Forestry in steep eroding hillcountry:

the good, the bad, and what the science says (30 mins)

Chris Phillips

Presentation to Northland Forestry Forum, Northland Regional Council, November 17, 2014

Landcare Research
Manaaki Whenua

Myths

1. Erosion ≠ sediment yield
2. Bare ground ≠ erosion
3. Surface erosion is important
4. New tools & technology will give us the answers
5. Modeling will give us the answer
6. New Zealand is different
7. We can mitigate & manage for all eventualities

The facts

1. Erosion is natural – it's the rate that's impt.
2. New Zealand is an erosion-prone, risky place
3. Mass wasting >> surface erosion
4. Erosion leads to loss of soil natural capital = $
5. Sustainability is a time-bound construct
6. There is no "one size fits all" tool to assess/manage
7. New Zealand is different – sort of
8. We can't mitigate/manage for all eventualities
9. Nature always wins

What the science says - 5 lessons

Our research

Understand the past to
understand the present and predict the future
(Climate Change)

Erosion process

Vegetation performance

Sediment & slope stability modelling
SedNetNZ, SoSlope

Outcome:

- Improved ability to model role of vegetation in landscapes
- Improved understanding of effectiveness of mitigation measures
- Improved land management practice & policy

The way it was – historical period

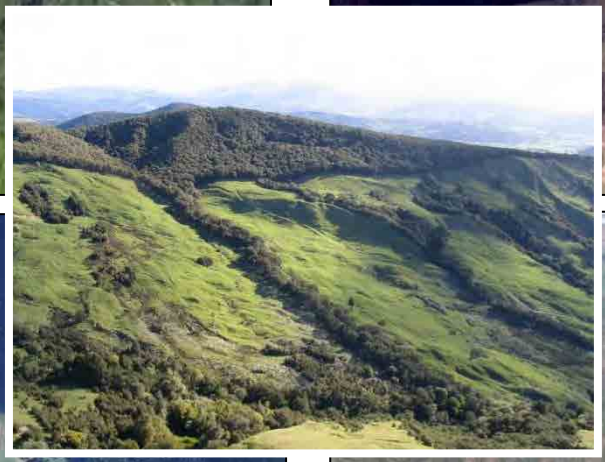
Erosion processes

*Marden et al. (**2014**). Erosion process contribution to sediment yield before, 10-years, and 28-years after the establishment of exotic forest:Waipaoa catchment, East Coast region, North Island New Zealand. Geomorphology.*

*Phillips CJ, Rey F, Marden M, Liébault F (**2013**) Revegetation of steeplands in France and New Zealand: geomorphic and policy responses. New Zealand Journal of Forestry Science 43:14.*

East Coast – best or worst example?

The Trees came back



but not everywhere

The Trees came back

again not everywhere

Weak geology/thin soils + lots of rain + steep slopes = many landslides/debris flows

Weak geology/thin soils + lots of rain + steep slopes + **trees** = few landslides

Why forests do good

Shallow landslides

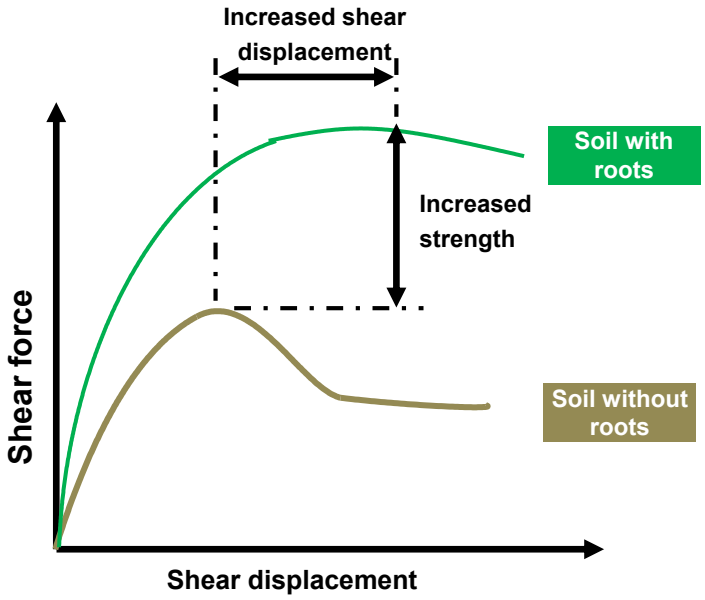
Earthflows

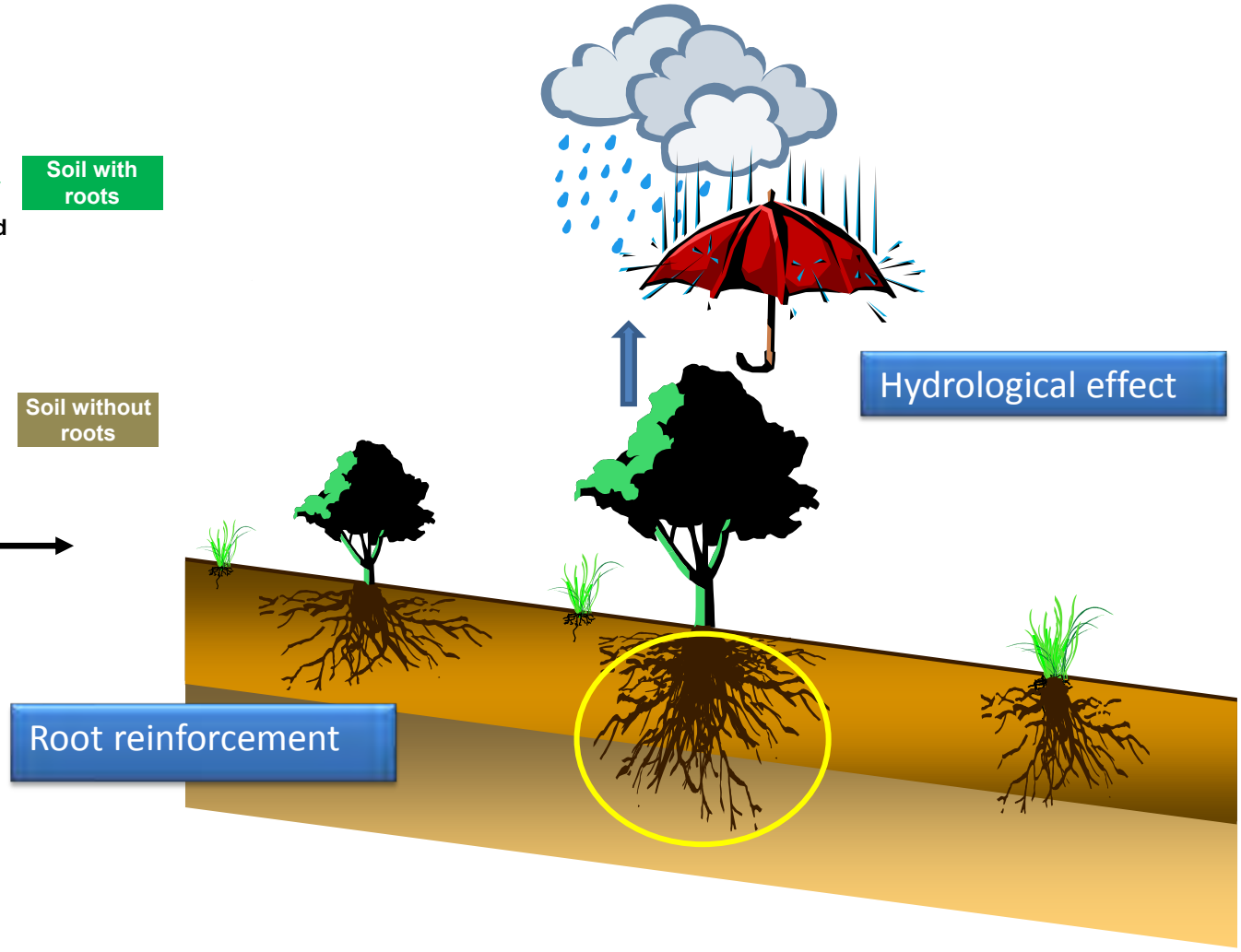
Gullies

"The greatest benefit of plantation forests is in reducing shallow landsliding, the most common and extensive form of mass movement in New Zealand." - LR Basher

*Basher LR (**2013**). Erosion processes and their control in New Zealand. In Ecosystem Services and Trends in New Zealand. Dymond, J (Ed), Manaaki Whenua Press, Lincoln.*

How forests work to prevent shallow landslides





*Phillips CJ, Ekanayake JC, Marden M (**2011**). Root site occupancy modelling of young New Zealand native plants: implications for soil reinforcement. Plant Soil 346 (1-2): 201-214*

*Ekanayake JC, Phillips CJ (**2002**). Slope stability thresholds for vegetated hillslopes: a composite model. Canadian Geotechnical Journal 39: 849-862.*

When forestry goes bad?

What happens when the trees are harvested?

Briefly to summarise ……

- Harvesting and re-establishment of plantations focussed on steep lands
- Wood coming on stream from these forests
- Concerns about risks from extreme weather events – some problems
- Things change when trees are removed – it is a natural and well anticipated response
- Is more public education needed?
- Can nature be managed?

*Phillips C, Marden M, Basher L (**2012**). Plantation forest harvesting and landscape response - what we know and what we need to know. New Zealand journal of forestry 56(4): 4-12*

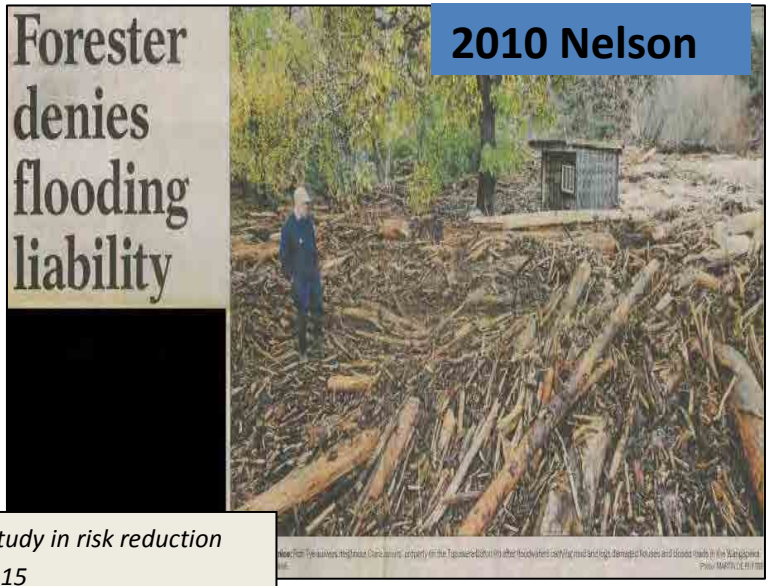
Post-harvest consequences

2010 Bay of Plenty

2010 Northland

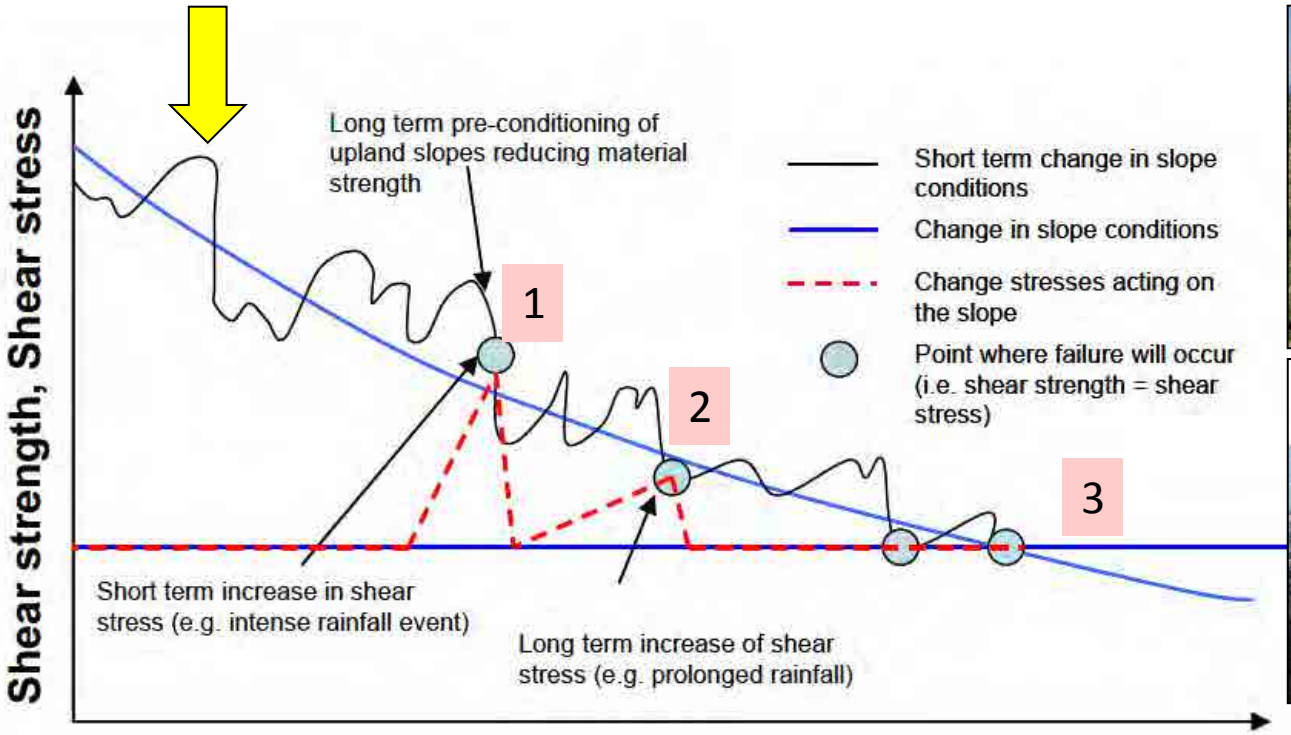
2010 Hawke's Bay

2010 Nelson

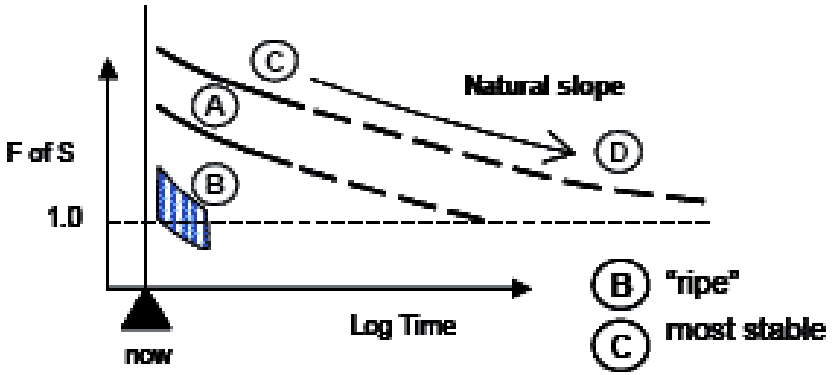


*Horner M(**2012**). After the storms-a case study in risk reduction New Zealand journal of forestry 56(4): 13-15*

Slope thresholds & time



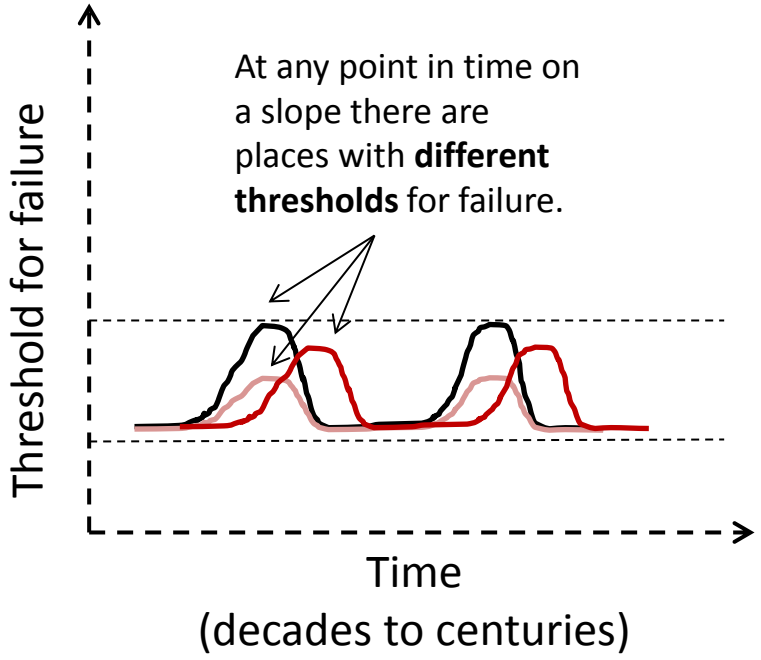
Shape of Factor of Safety vs Time curve (Ripening)

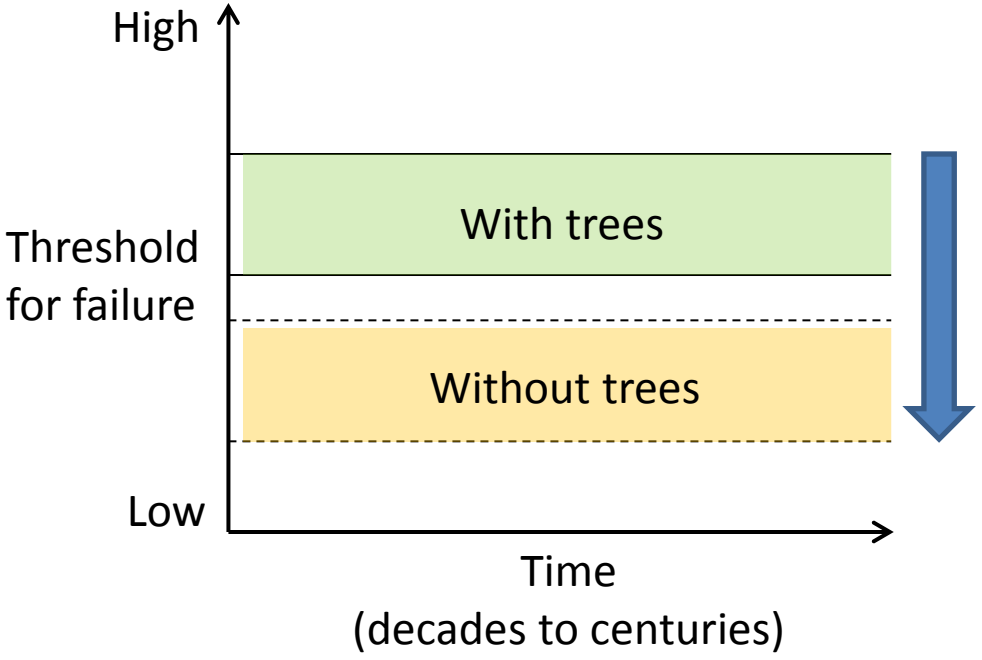


*Nettleton IM et al. (**2005**). Debris flow types and mechanisms. Chapter 4 in Scottish Road Network Landslides Study.*

Slope thresholds & time

What happens to the thresholds when we harvest the trees?





Landscape thresholds have been realised in these localities – shear stress > shear strength

Type 1 Failure

Oraukau Native slips

Q: Can this be managed?
A: No. Natural response.

Type 2 Failure

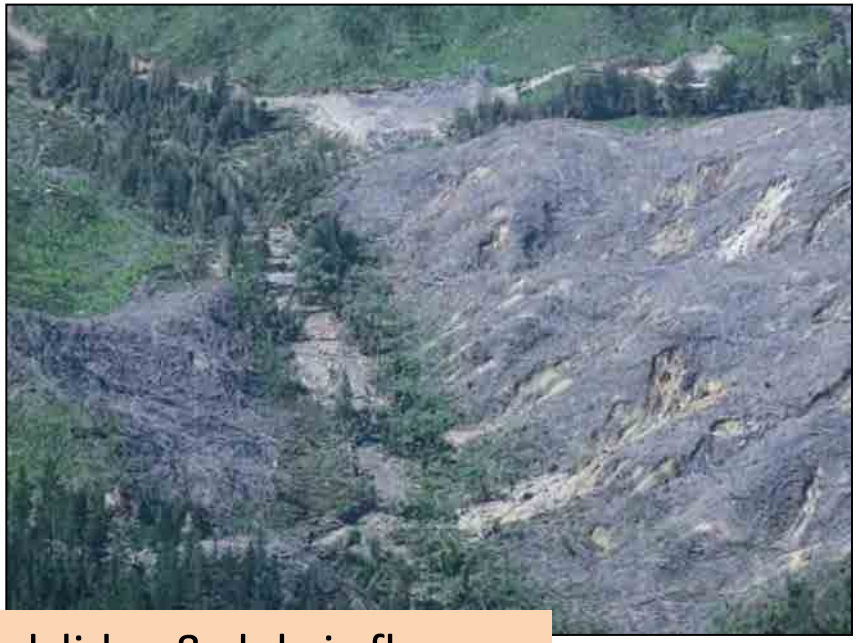
Canna Road Otaenga

Q: Did the road cause the failure?
A: Probably not. Incipient slump.

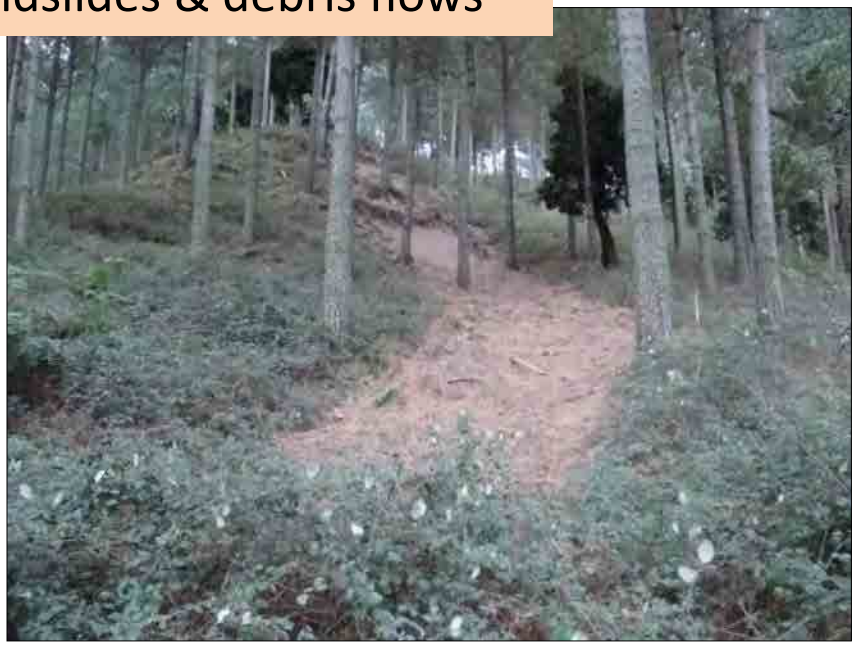
Landscape thresholds have been realised in all these localities – irrespective of cover

Same processes,
different land covers
= Nature at Work

Can this be managed? NO
This is landscape adjustment

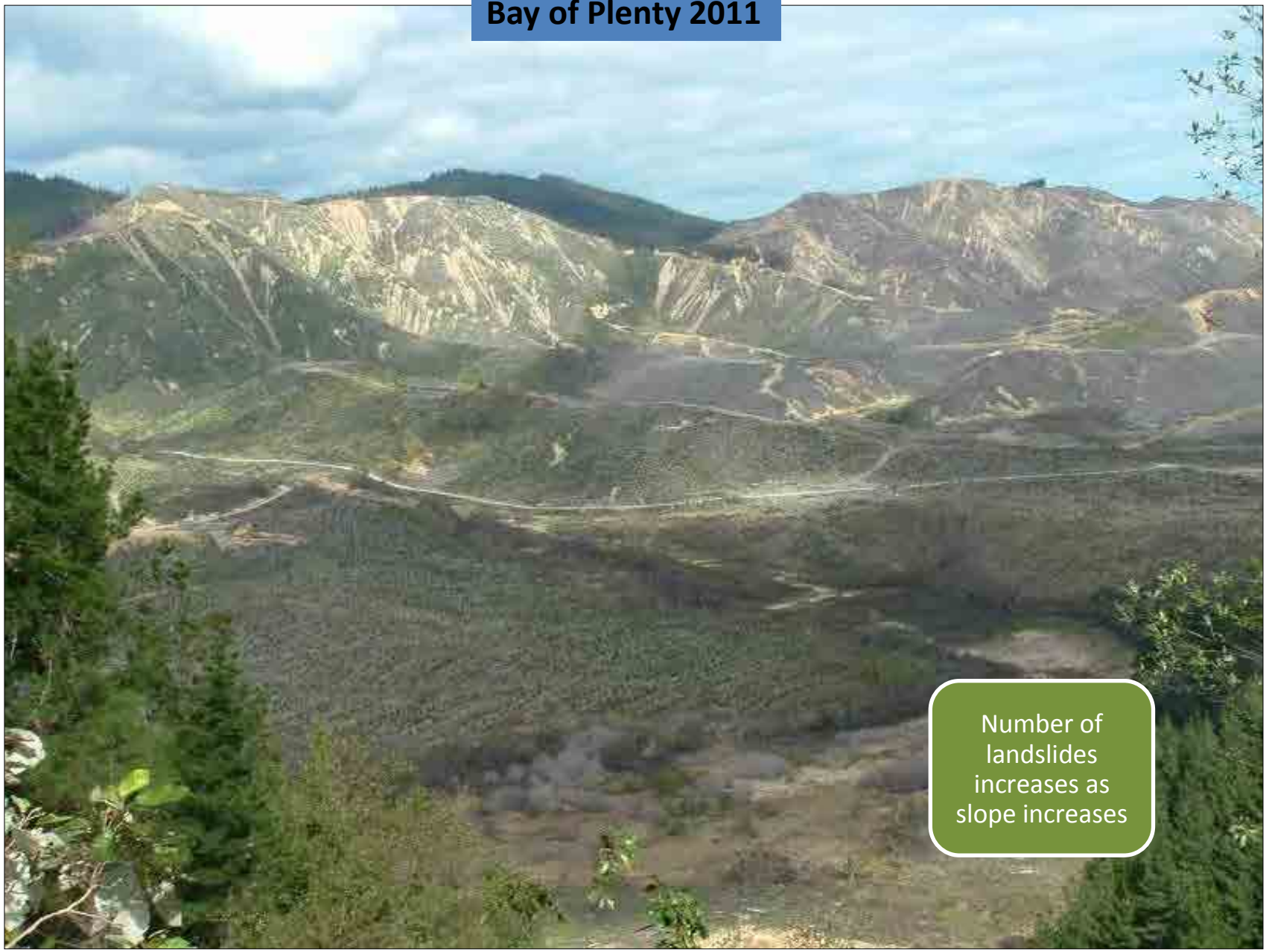


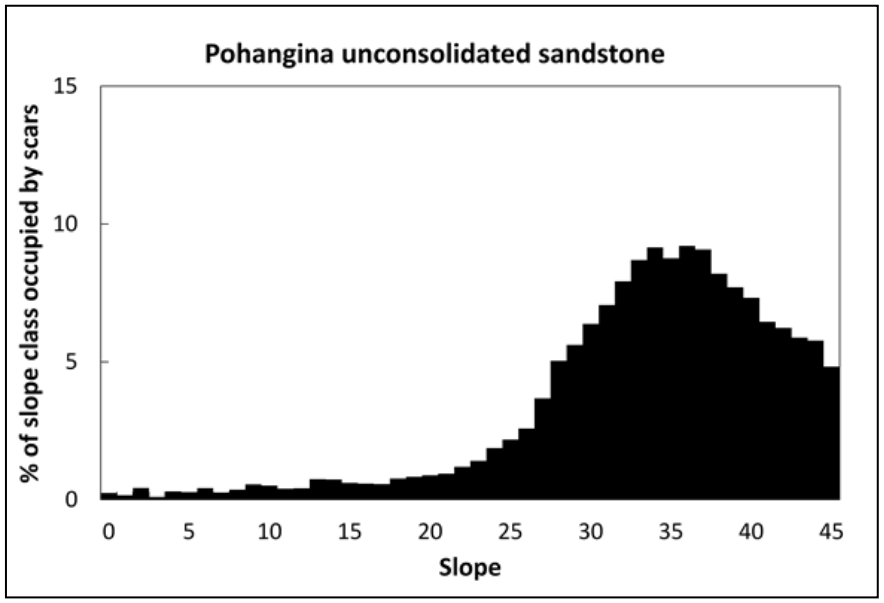
Forests not immune to landslides & debris flows



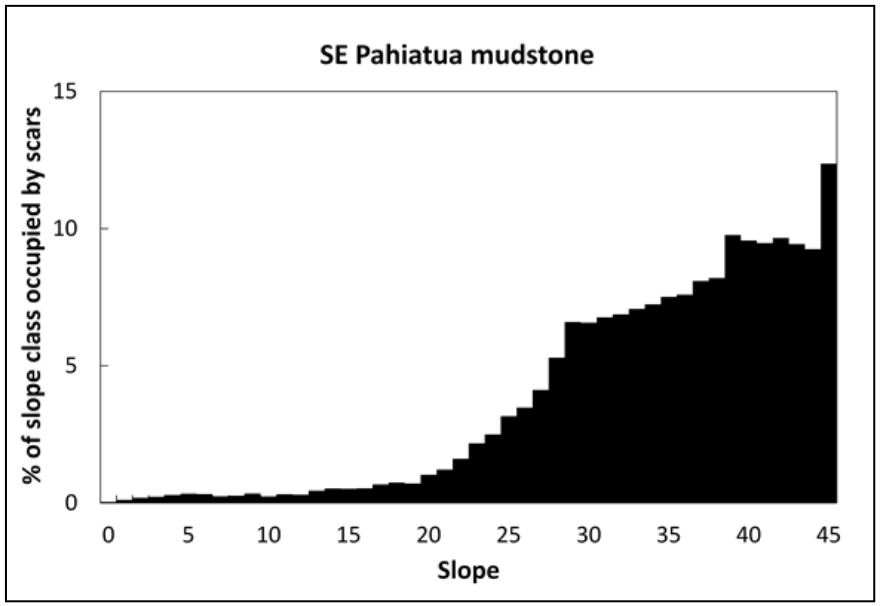
Failures usually 1 to 6 years after harvesting – but any time in rotation

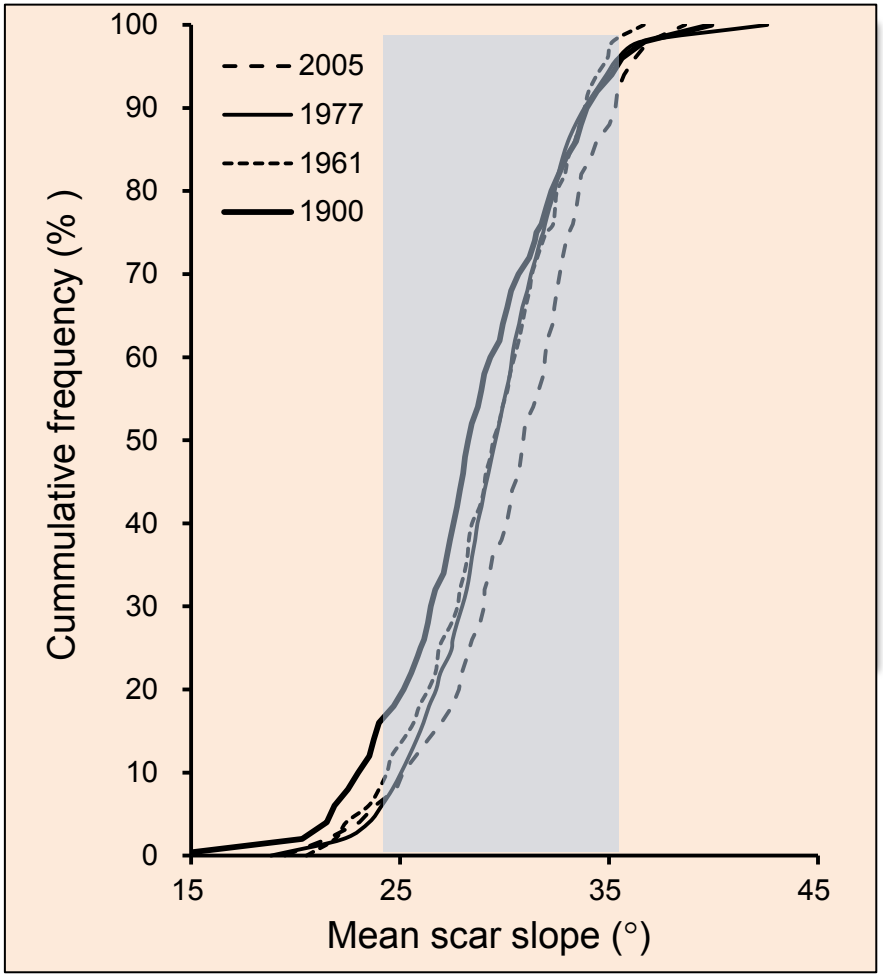
Bay of Plenty 2011





Geology is a key driver of shallow landslide-slope relationship



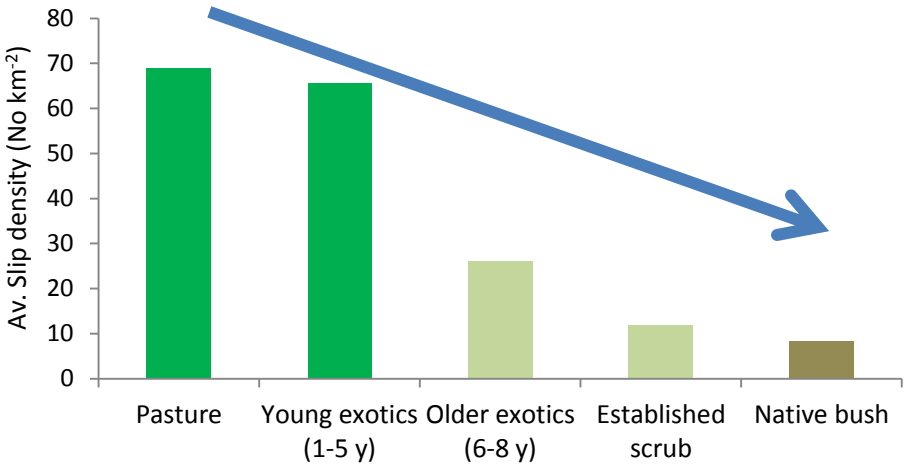


Number of landslides increases as slope increases

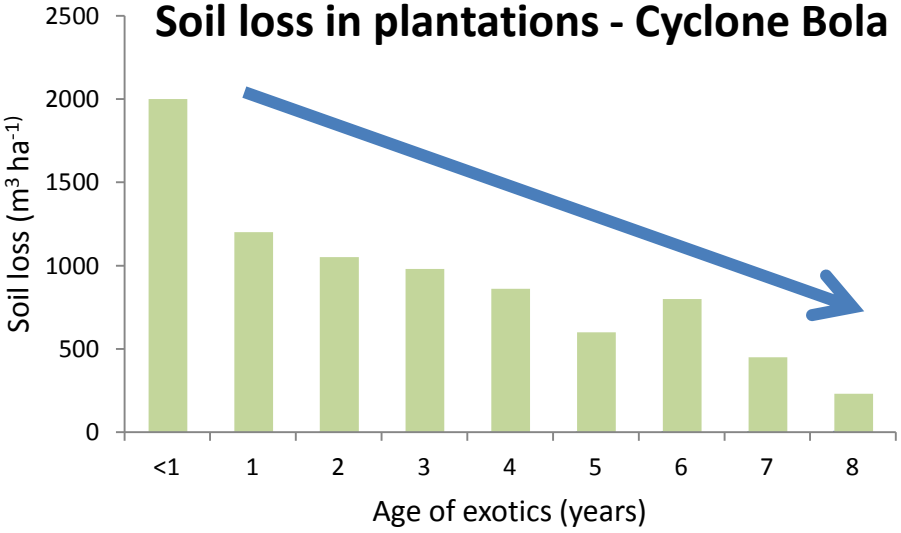
*De Rose R (**2012**) Slope control on the frequency distribution of shallow landslides and associated soil properties, North Island, New Zealand. Earth Surface Processes and Landforms 38(4): 356-371.*

Bay of Plenty 2011

Average slip density - Cyclone Bola



Soil loss in plantations - Cyclone Bola



Number of landslides varies with age of cutover and age of vegetation

*Marden M, Rowan D (**1988**) Protection value of different vegetation types in the east coast region after Cyclone Bola. Forest Research Institute Report.*

*Marden M, Phillips C, Rowan D (**1991**) Declining soil loss with increasing age of plantation forest in the Uawa catchment, East Coast region, North Island, New Zealand.*

Bay of Plenty 2011

All storms are not equal

2 storms of the same magnitude hitting the same place will produce different landscape responses.

The first maybe a slope forming event and the latter a channel forming event, i.e. cyclic with feedback loops

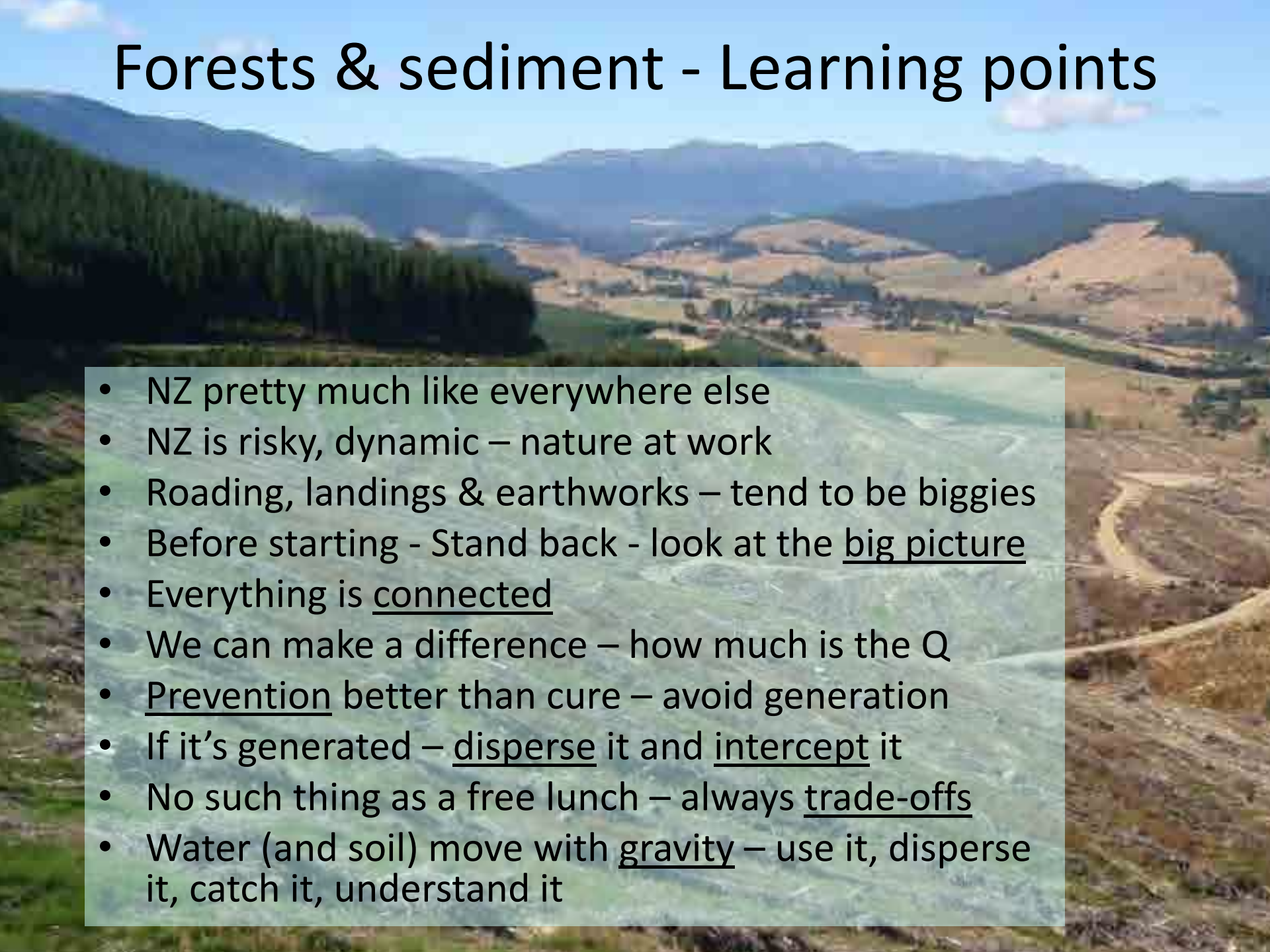
*Phillips C (**1988**)* Geomorphic effects of two storms on the upper Waitahaia River catchment, Raukumara Peninsula, New Zealand*. Journal of Hydrology (NZ) 27(2): 99-112.*

*Phillips CJ (**1989**)* Geomorphic effects of Cyclone Bola 1988 a note*. Journal of Hydrology (NZ) 28(2): 142-146.*

Is Northland different?

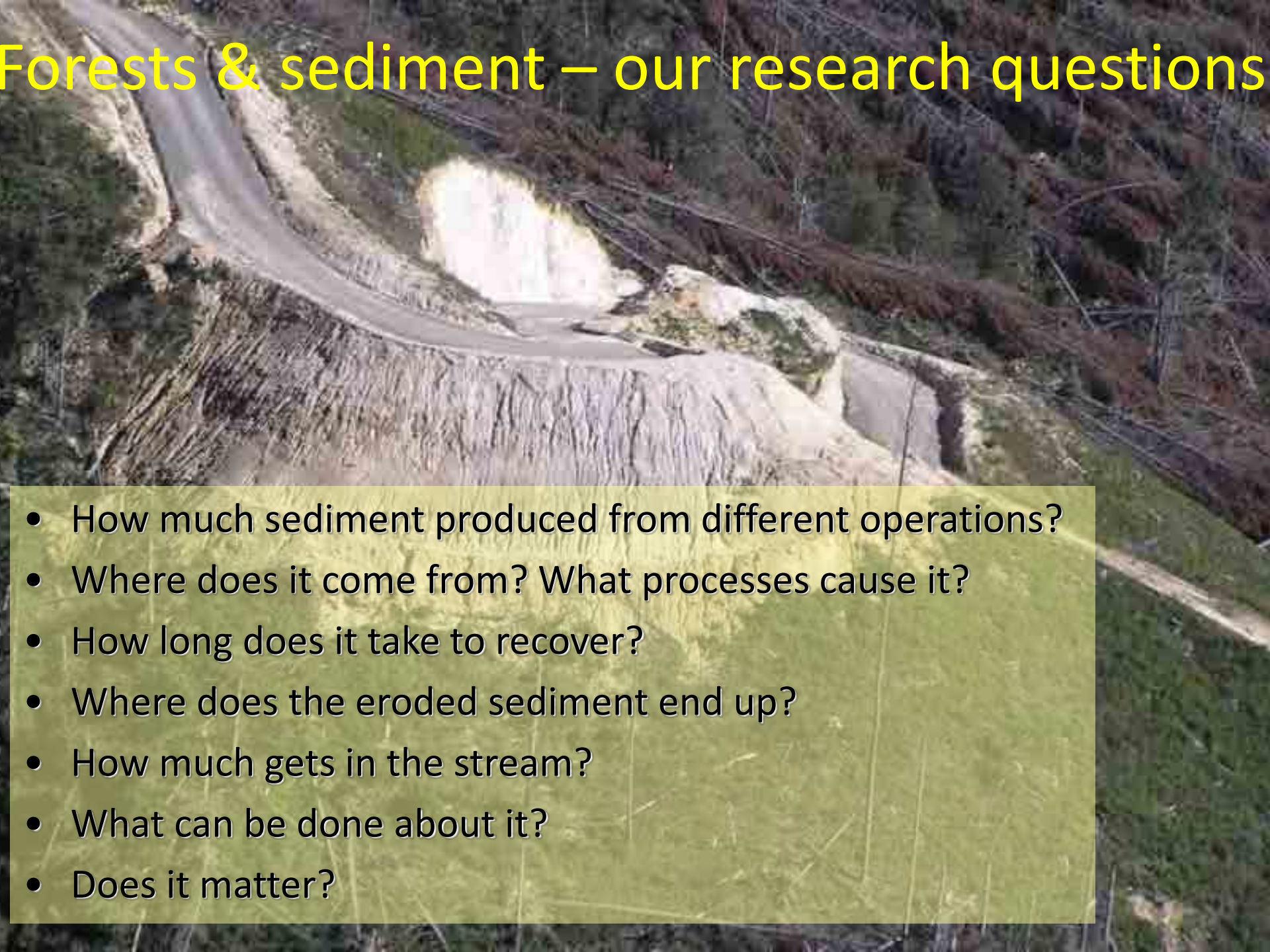
- Yes and No
- Landscape-shaping principles still apply
- The Big drivers of landscape change are geology, rainfall, slope – these are universal
- Northland does have some unique features (Bob)
- Clay contents likely to be higher
- Receiving environments different E-W

Forests & sediment - Learning points



- NZ pretty much like everywhere else
- NZ is risky, dynamic – nature at work
- Roading, landings & earthworks – tend to be biggies
- Before starting - Stand back - look at the big picture
- Everything is connected
- We can make a difference – how much is the Q
- Prevention better than cure – avoid generation
- If it's generated – disperse it and intercept it
- No such thing as a free lunch – always trade-offs
- Water (and soil) move with gravity – use it, disperse it, catch it, understand it

Forests & sediment – our research questions



- How much sediment produced from different operations?
- Where does it come from? What processes cause it?
- How long does it take to recover?
- Where does the eroded sediment end up?
- How much gets in the stream?
- What can be done about it?
- Does it matter?

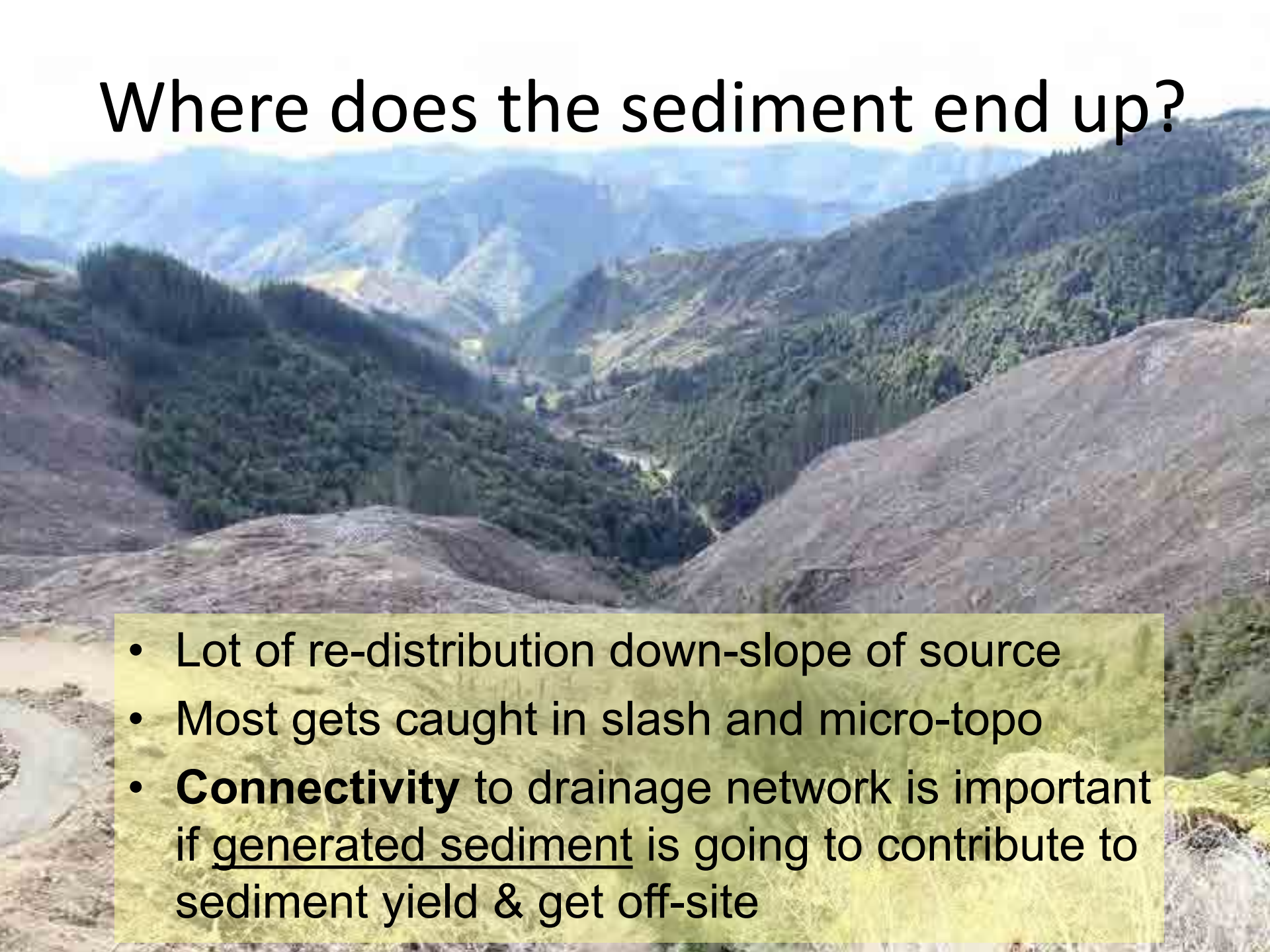
Sediment generation

Whangapoua Forest Coromandel	Area (ha)	Total Sediment (t)	t/ha
Undisturbed	14.5	0	0
LD plots	15.5	16	1
DD plots	3.6	48	13
Scalped	3.6	1200	333
Landslide (n=36)	0.4	600	1500

Small area – big contribution

*Marden M, Rowan D, Phillips C (**2006**). Sediment sources and delivery following plantation harvesting in a weathered volcanic terrain, Coromandel Peninsula, North Island, New Zealand. Australian Journal of Soil Research 44: 219-232..*

Where does the sediment end up?



- Lot of re-distribution down-slope of source
- Most gets caught in slash and micro-topo
- **Connectivity** to drainage network is important if generated sediment is going to contribute to sediment yield & get off-site

What's the biggest source for sediment entering the stream?

Process	Sediment generating site	Area connected to stream (ha)	Sediment generated & delivered (t)	% of total
Slope wash	Shallow dist.	n/a	n/a	n/a
	Deep dist.	0.18	2.9	2
Soil scraping	Scalped (40 mm)	0.18	60	26
Landsliding	Landslide source area	0.07 (n=9)	165	72
Totals	All sources	0.25	227.9	100

Note: roads not measured in this study

Most landslides cannot be prevented, especially "mid-slope" failures

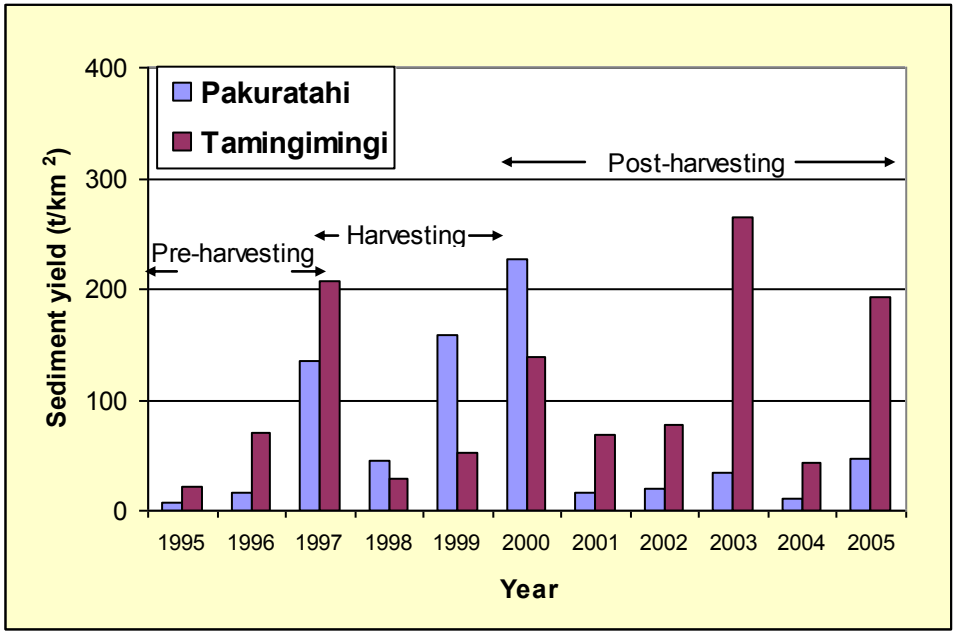
*Marden M, Rowan D, Phillips C (**2006**). Sediment sources and delivery following plantation harvesting in a weathered volcanic terrain, Coromandel Peninsula, North Island, New Zealand. Australian Journal of Soil Research 44: 219-232.*

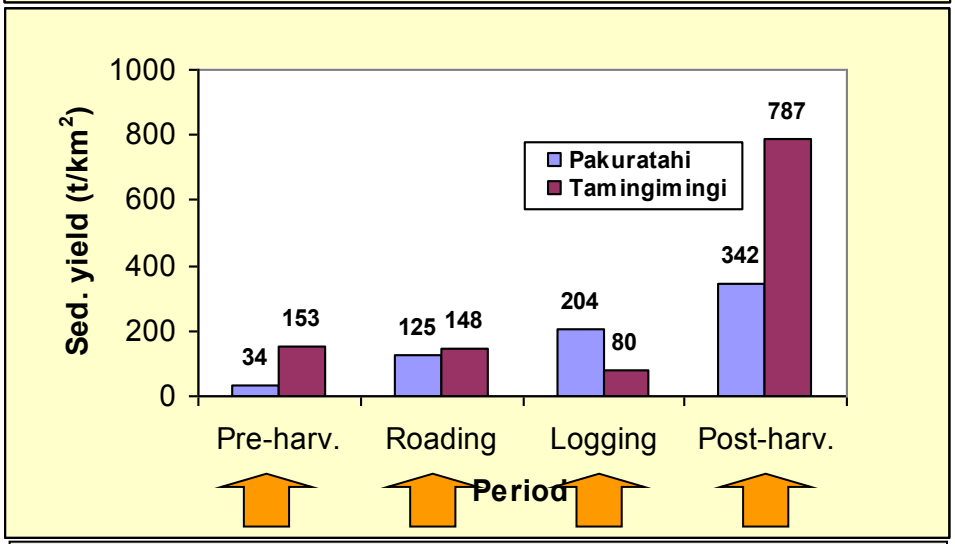
Annual sediment yields – Cpt 49

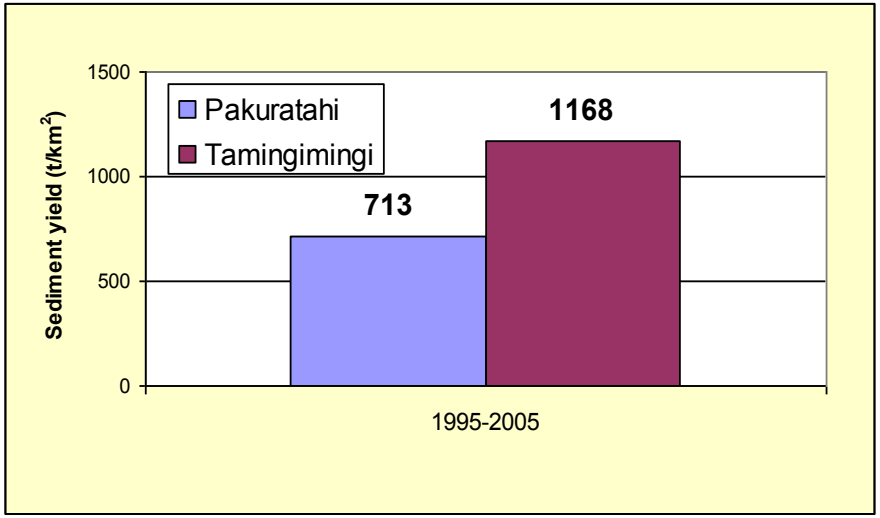
Whangapoua Forest Coromandel	2000 (Oct-Dec)	2001	2002	2003 (Jan-Mar)
Storms > 0.25m stage	1	11	11	6
Storms > 0.4m stage	0	4	5	3
Sediment yield (t)	1.5 (3 mths)	41	21.3	9.4 (3 mths)
Sediment yield (t km^{-2})	**4.4** (3 mths)	**116** (12 mths)	**59** (12 mths)	**26** (3 mths)

*Phillips CJ, Marden M, Rowan D (**2005**). Sediment yield following plantation harvesting, Coromandel Peninsula, North Island, New Zealand. Journal of Hydrology (NZ) 44(1):29-44.*

Land use & sediment yield – pasture/forest







Over 10 years, 40% less sediment from the forested catchment

*Eyles G, Fahey B. (Eds.) (**2006**). The Pakuratahi Land Use Study. A 12 year paired catchment study of the Environmental effects of Pinus Radiata Forestry. Hawkes Bay Regional Council plan No. 3868.*

*Fahey, B.D.; Marden, M.; Phillips, C.J. (**2003**). Sediment yields associated with plantation forestry, coastal Hawkes Bay, north Island, New Zealand. Journal of Hydrology (NZ) 42(1): 27-38.*

Post-harvest sediment yields

Where	Annual yield t km^{-2} y^{-1}	Reference
Maimai (native) - West Coast	**80 - 450**	O'Loughlin et al. (1980)
Big Bush (native) - Nelson	**18 - 44**	Fahey (unpub)
Glenbervie - Northland	**46**	Hicks & Harmsworth (1989)
Pakuratahi - Hawke's Bay	**18 - 112**	Fahey et al (2003)
Motueka - various Nelson	**21 - 148**	Hewitt (various 2001-2002)
Blue Mountains - Otago	**16**	Duncan (2012)
Coromandel - Whangapoua	**59 - 116**	Phillips et al (2005)
Coromandel - Opitonui	**10 - 279**	Wild & Hicks (2005)

10's to low 100's t km^{-2} y^{-1}

*Phillips CJ, Marden M, Rowan D (**2005**). Sediment yield following plantation harvesting, Coromandel Peninsula, North Island, New Zealand. Journal of Hydrology (NZ) 44(1):29-44.*

*Basher LR, Hicks DM, Clapp B, Hewitt T (**2011**). Sediment yield response to large storm events and forest harvesting, Motueka River, New Zealand. New Zealand Journal of Marine and Freshwater Research 45(3): 333-356.*

So…. what can we do about it?

1. Try & stop sediment being generated (can't reduce to zero)
2. Disperse it and catch it on slope before it gets concentrated
3. Break the connection - intercept it before it gets to stream
4. Accept at harvest sediment yields will rise – bare & H20
5. Get good numbers – more investigations on what works
6. Be pro-active rather than reactive – try, share & then tell

Does surface cover reduce sediment generated from bare areas?

Slopewash & surface cover

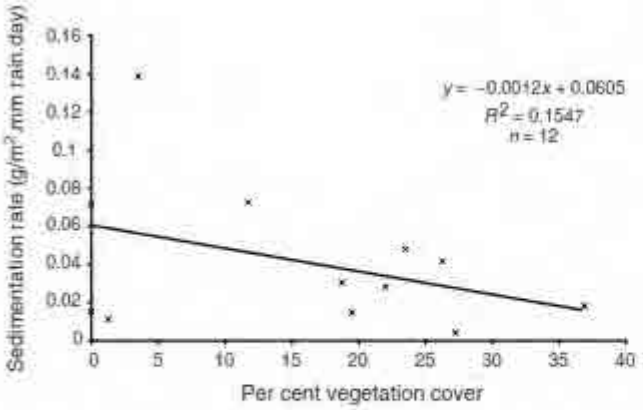


Fig. 5. Plot-scale regression analysis of the relationship between slopewash generation and percent vegetation cover on deep-disturbance sites, Compartment 43, Whangapoua Forest. The relationship was negative and non-significant ($F_{1,10} = 1.83$, $P = 0.206$).

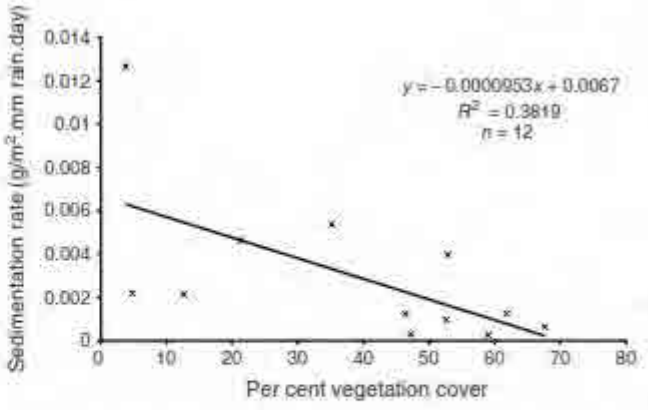


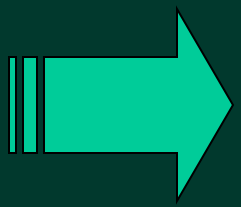
Fig. 6. Plot-scale regression analysis of the relationship between slopewash generation and percent vegetation cover on shallow-disturbance sites, Compartment 43, Whangapoua Forest. The relationship was negative and significant for shallow-disturbance sites ($F_{1,10} = 6.18$, $P = 0.032$).

Yes, surface cover reduces sediment generated from bare areas, but…

In the context of a forest setting, more effort has been devoted to reducing slopewash than to any other form of erosion because it is the most easily controlled. The results of this and other studies, however, show that slopewash is the **least important** of the erosion types found in a forested setting and a relatively minor contributor of sediment to streams.
- Marden et al (2006)

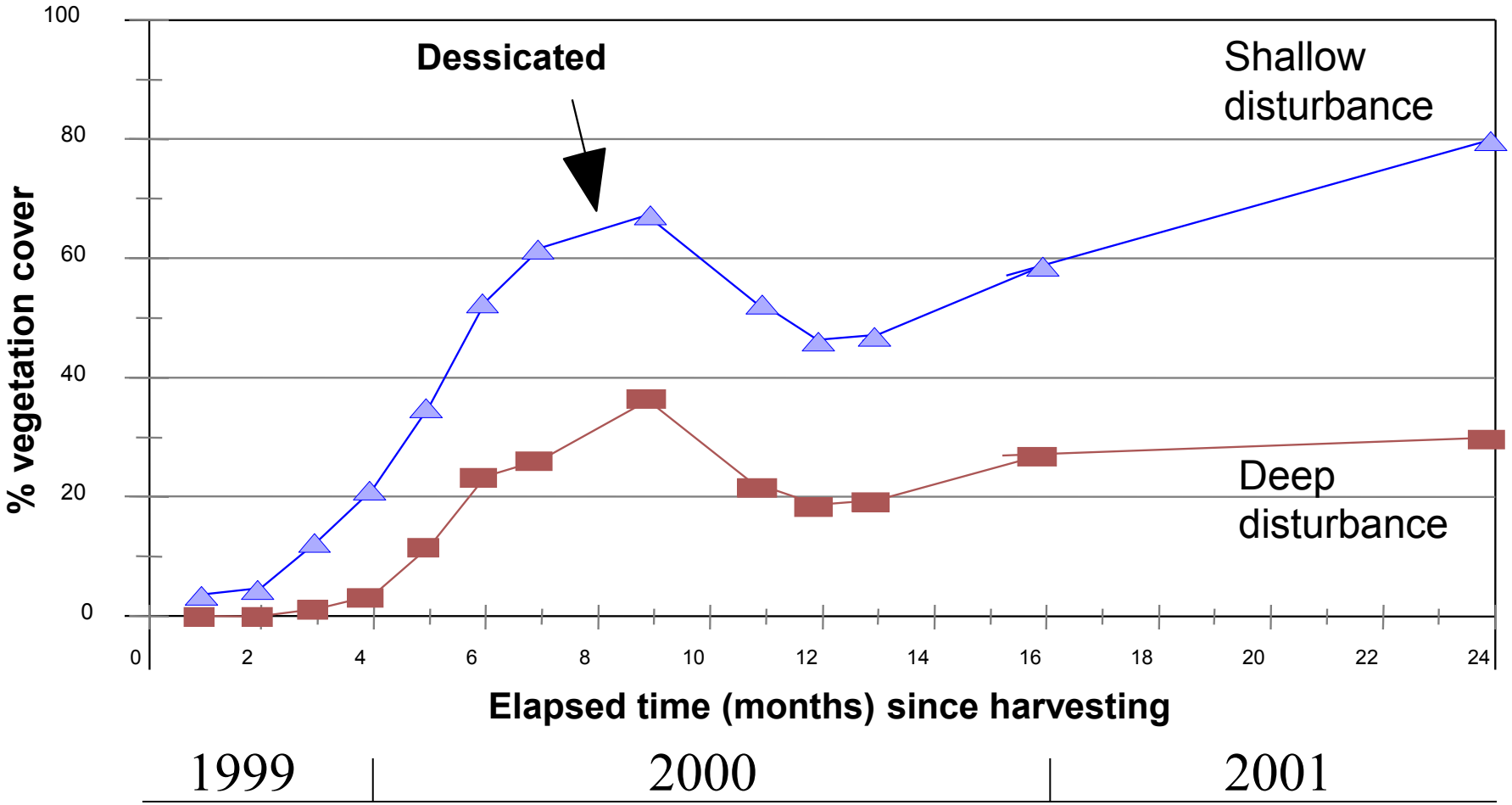
*Marden M, Rowan D, Phillips C (**2006**). Sediment sources and delivery following plantation harvesting in a weathered volcanic terrain, Coromandel Peninsula, North Island, New Zealand. Australian Journal of Soil Research 44: 219-232.*

Vegetation recovery



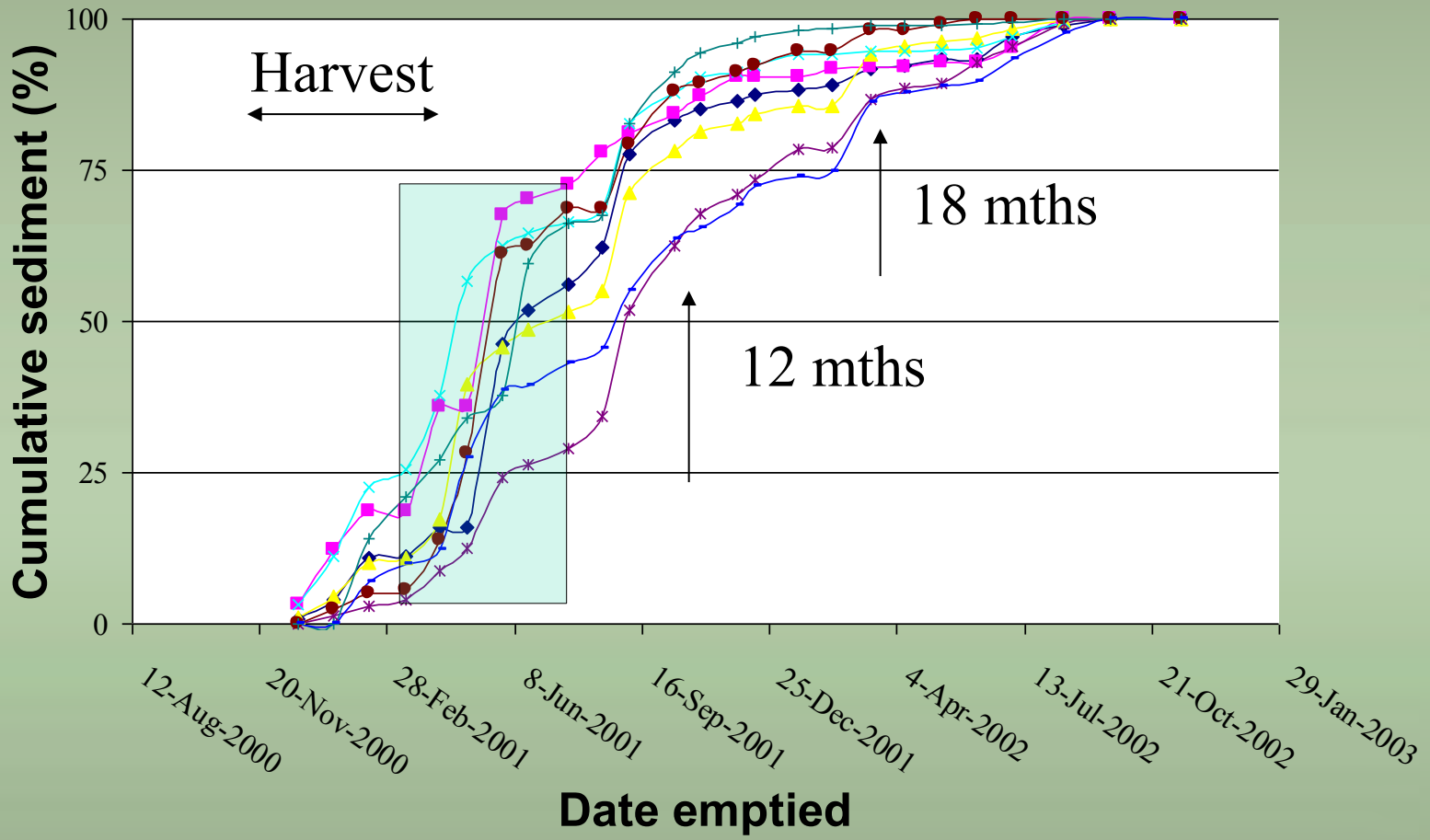
*Marden M, Rowan D, Phillips C (**2006**). Sediment sources and delivery following plantation harvesting in a weathered volcanic terrain, Coromandel Peninsula, North Island, New Zealand. Australian Journal of Soil Research 44: 219-232.*

Vegetation recovery



*Marden M, Rowan D, Phillips C (**2006**). Sediment sources and delivery following plantation harvesting in a weathered volcanic terrain, Coromandel Peninsula, North Island, New Zealand. Australian Journal of Soil Research 44: 219-232.*

Sediment generation - plots

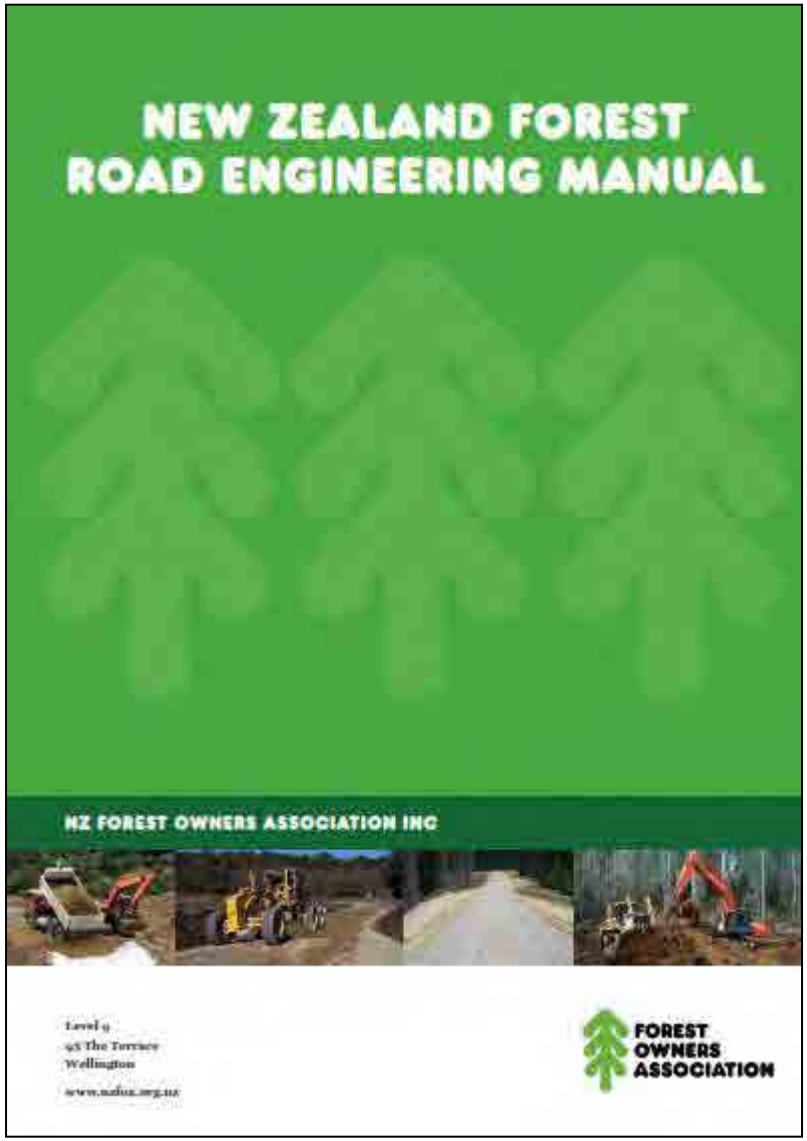


*Marden M, Rowan D, Phillips C (**2006**). Sediment sources and delivery following plantation harvesting in a weathered volcanic terrain, Coromandel Peninsula, North Island, New Zealand. Australian Journal of Soil Research 44: 219-232.*

Roads & earthworks

Historically, roads (and landings) were the operation that gave the industry a bad name. Generally, engineering practices better now – BUT things still go wrong.

Roads & landings used to be the key problem – better engineering has improved this greatly



Roads & E Works – what we can do – 1,2,3

1: Look to see where the water goes!

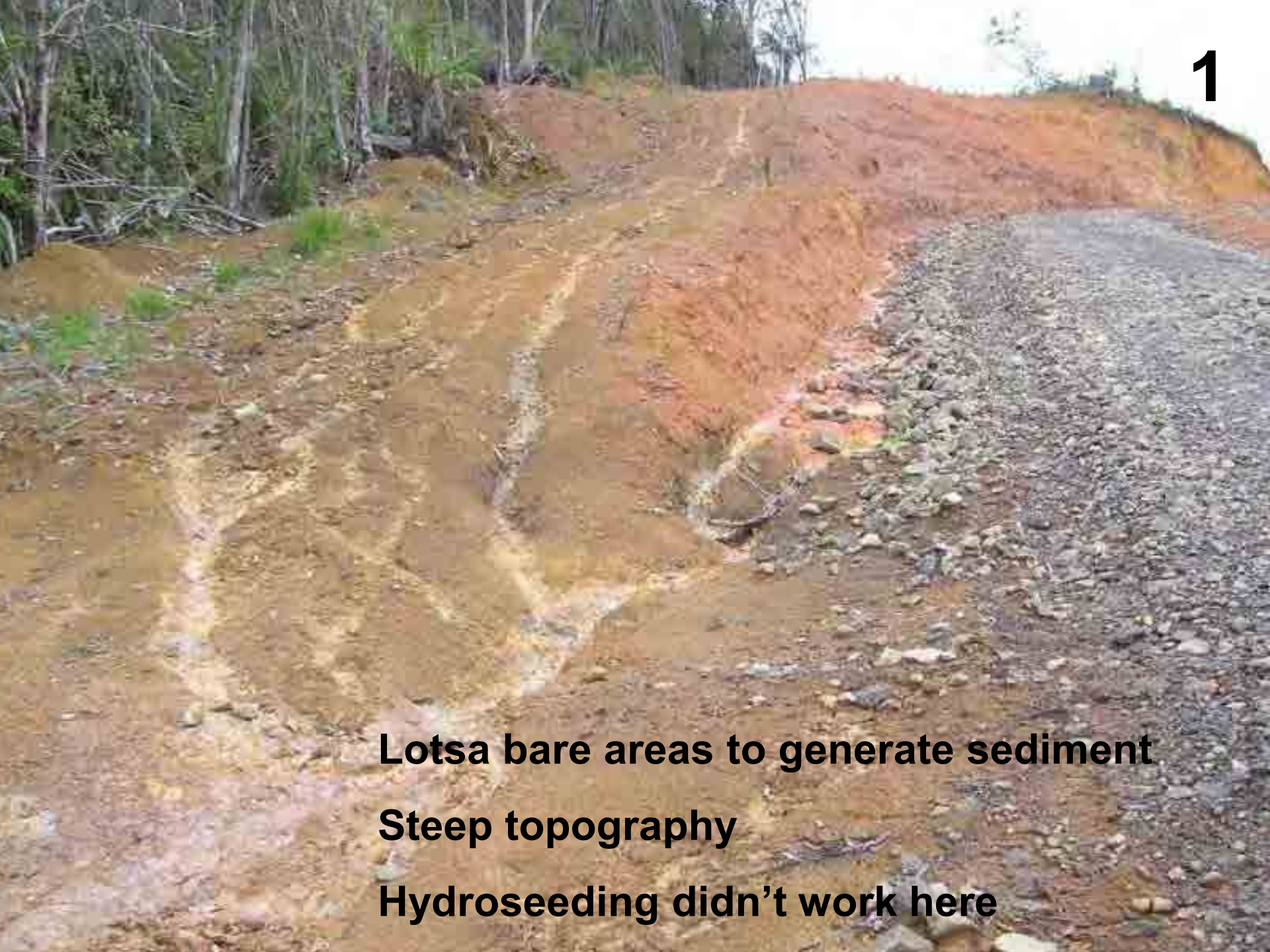
3: Follow best practice

Riparian buffers – do they work?

YES and NO

They are not the universal panacea for sediment control

3 examples


1
Lotsa bare areas to generate sediment
Steep topography
Hydroseeding didn’t work here


1
Sediment trap full
“Huge” native buffer
Very steep topography into stream

Coarse sediment drops out

but sediment will often go <u>through</u> the buffer into stream

Connectivity is key factor


2
Bare areas generate sediment
Highly weathered materials
Easy to erode
Hydro-seeding doesn’t work well here

Sediment will often go <u>through</u> the buffer into stream

Slope is a key factor

Micro-topography also impt.

Slope < 15
Buffer > 20m

Culvert

E&SC methods

from urban earthworks – applicable?

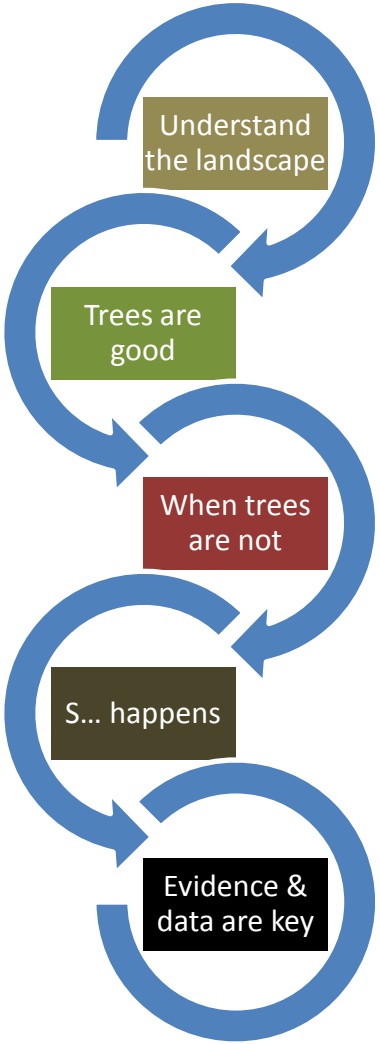
- Thinking & Planning – having one! FCOP & Roading manual.
- Water control – don't mix clean and dirty, bunds, channels, flumes, cutoffs, water bars, etc
- Covers – mulches, fabrics, blankets hydroseed, compaction, chemicals, etc
- Interceptors – surface roughners (across slope), slash, silt fences, hay bales, sediment traps, sediment ponds, check dams, filter strips, etc

- Principles apply – use/cost/performance may limit effectiveness
- If slopes steep, landslides probably >>> than other processes – E&SC methods often window-dressing and green wash!

Take home messages & learning points revisited

- Erosion ≠ dirty stream water & sediment yield
- Not all bare areas generate sediment or are impt. for sediment yield
- Delivery usually happens in first rain storm for scalped or DD areas
- Most surface sediment is generated in first 12 months - surface tends to crust reducing generation
- Vegetation recovery isn't fast enough to affect most sediment generation on bare areas
- Lot of redistribution of sediment downslope of source – slash and micro-topography catch it
- Surface erosion contribution is small compared to landslide & scalping
- Hydro-seeding needs to be done immediately after bare areas created to have much effect – can this be achieved in practice?
- Annual post-harvest SSY across NZ → 10's -100's t/km^2/y
- Connectivity of source to streams **THE** most critical factor for SSY
- Slope is 1º control on sediment delivery – not vegetation
- Roads, landings & earthworks better now than past
- Riparian buffers are not the panacea many think they are
- Increased sediment yield at harvest time is a fact of life!
  - It is all about re-adjustment in the landscape to new conditions, ie without a forest
- Question: can we improve on this?
- Yes – small gains from improved source control & runoff management – it will cost, ….. BUT
- will NOT be able to stop all sediment nor most landslides from occurring (Nature)

What we now know



- Settlers shouldn't have cut most trees down in our steeplands
- All NZ is susceptible to erosion – some places more than others
- Nothing is static – it's a dynamic landscape
- We can try to manage landscape response to the small events but not the large ones - Nature always wins!
- Trees are important for reinforcing soils & can help manage risk & reduce shallow landsliding & other processes in short to medium term horizons
- Erosion control efforts need to be targeted – to process & place
- Sediment control needs to focus on generation not end of pipe
- We need better mitigation performance numbers
- To improve landscape resilience, we need more trees in our steepland landscapes but maybe not blanket forests
- We need to continue to think catchments & connections – ICM
- A good conversation can bring about change

We can't stop erosion:
how we live with it, and try to manage it is our choice