffic:
  - Greater area compacted.
  - Soil not compacted = less traction and flotation → GPS technology.
- De-limbing and debarking:
  - At stump/deck/other area in compartment/mill – affects residue distribution (nutrients, organic matter, residue management, machine impact) and stump damage.
- Machinery movement:
  - Mixing of residues into soil.

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Amelioration

- Well timed non-inversion deep-tillage (subsoiling or deep ripping).
  - Knowledge of depth of compacted layer necessary - till to just below that - avoid creating a tillage hardpan.
  - Perform when soil is dry as possible - shatter rather than smear.
  - Only apply on areas in-field requiring this - GPS.
  - Harvest residues – mulch or burn?
  - Problematic as can require heavy machinery with high horsepower.
  - Sub-soiling can bring rocks to surface (rocky soils).
- Increase organic matter input.
  - Harvest residues.
  - Import organic material in cases where sites would drastically benefit → implications for nutrient dynamics and costs.

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Conclusions

- **Mechanisation of operations will continue, and will increase.**

- **Cumulative effects of machinery on SA forestry soils.**
  → Need to prevent and ameliorate effects.
  → Identify sites most susceptible to damage by mechanised operations.

- **Impact of machinery on residues, and impact of residues on reduction of effects of machinery on sites needs to be considered.**

- **Costs of harvesting/timber extraction operations ≠ cost of the operation.**

  = cost of operation
  + cost of other operations required (e.g. planting vs coppicing)
  + cost of amelioration (if necessary; e.g. ripping, fertiliser)
  + cost of productivity change (+ve or –ve).

- **Development of site-friendly or "green" machines and operations.**

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Conclusions cont.

- Holistic approach necessary to ensure foresters needs are met while maintaining or improving productivity of plantations.

Collaboration necessary between foresters, engineers, forest and soil scientists to ensure mechanised operations are appropriate for the task required, while ensuring the least impact to future operations and the site as possible.

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