Reducing erosion risk with native plantings.

This is a summary of the references suppled at the end of the document.

Background

- Chris Phillips of Landcare Research has an amazing review on Biophysical performance of erosion and sediment control techniques in New Zealand. https://www.landcareresearch.co.nz/assets/Events/Remote-sensing/2022/RA1.2_Review_final_2020_LC3761.pdf
- And gave a great talk to landowners in North Nelson https://youtu.be/OWrBx95AL8I on slip prediction and mitigation

- NZ has young steep weak soils, and combined with high rainfall and high intensity rainstorms, are highly erodible and slips are common. Removing native trees on the landscape and human intervention has increased erosion.
- To reduce slip risk, you need firstly to control water runoff, reduce water velocity and sediment generation and then maximize the strength of the soil
- Slips occur when the soil fills up with water (reaches saturation level), reduces soil strength and soil becomes very heavy. Soil is much heavier on slopes due to gravity and also soils on slopes are often thinner and less strong.
- The size of rainfall event is a key driver of slips along with the soil moisture before the event.
- For example 200 mm of rain falling over a few hours on a ha is equivalent will increase the weight of the soil by 2000 tonnes.
- Trees on slope reduce slips by increasing slope stability and soil strength through root reinforcement. But they also intercept rain in the canopy, increase evapotranspiration (pump water out of waterlogged soils), reduce soil moisture, increase the porosity of the soil and reduce runoff.
- Soil is stronger in compression and weak in tension. Conversely roots are weak in compression and strong in tension. Roots also secrete a glue into the soil that helps improve soil stability. And together soil and roots form a matrix that is stronger than roots and soil individually. Like concrete and concrete reinforcing!

Reducing sediment flows into waterways

- If sediment is produced, trap it and prevent it entering the water way (wetlands, sediment traps, silt fences, buffer strips, earth bunds). Some of these solutions are structural and some are biological (plants).
- Chris Phillips summarized the effectiveness of various erosion methodologies for the control of erosion or sediment contamination from land landslides and gully erosion.
- Effectiveness through biophysical processes
  - Wetlands 60-80%
  - Sediment ponds 30-70%
  - Silt fences 99%; debris dams 80%
- Effectiveness through planting
  - Grass buffer strips 40%,
  - Cover crops 40%
  - Space willows and poplars planted trees 70-90%%
  - Afforestation or reversion 90%

Slip Risk modelling

- Some of the forestry companies have paid for slip risk modelling on their estate

- TDC is hopeful of getting funding for carrying out a slip risk assessment for the whole region. This should be available for properties. Hopefully we canal then see where trees should be planted in the catchment to reduce slips

Planting to reduce slip risk

- The lateral roots in the top surface of the soil provides a membrane type strength to the surface.
- Vertical roots also helps bond the soil to stable subsoils or bedrocks and across slip shear planes and large structural roots anchor the tree in the soil. And all these are very important in storm events.
- Plants on the stream bank reduce erosion in a combination of reducing the scouring effect of water and increasing stream bank strength.
- Plants within the flood plain can however reduce the volume for flood waters.

Tree planting is used for controlling gully erosion

Basic principles

- Bigger trees above ground also have bigger roots
- Faster growing trees will have faster growing roots
- It takes time for trees to grow big enough to be effective at mitigating slips, start now
- There tends to be a constant 20-30% root to above ground mass in trees.
- Gullies and tracks have the highest risk of slippage because this is where the water flows
- Root growth of trees is greatly affected by soil conditions, and this is also reflected in above ground growth. Root growth can be restricted by pans, low soil moisture, low fertility, poor drainage.
- Trees grow poorly on disturbed ground that has slipped.

To be effective in reducing slip risk plantings need to

- Work in conjunction with other methods to control water flow across the soil.
- Have time to be effective (10 years dense planting, 15 years space planting)
- Tree planting may include also fast-growing vegetation cover such as grasses or clovers to protect the soil to reduce the action of rain splash on the soil surface.
- Needs to have deep roots that bind over the shear plane of the soil
- Roots need to occupy a big space in the soil and interlock
- But planting can increase the slip risk by adding weight to the slopes (poplars normally planted on edge of gullies, not in them) and by increasing cracking and therefore increasing water infiltration
- The ability of a plant's root system to reduce slips is based on its area of roots, distribution of roots, root depth, root spread, root: shoot ratio and root strength.
- For good erosion control plants need good root depth for anchoring and good lateral growth for overlapping and shallow fine roots for strong surface matt for hydraulic protection. In addition, you need lots of roots occupying a big volume and strong roots. You want a combination of deep and lateral roots and strong roots.
- Generally exotic trees in NZ outperform native trees in all of these measures.

Exotic trees

Poplar and willow poles

- Space planting with trees (non-native) on pastoral land started around 1930's largely with willows and poplars and this continues today particularly in gully's and along riverbanks.
- Poles are used so stock continue to graze the area while the trees grow. It is assumed that surviving poles are effective over 8-15 m spacing.
- Over plant to compensate for death rates. It is important that the roots intermesh.
- Poplars have a bigger lateral root spread than other trees and get them much more quickly

- Lateral roots in poplars are greater than 14 m in 7-year-old trees and achieve 8 meters after 9 months but still most of the roots are in the top 0.5 m.
- Poplar and Willow have much greater total root length than other species. Below is after 2 years at a highly favourable growth site.

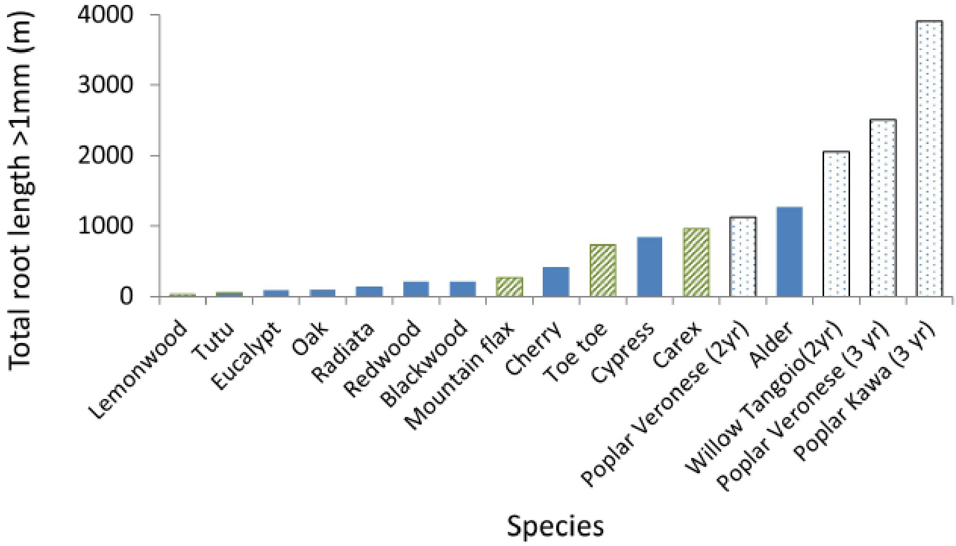


FIGURE 5: Total root length (roots > 1 mm diameter) from Philips et al. (2015 – Figure 9) trial (solid blue bars) compared with existing 3-year-old data from other species trialled at the same site. Mean values except for toe toe, carex, alder, poplar, and willow. Indigenous species (green diagonal shading - Marden et al. 2005). Poplars (V = 'Veronese';K = 'Kawa') and willow (lightly stippled bars – C. Phillips unpublished data). * = 2-year-old data.

FIGURE 4: Poplar 'Kawa' root development 3 years after establishment from a pole grown in a trial near Gisborne (Phillips et al. 2014) (Photo: C. Phillips)

Pine trees

- Like other trees at 8 years old most of the roots are in the top 40 cm of soil.
- After 5-7 years pine trees shift from their shallow root system to putting down vertical sinker roots that go down several meters.

- Laterals after 25 years can extend out 3 meters and vertically laterals extend down to 3 m Plantation forests have many intermingling roots. Redwood coppice after felling and their roots stay alive.
- Pine at comparable planting densities as manuka grow roots at twice the speed as manuka.
- Slips still occur in native stands or old pine (8%) but this is compared to 40% in pasture (Manawatu).
- After trees are harvested the roots die and begin to lose their strength. Pine trees after harvest lose half their strength with 15 months and they are largely decayed after 3 years.
- Native and hardwood exotics will decay more slowly after clear felling.
- Based on post storm event landscape full canopy old native and pine forest older than 8 8 years is the most effective landcover at preventing slips
- Wind throw is also an indicator of the strength of the tree roots Pine seedlings grown from cuttings are less likely to blow over than those grown from seedlings and cuttings can have a 1.5 x more root:shoot ratio and 6 times more vertical roots. I couldn't find any such information on native plants.
- At 2 years toppling incidence was 86% for seedlings and 10% for cuttings. It is also known that careless planting leads to deformed roots and tree toppling. It is important roots are straight when planted.
- Direct seeded pine has less wind throw.

Redwoods

- Redwoods have lots of fine roots and similar but slightly total root length as pine over 1-4 years but have more fine roots in the top 50 cm of soil.
- Redwoods from different trees can graft their roots together
- Redwoods coppice after felling and their roots stay alive the root mass does drop back especially if clear felled
- Redwoods need favourable growing conditions.

Native plants.

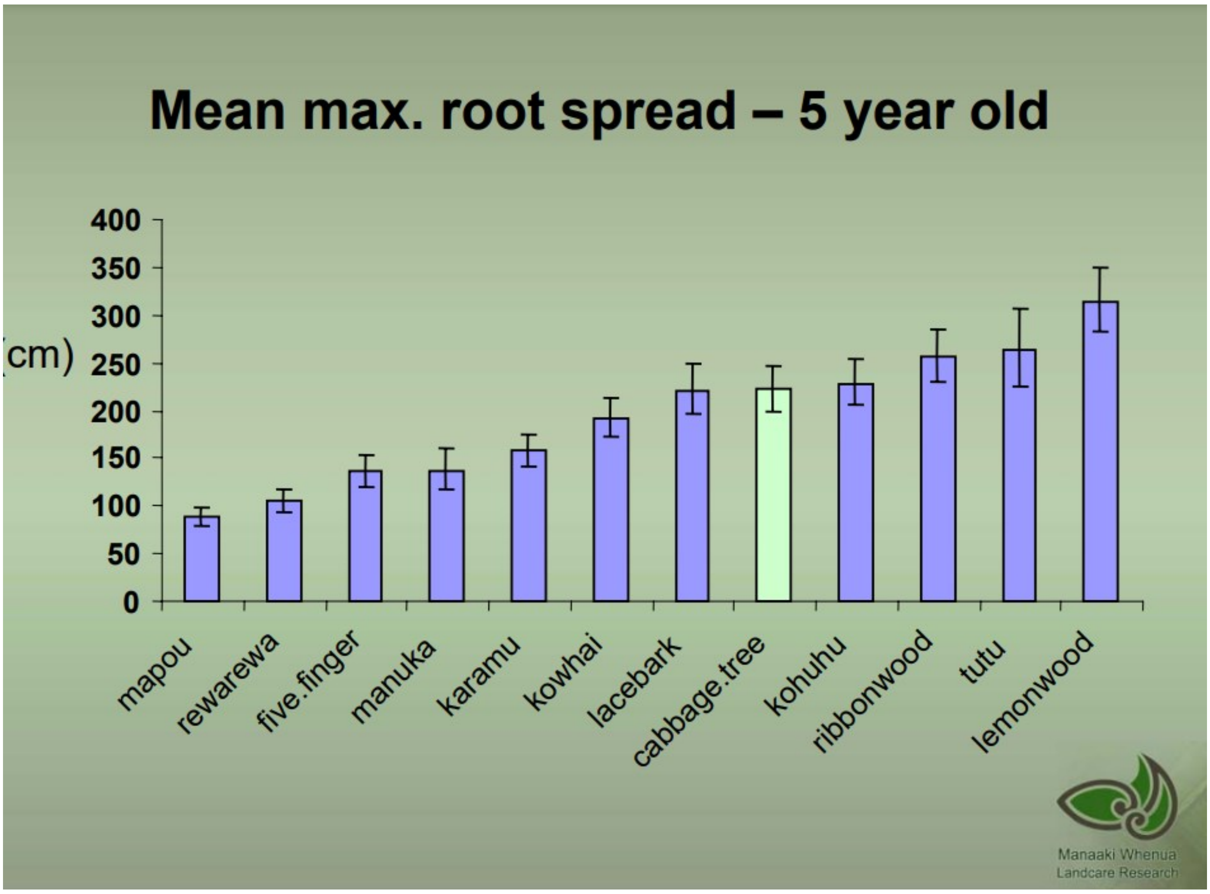
Background

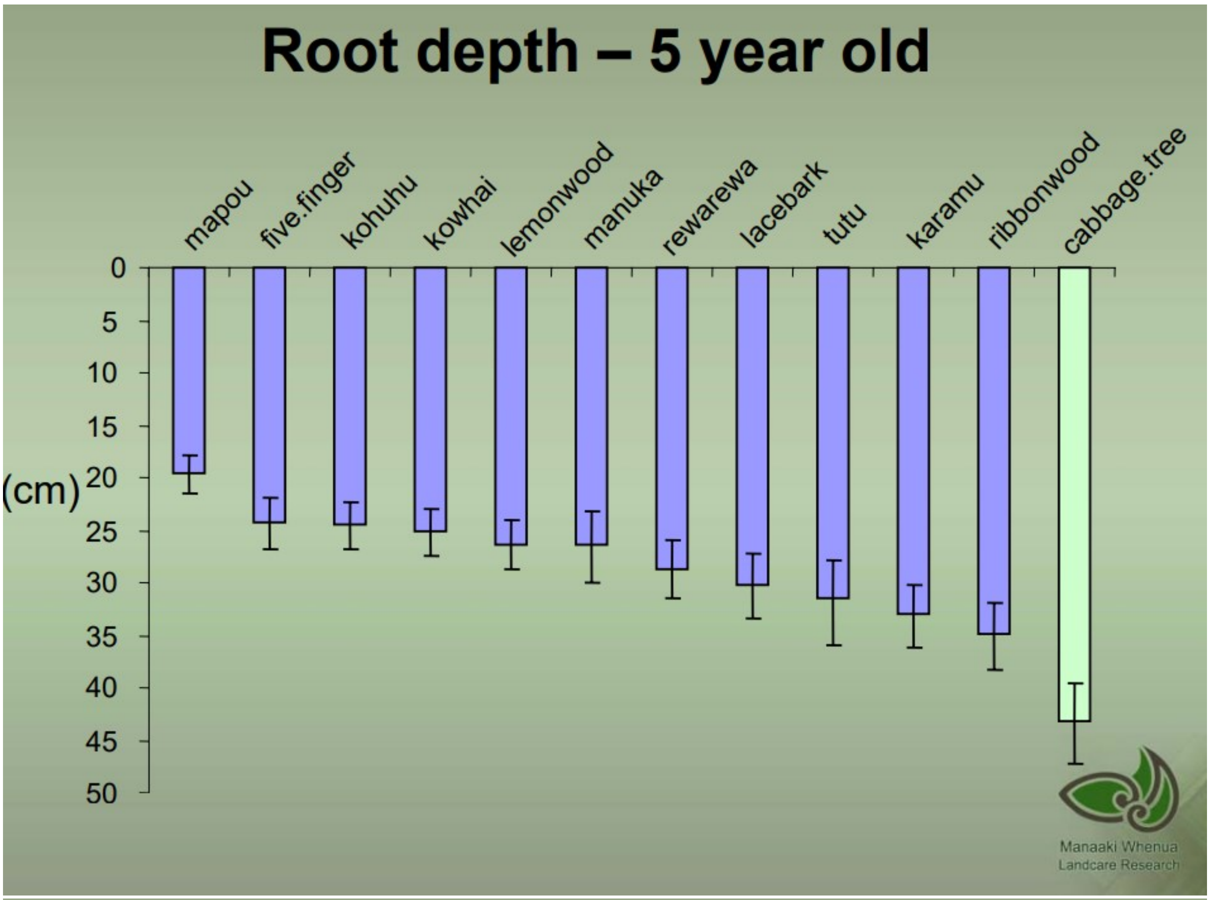
- The native species used for slip mitigation on open land will be those that are first colonisers suitable for your location and to the climatic conditions and that grow the fastest.
- Native plantings will not reduce slips for 10 years after planting.
- Native plants have not commonly been used for active erosion control because of their slow growth rate and lack of information.
- Root growth (like above ground growth) is highly variable depending on growing conditions and growth rates are also influenced by mycorrhizal status.
- There are many different measures used to quantify plants erosion fighting status. From mass of roots, length of root, spread of roots, depths of roots, size distribution etc.
- Most native species have shallow roots largely made up of lateral and fine roots that remain less than 0.5 m from the surface and are largely in the humus layer
- Generally, the roots extend slightly beyond the spread of the tree above ground.
- Some native species have plate root systems others have tap rooted systems. And not all have sinker vertical roots e.g., Rimu while others e.g., Manuka and cabbage trees have both vertical and lateral roots. Some natives have tap root systems (Kauri, Kahikatea, Rimu, Totara, Puriri) and others have plate root systems (Titoki, Matai, Miro). Tap roots are probably an adaption to drought.
- Planting on riverbanks stablises the banks, takes up nutrients, removes nitrogen, provides shade and reduces temperature, provide wood and leaf litter, enhance fish habitat and help control adverse effects of flooding

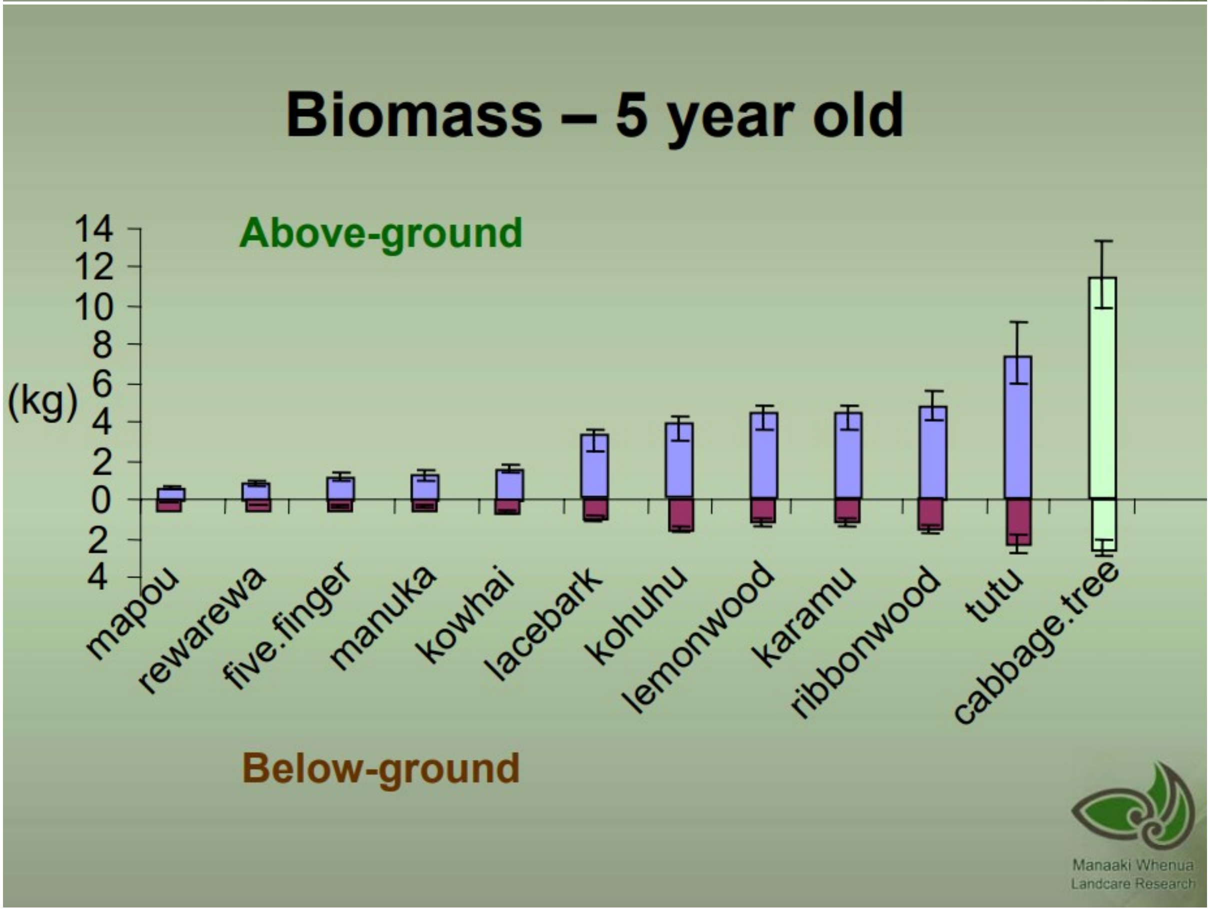
Research data from Motueka River

- The size of the trunk at ground level is a great predictor of root mass.
- That approximately 20%-30% of the biomass of a tree is underground.
- An ICM Motueka catchment project looked at planting 12 common species on riverbanks in Motueka catchment. They found that natives don't grow as fast as willows along riverbanks and natives don't begin to be effective for 5 years but can still be useful and ultimately can end up with stronger roots.
- Roots struggle to get down to depth needed to stabilize undercut banks or to anchor shear planes deeper than 1 m.
- Roots in the first 5 years were largely confined in the 30 cm of the topsoil and spread an equal distance.
- Cabbage trees had the deepest roots and Pitosporums, tutu, ribbonwood, cabbage tree, lace bark had the biggest spread of roots.

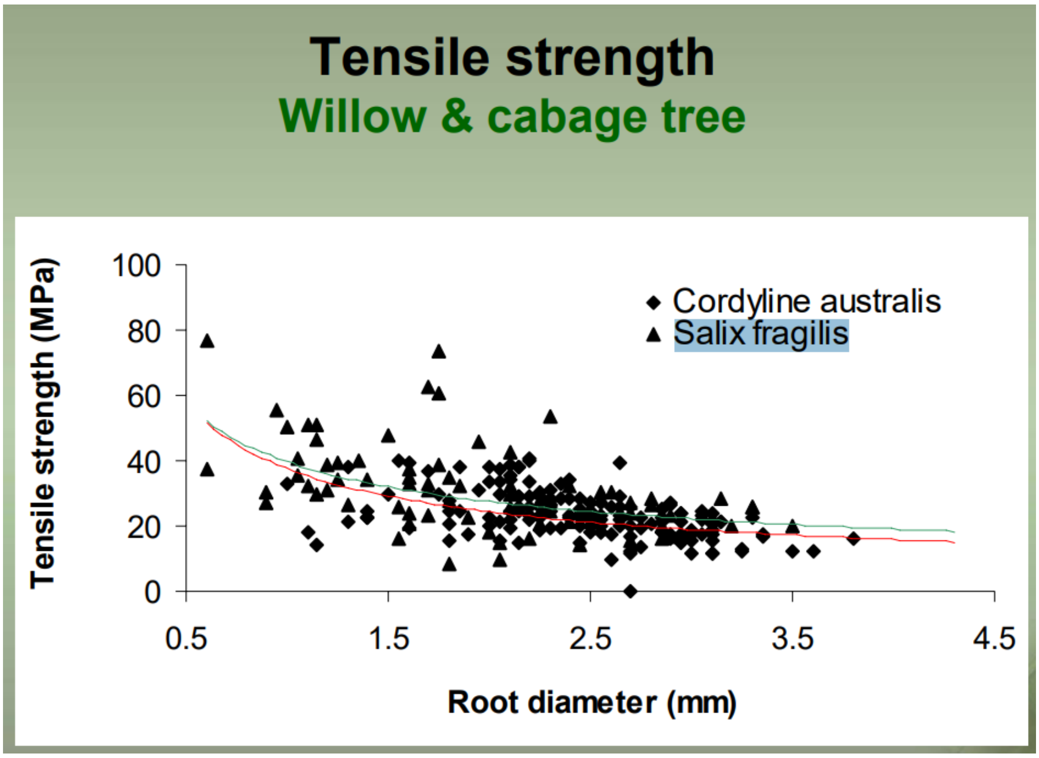
https://icm.landcareresearch.co.nz/knowledgebase/publications/public/LM_Aug_05_phillips_veg.pdf

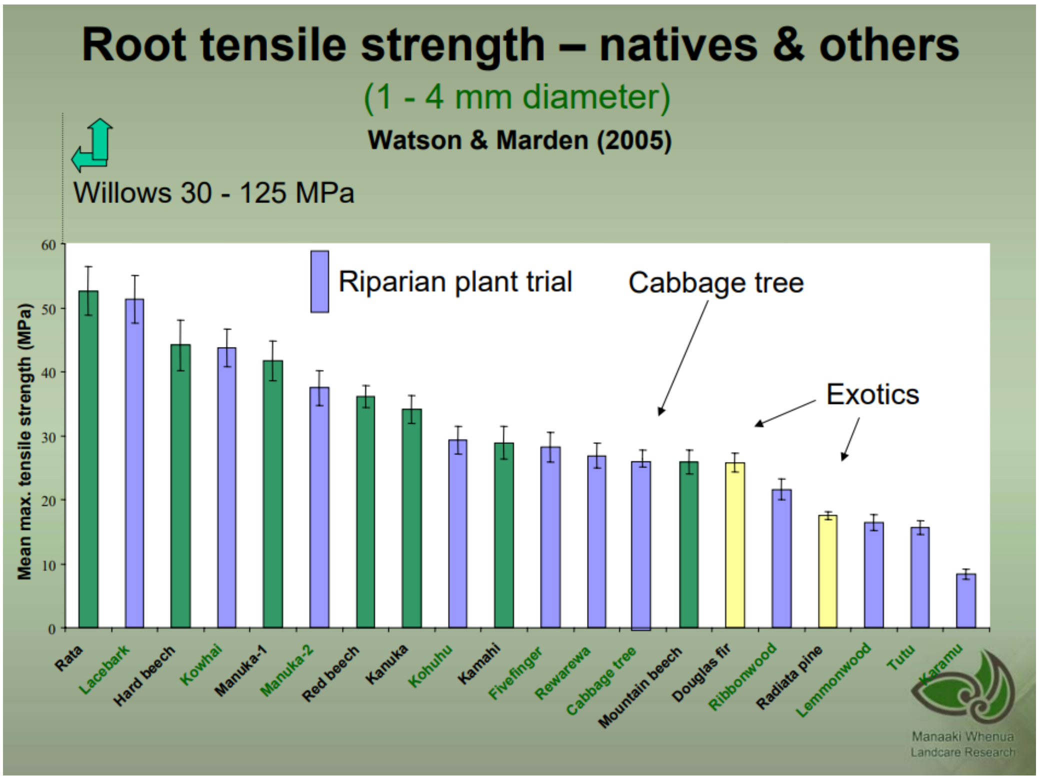



Root depth – 5 year old
mapou
five.finger
kohuhu
kowhai
lemonwood
manuka
rewarewa
lacebark
tutu
karamu
ribbonwood
cabbage.tree
0
5
10
15
20
25
30
35
40
45
50
(cm)
Manaaki Whenua
Landcare Research


Biomass – 5 year old
Above-ground
14
12
10
8
6
4
2
0
2
4
(kg)
mapou
rewarewa
five.finger
manuka
kowhai
lacebark
kohuhu
lemonwood
karamu
ribbonwood
tutu
cabbage.tree
Below-ground
Manaaki Whenua
Landcare Research

- Root Strength. Strength of roots is usually defined using break tests of individual roots or tests of pullout strength of roots (shear force in ground) from the ground or stump pull out (wind fall strength).
- For the same diameter of root crack willow and cabbage trees have the same strength (figure below). Other willow species such as the Rosmery willow have stronger roots.
- Many of our native species have stronger roots than exotic plants.





Research from Bay of Plenty

Root depth

- The above and below ground growth was compared in the Bay of Plenty in 8 species of our large podocarps or broad leaf trees of our permanent native forests for 5 years.
- Studies in older mature stand found that manuka trees penetrated to less than 1 m while Kanuka reached 2m. Root depth is affected by soil type.
- Adult cabbage trees had roots down to 2m.
- The rooting depth of most of NZ podocarps rarely exceeds 2 m though sinker roots down to 4 m have been found.
- Generally, NZ native trees have higher root strengths than exotics but are slower growing and have shallower root systems.
- The below ground root mass was greatest in Puriri, followed by Totara, Kauri, Kahikatea, Titoki and Rimu and then lower in Miro and Mati. Most of the roots were in the top 0.5 m. And by year 5 Puriri had 66% (the lowest percentage) of its roots within 0.5 m of trunk.
- Puriri had a higher root to shoot ratios than the other cultivators and greatest total root length.
- Native conifers and broadleaved trees are only suitable for erosion control in a successional role over the long term. Dense planting with quick canopy closure and roots on multiple levels. In optimal conditions Puriri achieves this at 5 years, faster than Totara and the slow growing Matai and Miro will take 10-15 years and Kauri even longer.
- The best strategy is to use a mix of early and successional species with both plate and tap-rooted characteristics. Any where slip risk is high adding poplar poles on hills and willow poles on riverbanks could be justified.

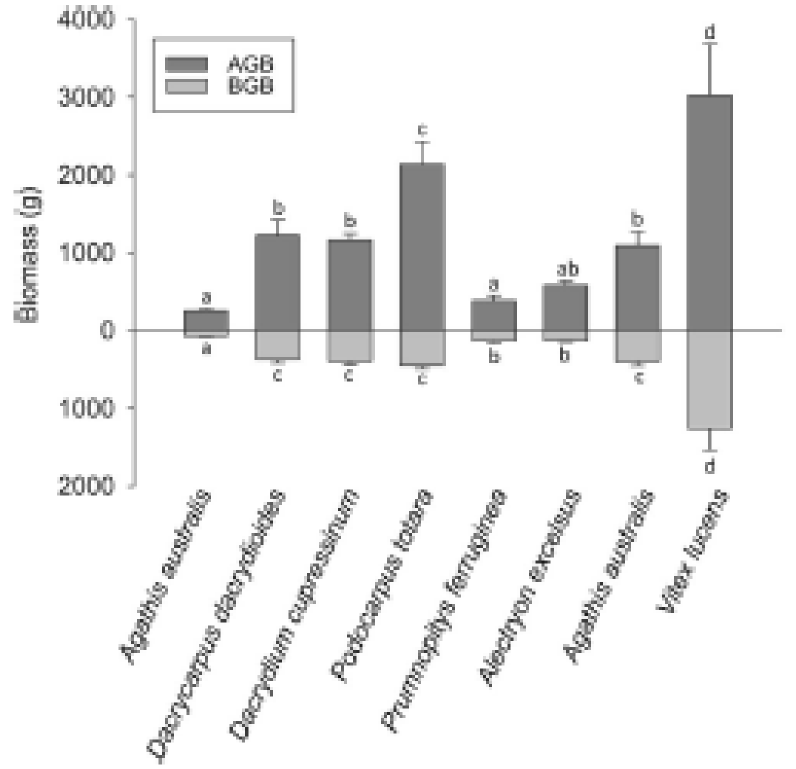


Fig. 5 Plant biomass above- (dark bars) and below-ground (light bars) in year 5. Error bars represent one standard error of the mean. Bars within each parameter with a different letter were significantly different ($P = 0.05$)

- Most NZ conifers and broadleaved trees will have limited effectiveness in flood plain reaches where channel hydraulic conditions are likely to result in undercutting of stream banks to a depth greater than that root depth. This is why physical intervention is normally applied.
- Totara and Kahikatea have the ability to produce new root systems after flooding (Kahikatea not if silt >60 cm) and totara can produce roots from buried trunks if they fall.

Auckland Study

- Study undertaken in Auckland and published in 2023 with the goal of building a predictive model for erosion project from plantings for the Kaipara Catchment project.
- They found that for riverbanks Cabbage Trees were by far the most effective native plant during juvenile stage and Lacebark, Mahoe and Manuka came into their own later on at maturity.
- The grasses provide little root stability but were important in providing ground cover to limit erosion.
- Grasses and all native woody species studied, except cabbage tree, had a typical decline in rooting density with depth.
- All native woody species, except cabbage trees, had many finer than coarse roots.
- Cabbage trees have a unique root structure (see photo below)

Figure 4. **Photo showing grid used to collect information on the distribution of root diameters for a Tī Kōuka/Cabbage Tree using the 10 cm x 10 cm grid attached to the bank face.**

Table 2 **List of native species selected for investigation in this study.**

Te Reo name / Common name	Species Type	Latin Name	Code based on Latin name
Houhere/Lacebark	Woody	*Hoheria populnea*	HOPO
Karamū	Woody	*Coprosma robusta*	CORO
Māhoe	Woody	*Melicytus ramiflorus*	MERA
Mānuka	Woody	*Leptospermum scoparium*	LESC
Tarata/Lemonwood	Woody	*Pittosporum eugenioides*	PIEU
Tī Kōuka/Cabbage Tree	Woody	*Cordyline australis*	COAU
Giant Umbrella Sedge	Herbaceous	*Cyperus ustulatus*	CYAL
Pukio	Herbaceous	*Carex virgata*	CAVI
Rautahi	Herbaceous	*Carex lessoniana*	CALE
Toetoe	Herbaceous	*Austroderia fulvida*	AUFU
Wīwī/Juncus	Herbaceous	*Juncus edgariae*	JUED

Only Cabbage tree in above list produced tap roots,

Tensile strength results!!

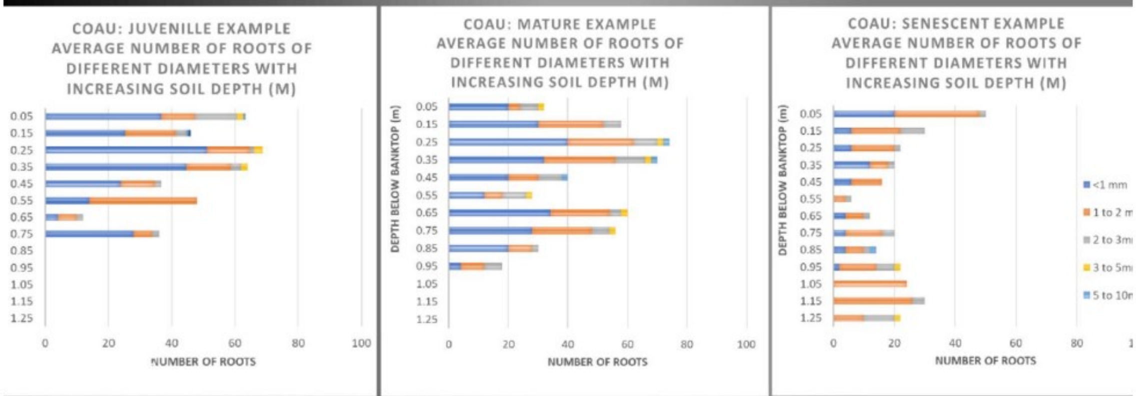
pecies Code	Name	Coefficient Strength at 1 mm in Mpa	Strength at 5 mm in Mpa	Class
COAU	Cabbage tree	67.0	**9.4**	W
AUFU	Toetoe	40.9	2.7	H
LESC	Manuka	37.5	**6.8**	W
HOPO	Lacebark	32.7	**7.6**	W
CALE	Carex lessoniana	26.8	3.7	H
CYUS	Umbrella sedge	26.5	3.7	H
CORO	Corposma	26.4	3.9	H
CAVI	Carex virgata	24.3	3.2	H
MERA	Mahoe	23.0	**6.3**	W
JUED	Juncus	19.5	1.4	H
PIEU	Lemmonwood	17.3	**5.8**	W

1mm - fine roots

Species Code	Name	Coefficient Strength at 1 mm in Mpa	Strength at 5 mm in Mpa	Class
COAU	Cabbage tree	67.0	**9.4**	W
HOPO	Lacebark	32.7	**7.6**	W
LESC	Manuka	37.5	**6.8**	W
MERA	Mahoe	23.0	**6.3**	W
PIEU	Lemmonwood	17.3	**5.8**	W
CORO	Corposma	26.4	3.9	H
CALE	Carex lessoniana	26.8	3.7	H
CYUS	Umbrella sedge	26.5	3.7	H
CAVI	Carex virgata	24.3	3.2	H
AUFU	Toetoe	40.9	2.7	H
JUED	Juncus	19.5	1.4	H

5mm roots

Example species: Ti kouka (*Cordyline australis*)



Manuka and Kanuka Regeneration

- The bulk of the mānuka and kānuka root mass and root length for trees up to 50-years old is concentrated in the top 0.5 m of soil and within a 1.0 m radius of the root bole (stump).
- After 16 years there is no increase in root spread and root mass decreases.
- Manuka and Kanuka roots have similar strength
- After felling kanuka roots increase in strength for 2 years.

- For example, mean tensile strength in living roots is 18 MPa and 32 MPa in pine versus kanuka and after 4 years Kanuka is still at half strength whereas pine after 2/12 years pine root depth dropped to 20%.
- Manuka and kanuka roots are flexible and this helps to maintain soil stability.
- Closed canopy manuka intercepts about a third of rainfall and kanuka stands slightly more. At 1 plant every 3 m canopy closure will occur after 8 years.
- Kanuka and Manuka ability to reduce slips in natural regeneration is probably more a factor of the density of plants than their root morphology. Manuka is normally planted at 1000 stems per ha for honey production and this may not be enough to stabilise slopes in large storm events.

There is a PhD Student, Joan Ropiha, at Massey University that is studying native plants on hill country for forage for stock and looking at it from a Māori prospective. No erosion effects published yet. Based in Wairoa district.

References.

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