Manaaki Whenua
Landcare Research

MANAAKI WHENUA – LANDCARE RESEARCH

How will climate change our landscape

Manaaki Whenua LINK seminar: 100

OUR VISION

Kia matomato te tupu a Tāne, a Rongo, a Haumia-Tiketike

Let it be that the land and all its fruits may flourish

What we do is focussed around:

Four ambitions for New Zealand

OUR ENVIRONMENT
We are an environmentally informed nation, taking action together.

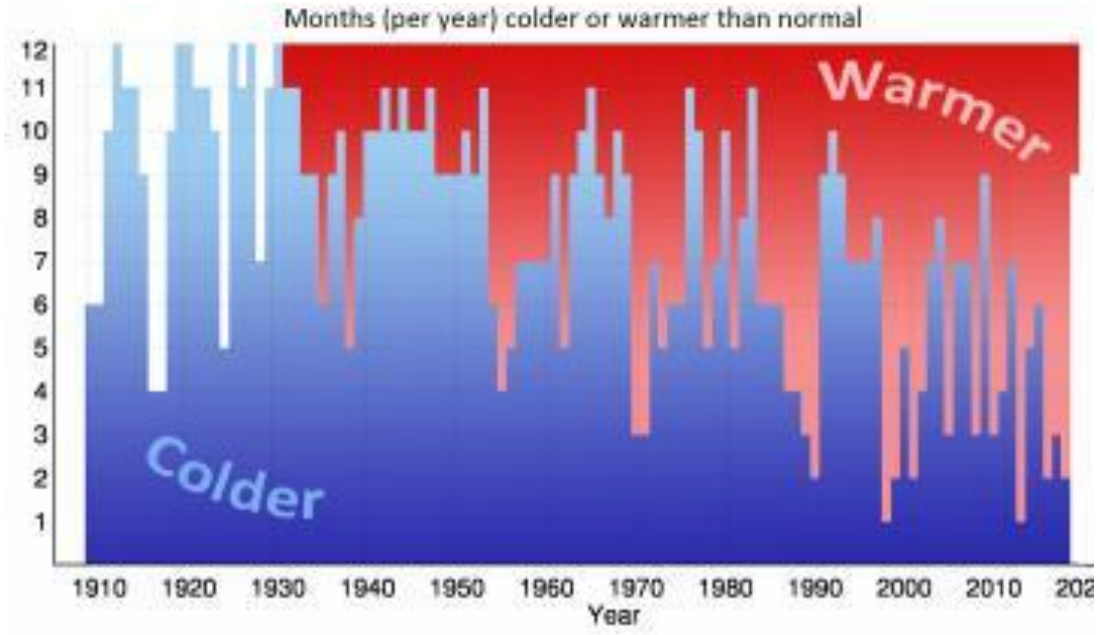
OUR BIODIVERSITY
We know, value and actively preserve our unique biota and ecosystems.

OUR BIOSECURITY
Our land is protected from invasive biological threats.

OUR LAND
We use our land, soil and water resources wisely.

March temperatures more evidence of a warming climate

- Officially, this March was the second equal hottest on record,
- According to NIWA's long-term temperature record, last month's temperature was 1.89°C above average.
- The first three months of this year have been the fourth warmest start to the year since records began in 1909.



Ross Ice Shelf melting 10x faster...

- "We've shown that the ocean is melting the north-western corner of the Ross Ice Shelf much faster than the rest of the shelf, and a lot of that melting is linked to summer heat from the top layer of the ocean,"

NIWA

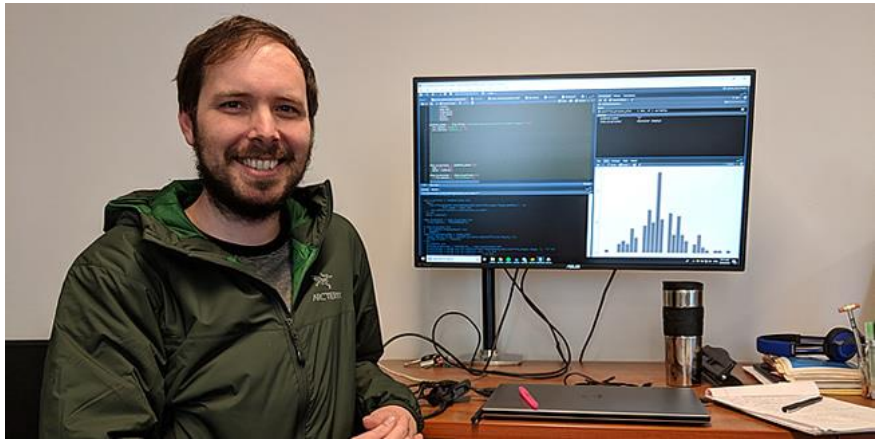
Image: Science Media Centre

Environment Aotearoa 2019

- **Theme 1: Our ecosystems and biodiversity**
- Our native plants, animals, and ecosystems are under threat
- **Theme 2: How we use our land**
- Changes to the vegetation on our land are degrading the soil and water
- Urban growth is reducing versatile land and native biodiversity
- **Theme 5: Our changing climate**
- New Zealand has high greenhouse gas emissions per person
- Climate change is already affecting Aotearoa New Zealand

Why Manaaki Whenua

- Multi- and trans-disciplinary research
- Ecosystems approach
- Global perspective
- Climate change cuts across all areas of research, our ambitions
- Research excellence



Empirical measurement of the impact of climate change: correcting for measurement error in precipitation and understanding the incidence of impacts, looks at how rainfall impacts agriculture and land. **Kendon Bell, Rutherford Foundation Fellowship**

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How will climate change our landscape:

- soils and carbon
- the economics of flooding
- resilience and adaptation

Paul Mudge
Patrick Walsh
Nick Cradock-Henry

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Climate change and soil carbon: risks and opportunities

Paul Mudge

Link seminar 100, May 2019

Outline

1. Why is **soil** carbon important in relation to climate change?

2. How much carbon is in NZ soils?

3. How are our soil carbon stocks changing?
   - Impact of **land use, land management** and **climate**

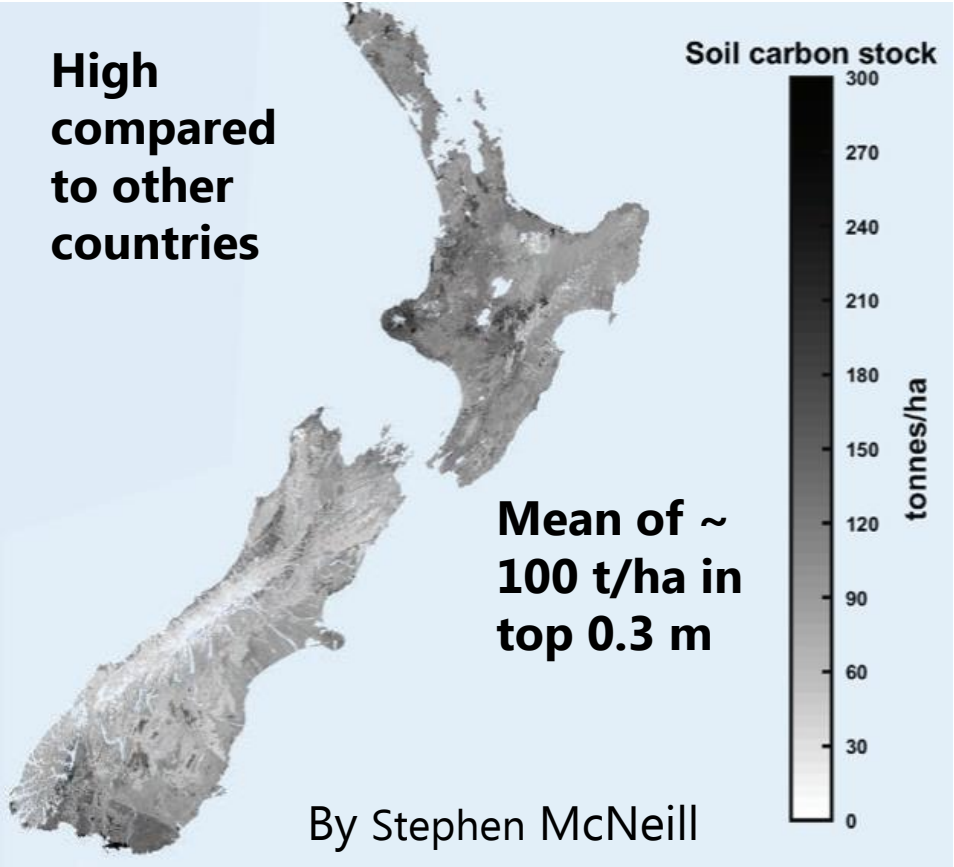
4. Summary

Why is soil carbon important?

1. **Critical for soil health**
   - Maintenance of soil structural stability
     - Affects root growth, air/water movement, runoff/erosion
   - Food source for soil biota
   - Nutrient cycling
   - Soils with higher carbon are generally more **resilient** to perturbations
     - e.g. **climatic** extremes; intense rainfall, drought

2. **Feedbacks with climate via CO_2 release or sequestration**
   - Globally soils contain about twice as much carbon as the atmosphere
   - Changes could have a big impact on atmospheric CO_2 concentrations.
     - Risk and opportunity

How much carbon is in NZ soils?



Totals

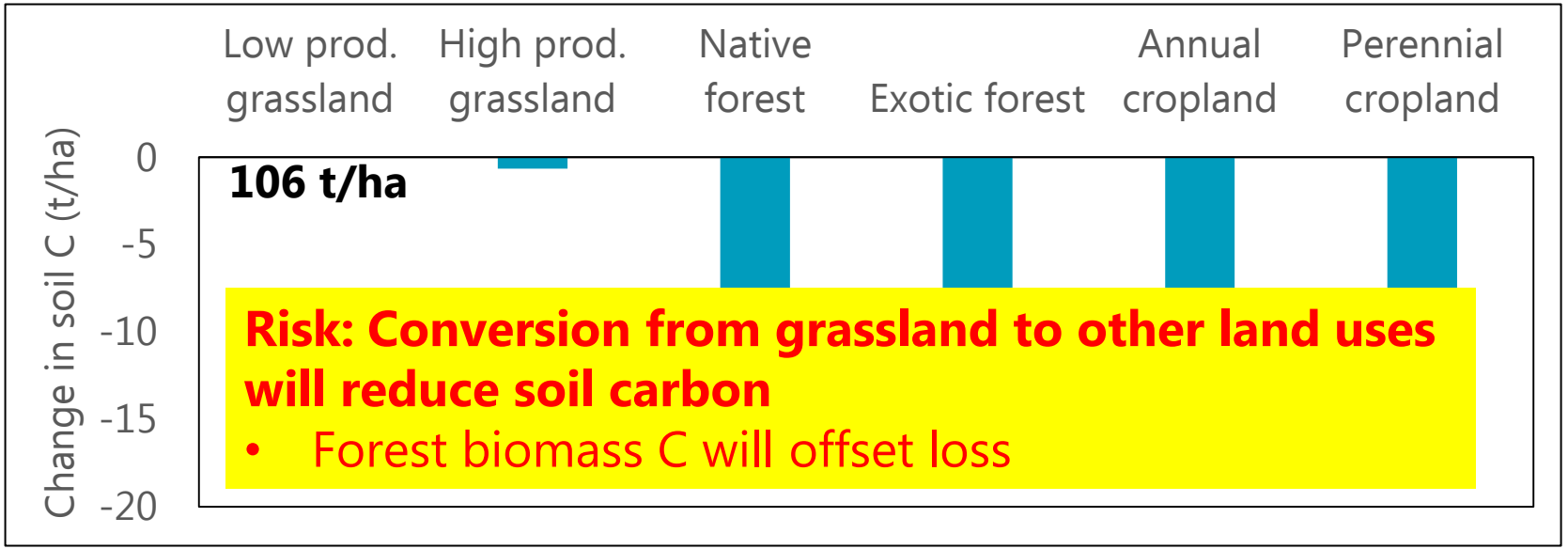
- About 2.5 Gt in top 0.3 m
- About 3.7 Gt in top 1 m
  = \$350B @ \$25 t CO_2

- Forests have about 1.9 Gt carbon in biomass

How are our soil carbon stocks changing?

Current NZ soil carbon monitoring system:

- National scale statistical model recently refined by Stephen McNeill
- Predicts changes in soil carbon stocks with changes in land use



How are our soil carbon stocks changing?

Current NZ soil carbon monitoring system

- National scale statistical model recently refined by Stephen McNeill
- Predicts changes in soil carbon stocks with changes in land use

Limitations of the current system

- Assumes equilibrium reached after 20 years for given land use
- Does not account for long-term temporal changes or management effects within land uses

- Currently no system to directly measure soil carbon changes in NZ's agricultural soils

Statistical design of a national soil carbon monitoring programme (direct measurements)

- We recommended that a **minimum** of 377 sites be established to monitor changes through time within each of:
  - Cropland (78)
  - Horticulture (92)
  - Dairy pasture (71)
  - Flat-rolling drystock (76)
  - Hill-country drystock (60)

- Designed to detect change of **2 t ha^{-1}** within each target area at the **national** scale. Re-sample every 3-5 years.

- More sites required if finer resolution is wanted (e.g. detection of change within different regions, soils, crop types, or grazing intensities)

Soil carbon monitoring: Farm scale

- Many farmers are interested in, and beginning to measure soil carbon
  - No consistent method for in NZ…
- Current MPI funded project to design and document a consistent repeatable system to monitor soil carbon stocks at the farm scale

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CSIRO

THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

Plant & Food RESEARCH
RANGAHAU AHUMĀRA KAI

- Another aligned project to develop of an efficient nested system to monitor soil carbon stock changes across **multiple scales** (national – sector/region – farm)

Specific studies on the impact of management on soil C

1. **Sampling existing long-term field experiments**
   - Long-term P fertiliser, irrigation and tillage trials
2. **National/regional sampling on commercial farms: paired site approach**
   - Dairy vs sheep & beef pastures
   - Maize cropping vs pasture
   - 'Conventional' vs 'regenerative' pastoral systems (grazing mgmt.)
   - Irrigated vs dryland pastures
3. **New experimental manipulations aiming to increase soil C stocks**
   - Full inversion tillage for pasture renewal (Plant & Food Research)
   - More diverse pastures (more resilient to CC + other benefits)
   - Irrigation and deep rooting lucerne

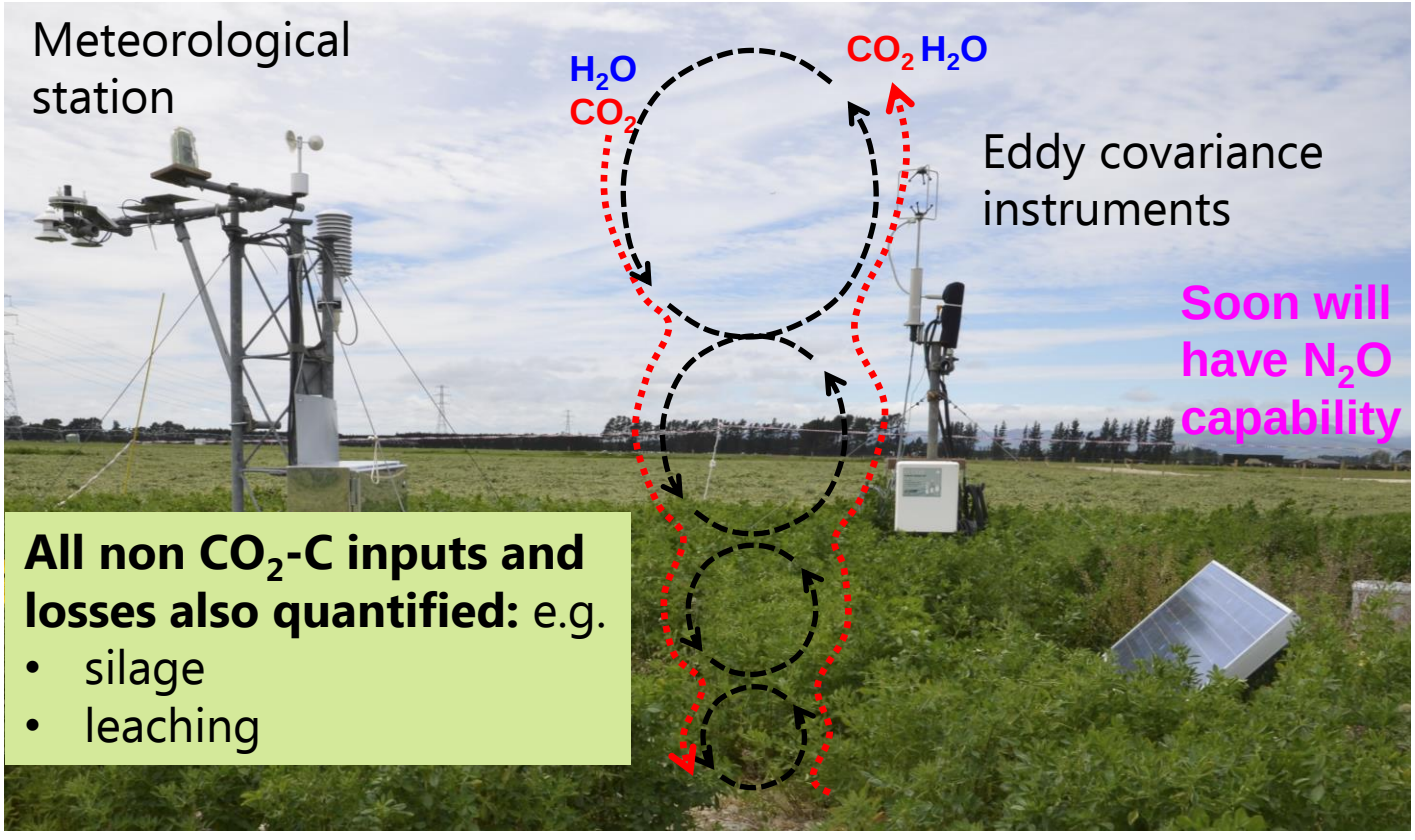
Paired site approach:

Impact of irrigation on soil C and N stocks

Study 1: Significantly **less** C & N under irrigated pastures (7 t C ha^{-1}, 0.6 t N ha^{-1})

Mudge PL, Kelliher FM, Knight TL, O'Connell D, Fraser S, Schipper LA 2017. **Irrigating grazed pasture decreases soil carbon and nitrogen stocks**. Global Change Biology 23: 945-954.

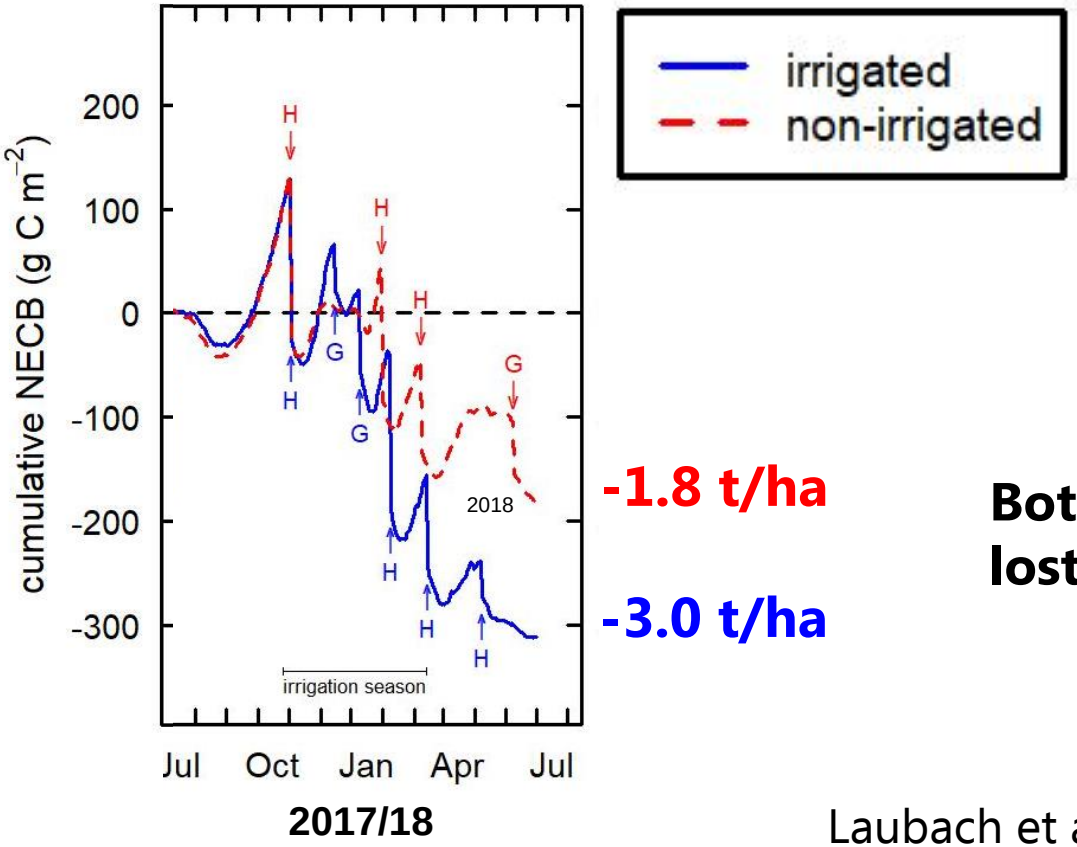
New experiments: Paddock scale carbon balances of irrigated and non-irrigated lucerne



Drainage, carbon and nutrient leaching

Lysimeters 1.5 m deep, 2 m diameter

Cumulative carbon balance



-1.8 t/ha

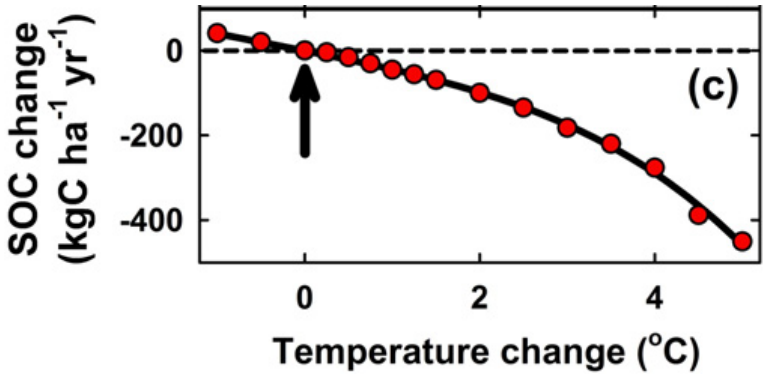
-3.0 t/ha

Both systems lost carbon!

Laubach et al. (submitted)

How will warming impact soil carbon?

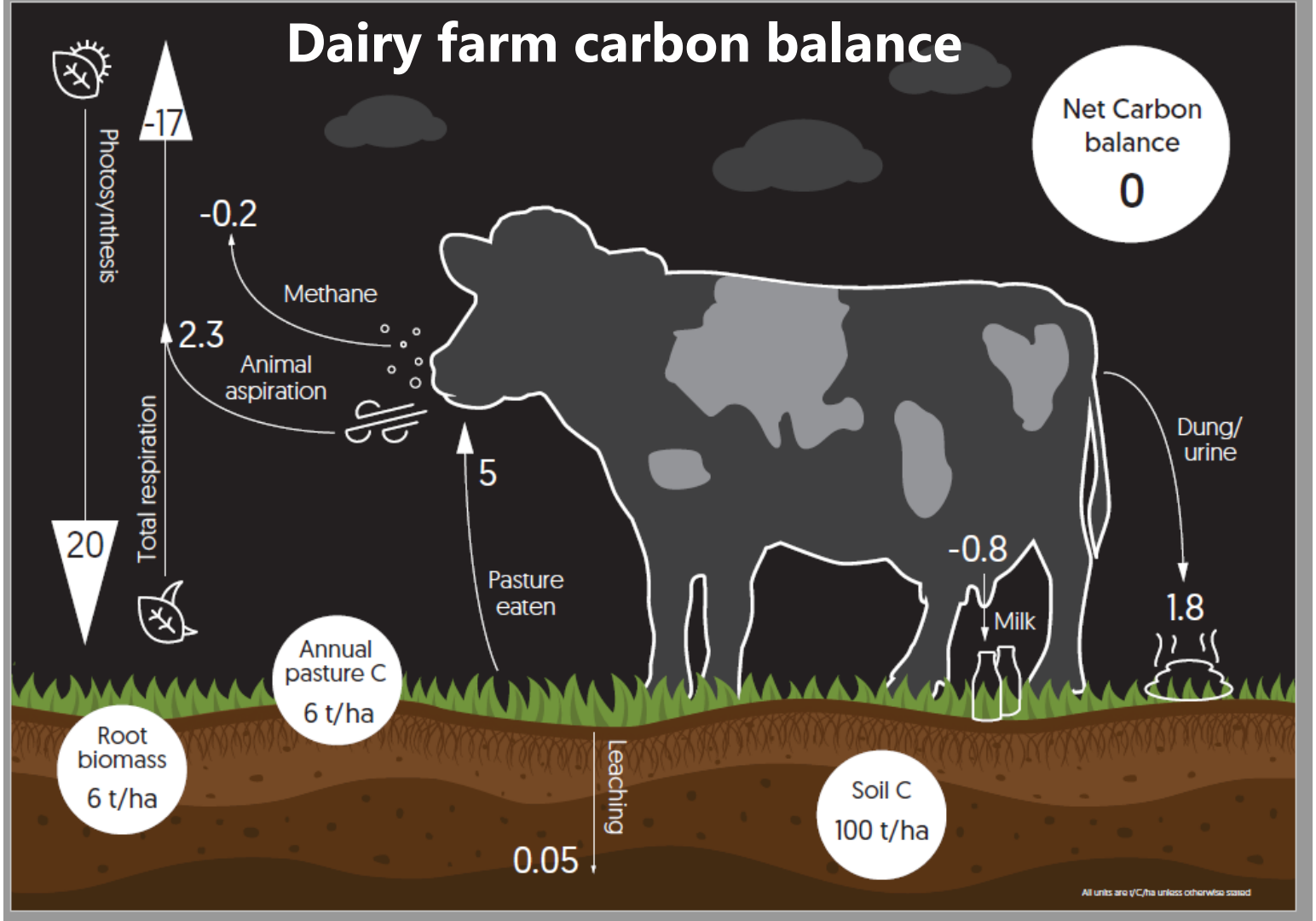
- Modelling of a Waikato dairy pasture system indicates warming will **reduce** soil carbon stocks



Kirschbaum, M.U.F.; Schipper, L.A.; Mudge, P.L.; Rutledge, S.; Puche, N.; Campbell, D.I. (2017). The trade-offs between milk production and soil organic carbon storage in dairy systems under different management and environmental factors. Science of the Total Environment 577: 61-72.

Summary

1. Soil carbon is critical for many ecosystem functions
2. NZ soils contain lots of carbon. **We need to maintain what we have!**
   - Keep soils vegetated. Pasture is best.
   - Minimise time between sward/crop removal and resowing
   - Reduce irrigation expansion? Optimise irrigation scheduling??
3. 'Potential' opportunities to increase soil carbon
   - Increase sward diversity and rooting depth
   - Modify grazing regimes ('regenerative agriculture'??)
   - Implementation of full inversion tillage
   - Restore wetlands! (this will definitely work)
4. Current development of national and farm scale carbon monitoring systems will help identify land uses and management regimes which increase soil carbon


Dairy farm carbon balance
Net Carbon balance
0
-17
Photosynthesis
-0.2
Methane
2.3
Animal aspiration
Total respiration
20
5
Pasture eaten
-0.8
Milk
Dung/ urine
1.8
Annual pasture C
6 t/ha
Root biomass
6 t/ha
Leaching
0.05
Soil C
100 t/ha
All units are tC/ha unless otherwise stated

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Flood Mitigation Schemes: Distributional Implications and Analysis

- Patrick Walsh, Landcare Research-Manaaki Whenua
- with
- Thomas Robertson, Contractor
- Ryan Paulik, NIWA

- LINK SEMINAR 100

- Funding – Deep South National Science Challenge

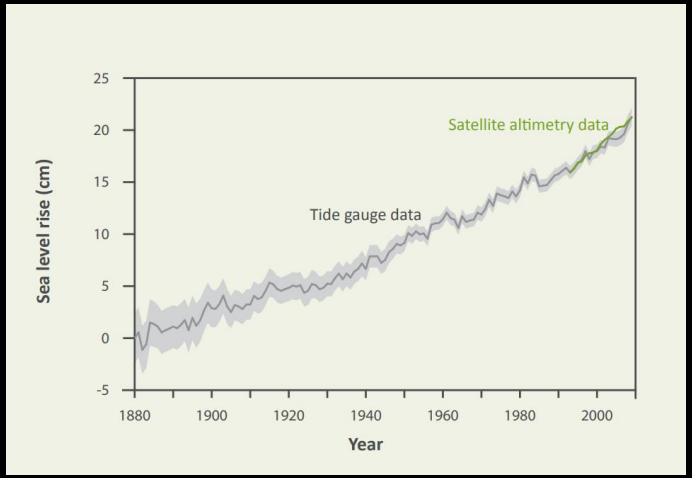
Floods in New Zealand

Flood damage increasing rapidly

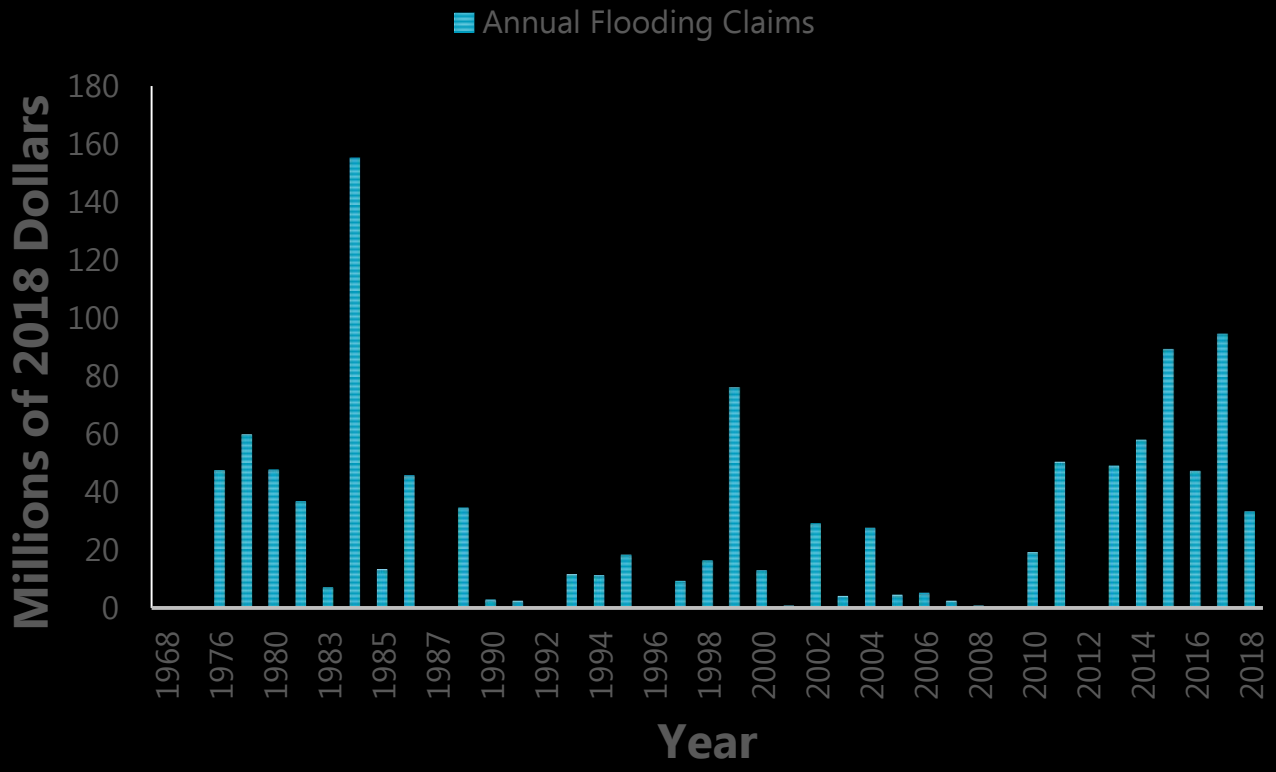
Over $300 million in insurance claims since 2014

Increasing population movement towards the coast.

Increasing threat of sea level rise



Insurance Council NZ Private Insurance Claims



Flood Risk Management in New Zealand

Ad hoc approaches early to mid 1900's

Centralized approaches – Central Government – Up to early 1990's

Devolved Approach Local risks - responsibility of local authorities

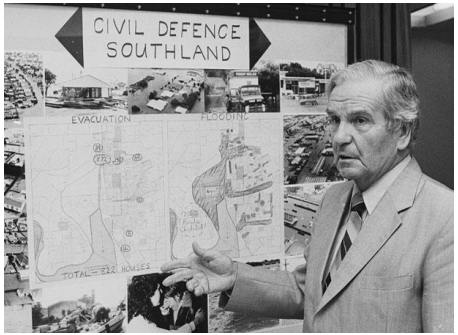
Centralised Flood Management

Problems with early flood management: *Soil Conservation and Rivers Control Act 1941*.

Significant subsidies for river management and flooding works.

Catchment Boards –broad powers and funding.

Under this regime many of New Zealand's current flood protection structures were built.



HEAVY GALE AND FLOODS IN OTAGO.

LOSS OF THE STAR OF TASMANIA, WATER NYMPH, AND WILLIAM MISKIN.

NINE PERSONS DROWNED AT TOTARA STATION.

By the arrival of the s.s. Beautiful Star from Dunedin yesterday we learn that the heavy gale which passed over the province on Monday and Tuesday night, the 3rd instant, had the most disastrous effects. The streets of Dunedin were flooded—there being in one part of Rattray street quite two feet of

Government Reforms

Variety of local government reforms 1980's and 1990's

Catchment boards authority given to regional councils

Ministry of Works and Development – previously $40 million

1991 Resource Management Act

Resource Management Act 1991

Public Act 1991 No 69
Date of assent 22 July 1991
Commencement see section 1(2)

Devolved system - consistent with Government's policy on civil defence and emergency management

Local risks are the responsibility of local authorities.

Flood Management Funding

Central government funding mostly gone after RMA and devolved approach.

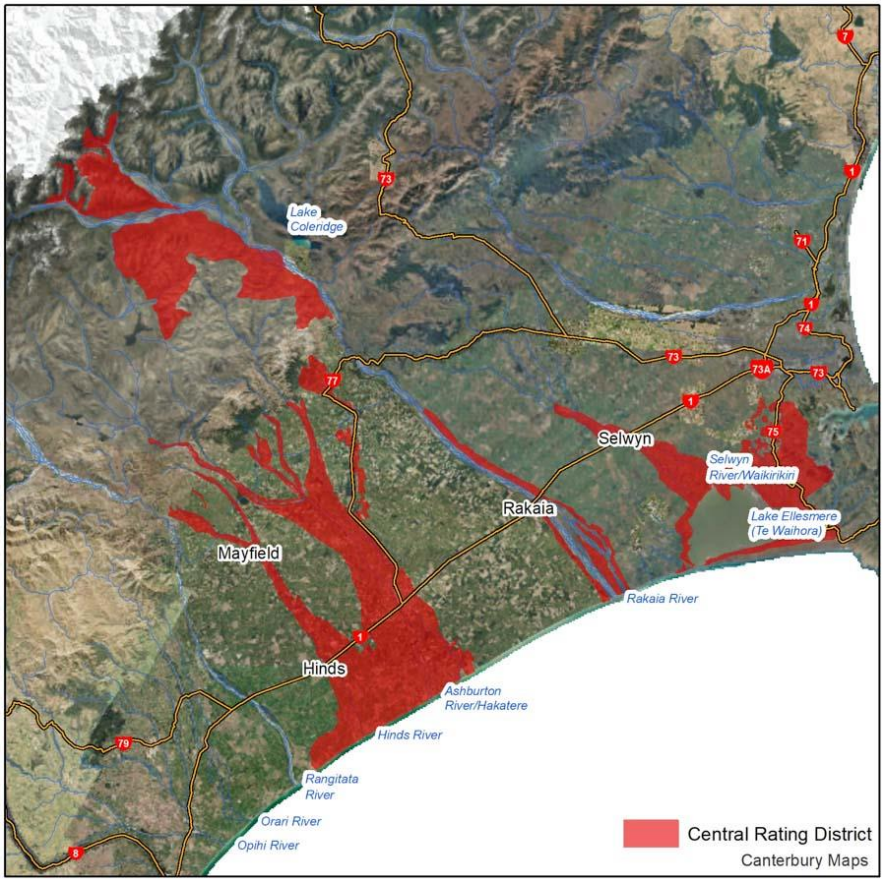
Two main sources now

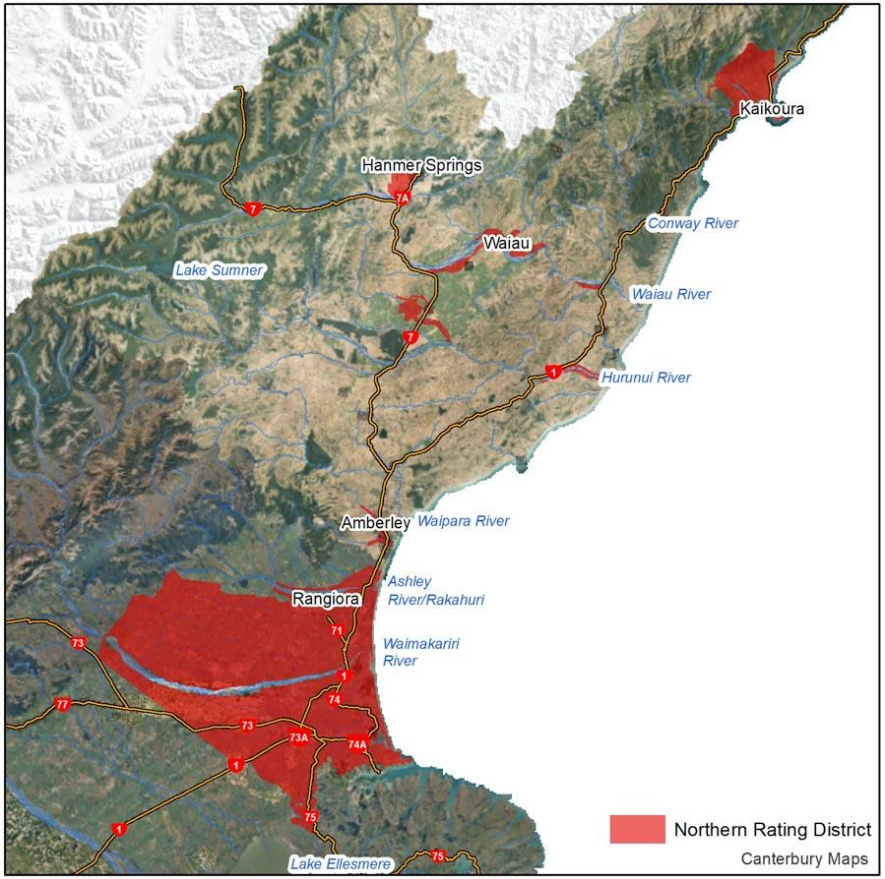
1. Regional Council funding from general taxes

2. Flood schemes

- Use targeted rates (property taxes) on homes in flood risk areas.
- Augment flood management funding
- Some of the biggest "losers" in funding flood infrastructure:
  - Flood risk-free general tax payers
- Flood schemes – those who benefit most pay more.

Canterbury – Flood Scheme locations

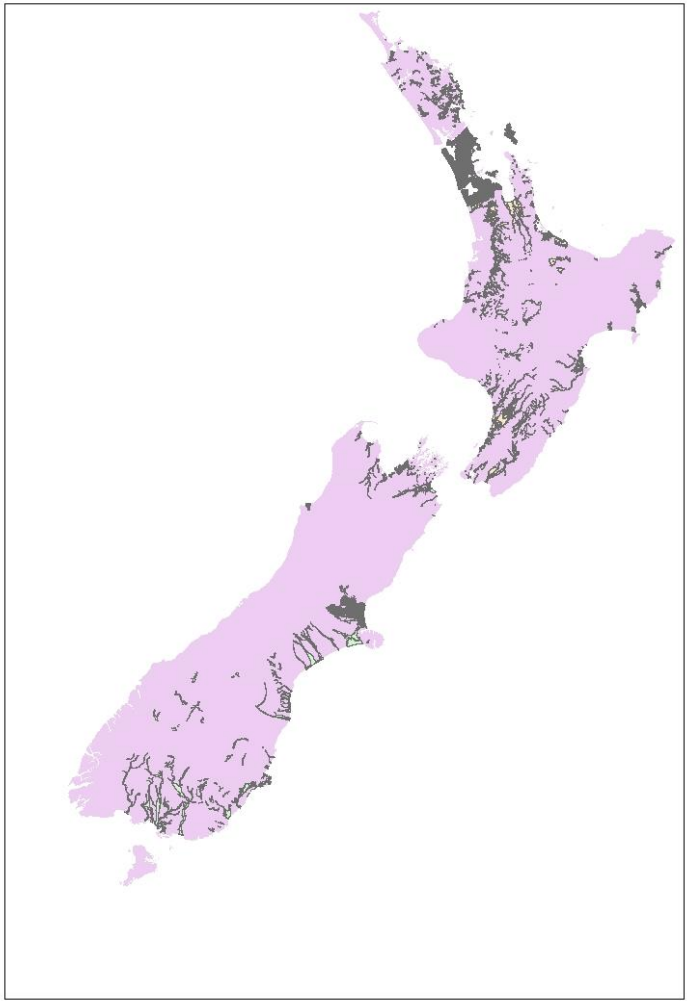




Flood Zones

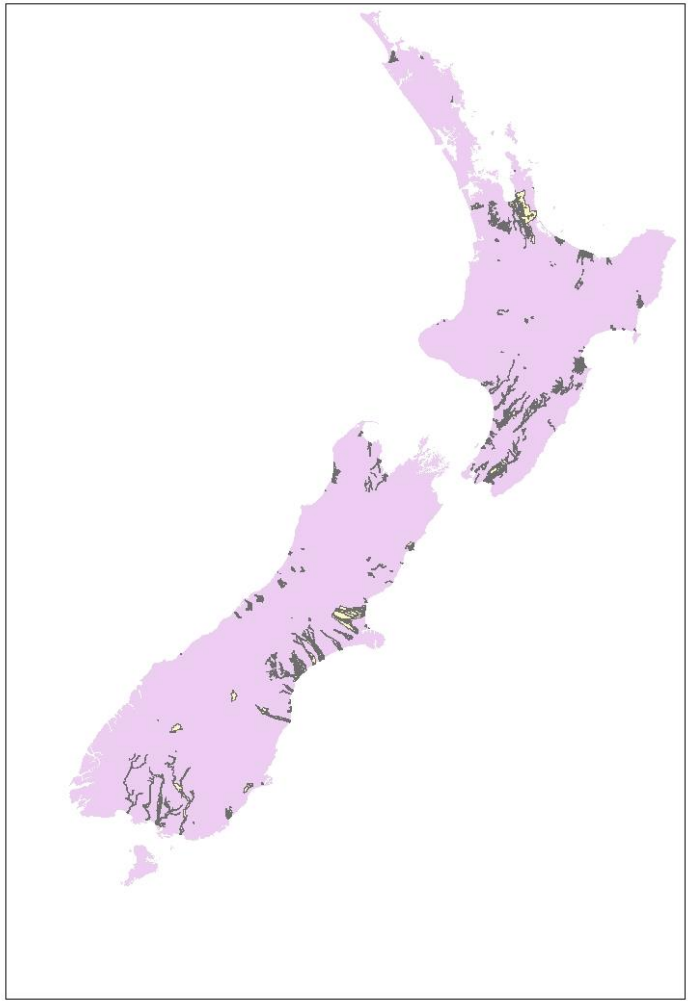
Data collection through NIWA partners

Best estimate of flood hazards from publicly available data



Flood Schemes

- No Schemes in Auckland, Nelson, Marlborough



Survey of Rural Decision Makers

"historically, has flooding been a concern" in your area?

Rural Decision Makers SURVEY2017

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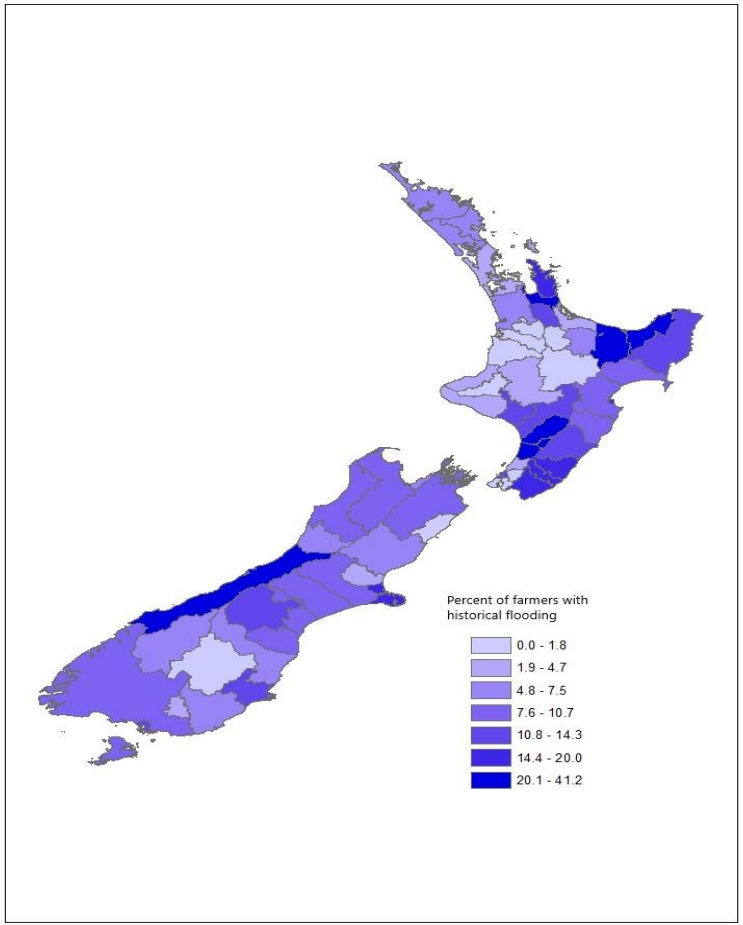
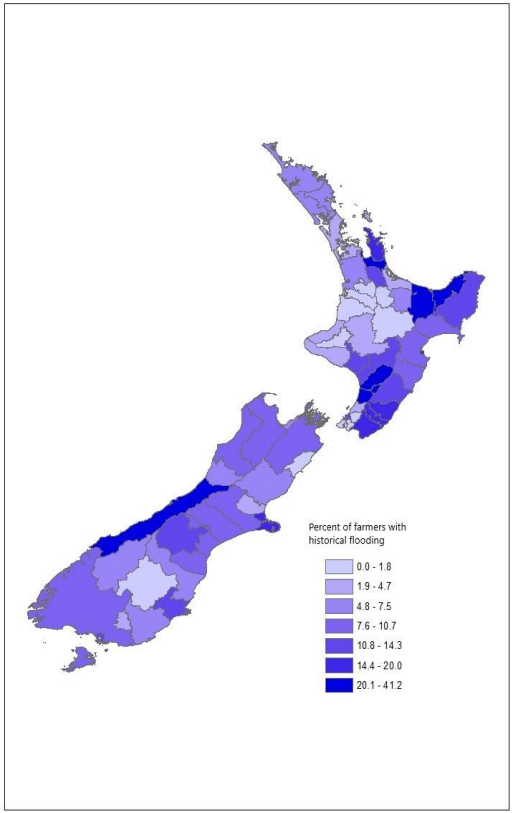
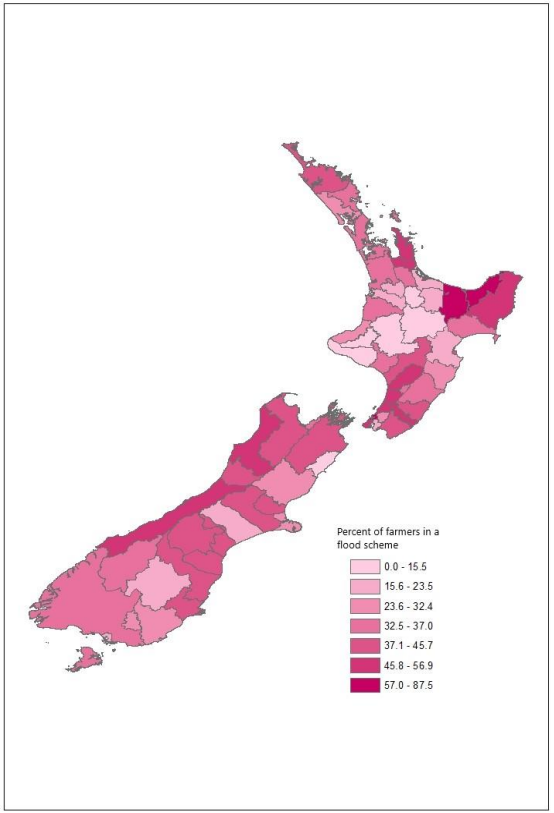


Flood Risk data

Flood Risk – perception



Participation in Scheme



Flood Scheme Analysis

Several meshblock-level analyses of flood schemes.

Briefly Review two today.

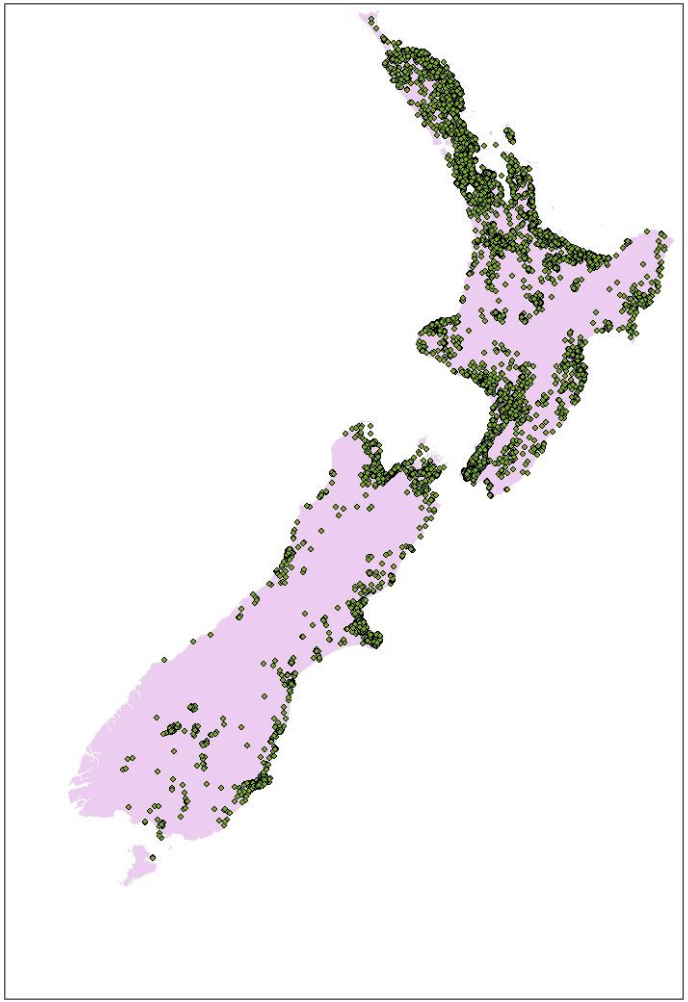
1. Impact of schemes on flood insurance claims
2. Scheme location analysis – what local factors associated with schemes.

First – Impact of Schemes

Do schemes have an impact on flood damages?

Data on EQC Claims

EARTHQUAKE COMMISSION
Kōmihana Rūwhenua



ICNZ Insurance Council of New Zealand

Private Insurance Claim data?

	Year	Description	Date	Cost
1	2017	South Island flooding	20-22 Jul	31.2
2	2017	Nationwide snow/wind/rain	12-14 Jul	12.5
3	2017	Cyclone Cook Remnants	13-16 April	18
4	2017	Cyclone Debbie Remnants	3-7 April	66.4
5	2017	Upper North Island Flooding	7-12 March	61.7
6	2017	Port Hills Fires	13-17 February	18.3
7	2017	Dunedin Flooding	13-Feb	1.7
8	2017	Nationwide Severe Weather	18-23 January	8.6
9	2016	Lower North Island Flooding and Wind	14-17 November	9.1
10	2016	Flooding - Auckland to Waikato and Hailstorm Hawke's Bay	2-3 October	.55
11	2016	Heavy Rain and Flooding - Coromandel, Bay of Plenty, Gisborne and Hawke's Bay	25-30 September	1.16
12	2016	Nationwide Storm	7-9 September	3.8
13	2016	Flooding and Gales - Auckland	29-Jun	1.81
14	2016	Flooding- Lower North Island	5-May	3.9
15	2016	Flood - Coromandel and Auckland	17-Apr	.59
16	2016	Flooding and Wind - North and South Islands	23-24 March	30.2
17	2015	Flood - Gisborne	21-Sep	.81
18	2015	Flooding and Storm - Upper North Island	18-19 July	6.15
19	2015	Flooding and Storm South Island West Coast	19-22 June	8.4
20	2015	Flooding and Storm Lower North Island including Whanganui	18-21 June	41.5
21	2015	Flood and Storm - North and South Islands excluding Otago	2-5 June	3
22	2015	Flooding and Storm - Otago	2-4 June	28.2
23	2015	Bay of Plenty Tornado	14-May	2.8
24	2015	Extreme Weather Lower North Island	13-15 May	21.9
25	2015	Cyclone Pam	15-18 March	1.45
26	2015	Flooding and Storm North and South Islands	6-7 March	1.25
27	2014	Hailstorm - North and South Islands	4-Nov	4.9
28	2014	Auckland Power Outage	5-Oct	2.6
29	2014	Northland - Coromandel Storms	8-10 July	18.8
30	2014	Nelson-Tasman Floods	25-Jun	2.7

Figure 5: Total value of weather-related: EQC pay-outs (upper) and private insurance payments (lower)

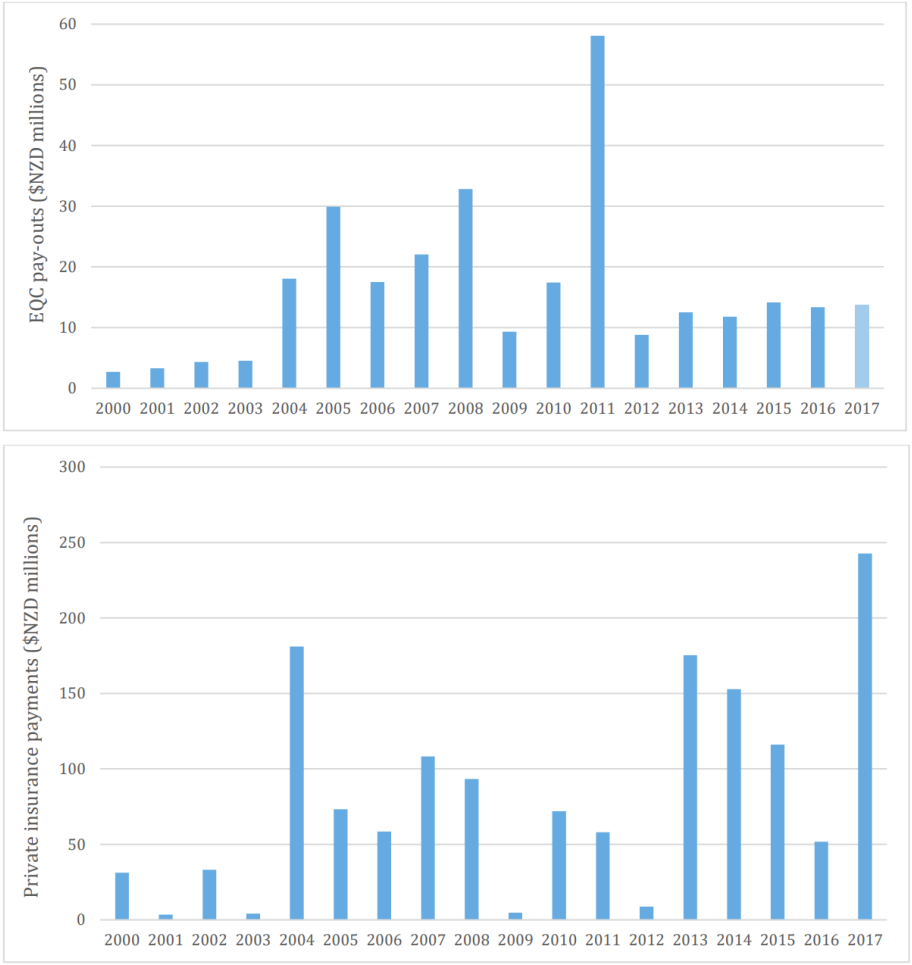


Table 1 - Descriptive statistics: NZ Landslip/Storm/Flood claims (2000 - 2017)

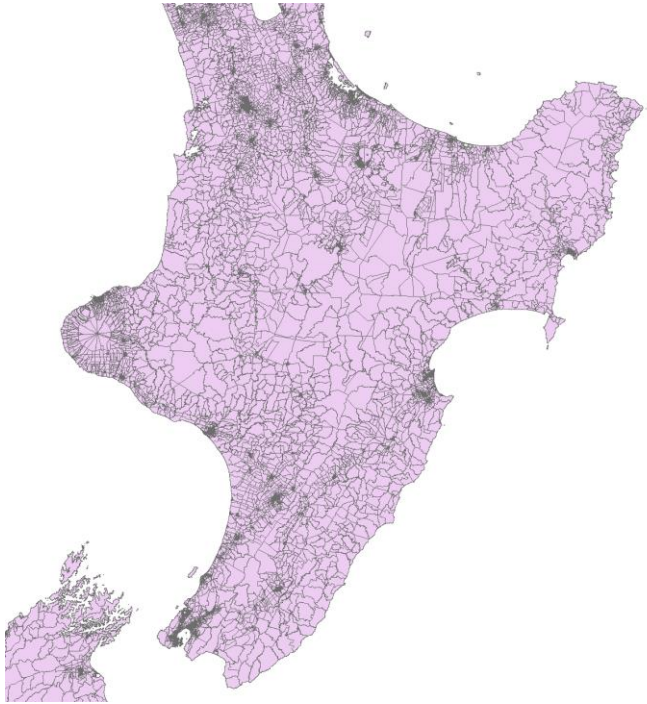
Total number of claims received	26,180
Claims with property location data	18,930
Unresolved claims	803
Claims from properties that had lodged a prior claim	2,194
Total amount paid for land damages (millions)	$ 198.89
Total amount paid for building damages (millions)	$ 92.99
Total amount paid for contents damages (millions)	$ 2.62
Number of resolved claims - including zeroes	25,377
Mean amount paid - all resolved claims including zeroes	$ 11,420
Standard deviation of amount paid - all resolved claims including zeroes	$ 40,340
Number of resolved claims - excluding zeroes	14,546
Mean amount paid - all resolved claims excluding zeroes	$ 19,930
Standard deviation of amount paid - all resolved claims excluding zeroes	$ 51,670

Notes: This table contains descriptive statistics, for claims classified as 'Landslip/Storm/Flood', which were lodged with New Zealand's public natural hazard insurer (the NZ Earthquake Commission "EQC") between Jan 2000 and Oct 2017. "Claims with property location data" refer to those for which EQC hold the data to link the claim's unique property identifier to longitude-latitude coordinates. Unresolved claims are those which EQC classify as 'Open' – where the claim has not yet been settled. A prior claim refers to claim lodged relating to a different weather event. 'Zeroes' refer to claims which were lodged but for which the records indicate that the EQC did not pay out. All monetary values are expressed in 2017 NZ dollar values (specifically, by inflation using the NZ CPI to the second quarter of 2017). All claims exclude GST.

Econometric Models

Controlling for other social and economic factors, do schemes have an effect on:

Total sum of claims in a meshblock ($)

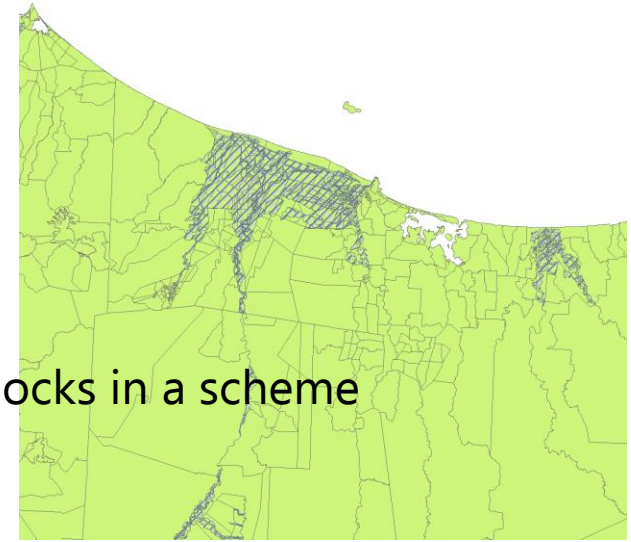


Total sum of EQC claims paid

Tobit Regression Models

On average, flood schemes reduce meshblock claims amount by approximately

$20,000 – $40,000



There are multiple meshblocks in a scheme

However…

Location Analysis – where are Schemes

Targeted rates – homeowners – affordability?

Distributional implications?

Hawke's Bay: "Where local landowners consider that a local community drainage/flooding scheme may be necessary in their catchment, ***please discuss with your local HBRC Councillor or HBRC asset management staff****."*

Social Capital

Community Strength

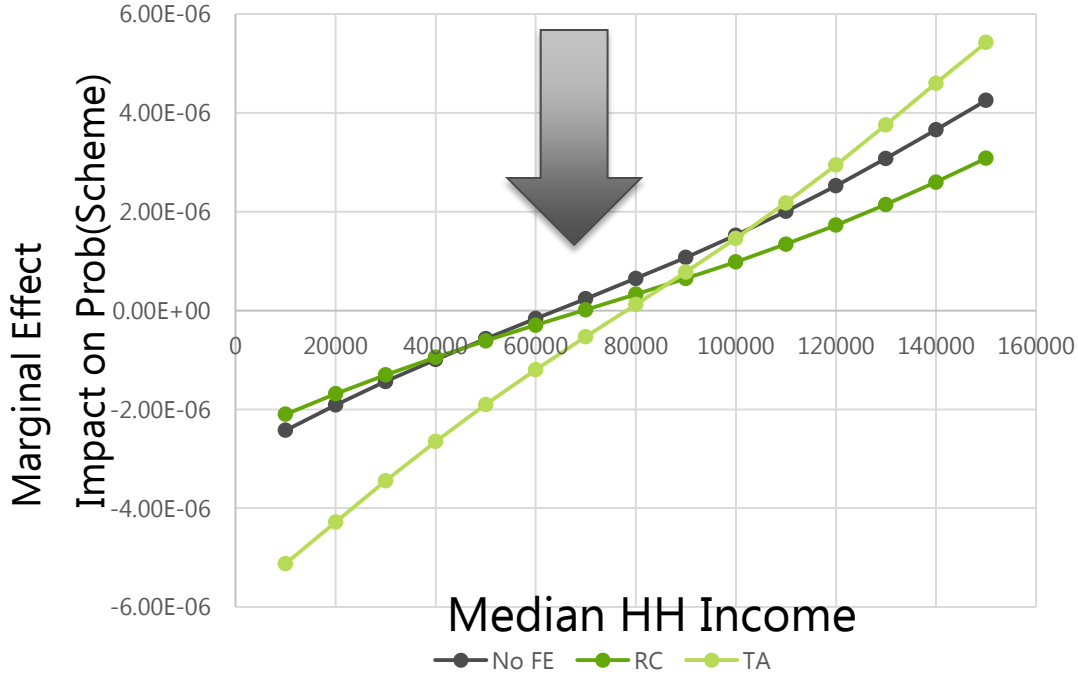
Wealth/Assets

Analysis – determinants of flood scheme location.

Results

- Flood schemes are widely used – largely protecting ag industry/infrastructure.
- Flood risk consistently significant predictor
- Schemes have a significant impact on EQC claims
- However, potential distributional concerns
- Income is a significant factor.
- Very few studies of schemes

Marginal Effect of Income



BUSINESS | Personal Finance

Biggest home insurer to charge more for natural disaster and weather risk

29 Apr, 2019 5:40pm

4 minutes to read

IAG, New Zealand's largest home insurer, will take natural disaster and weather related risk into account in its premiums. Photo / File

By: **Tamsyn Parker**
Money Editor, NZ Herald
tamsyn.parker@nzherald.co.nz

Will this reduce migration into flood/hazard zones?

Depends on information about flood zones

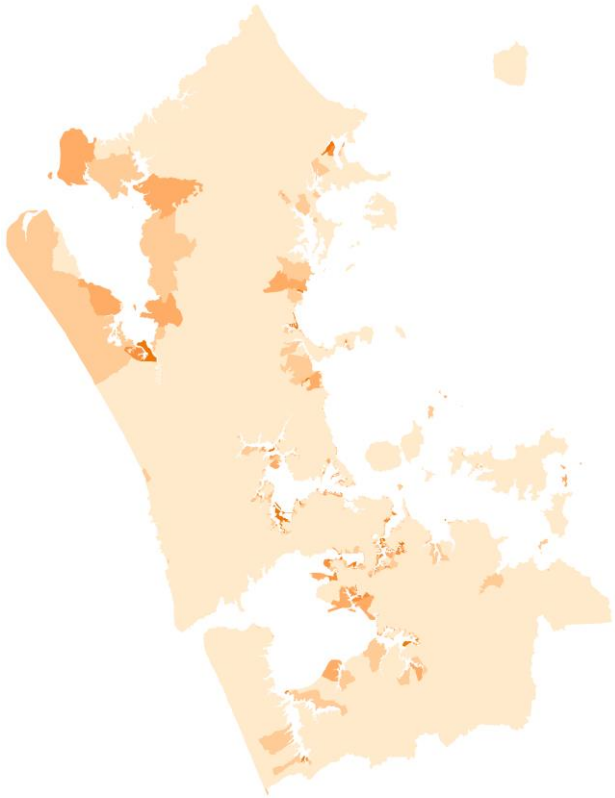
- More demand for flood hazard data.

Auckland Sea Level Rise

Darker meshblocks have higher SLR risk.

Will require more flood management and schemes.

Other policies?



Thank you!

walshp@landcareresearch.co.nz

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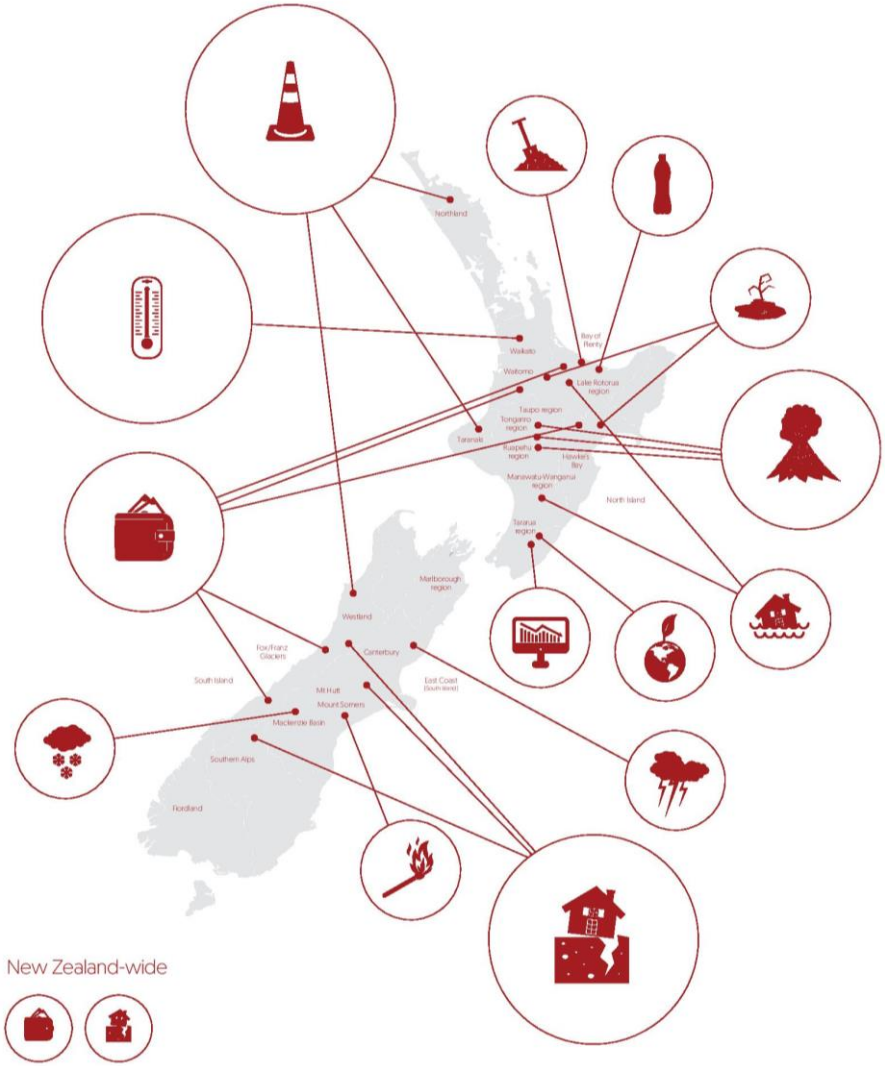
Enabling adaptation to climate change: Impacts, Implications, Decisions, Actions

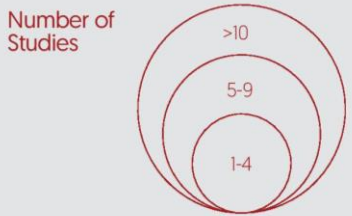
Nick Cradock-Henry



Primary industries contend with shocks and stressors.

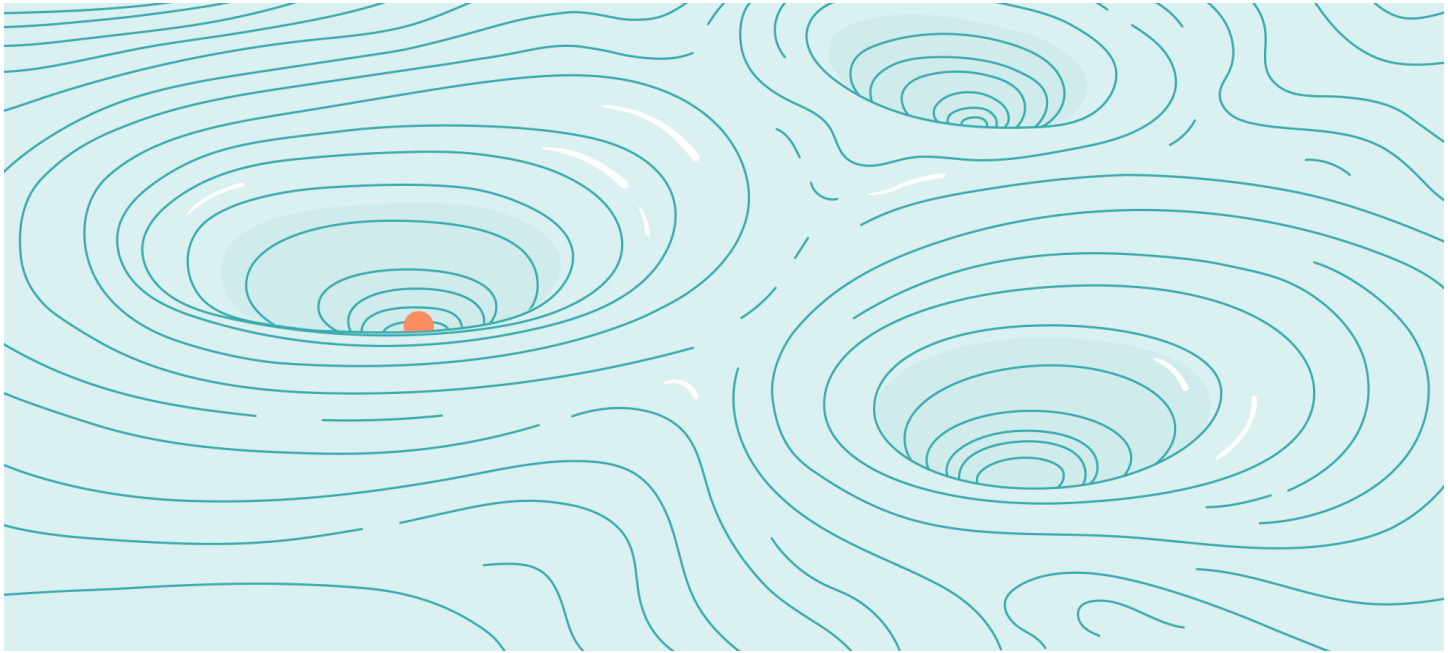
- low-frequency, high-magnitude
- slow-onset, creeping hazards
- geo-climatic, socio-economic

Compounding and cascading effects.



Spector, S., Cradock-Henry, N.A., Beaven, S., Orchiston, C., 2018.
https://doi.org/10.1007/s10113-018-1418-3

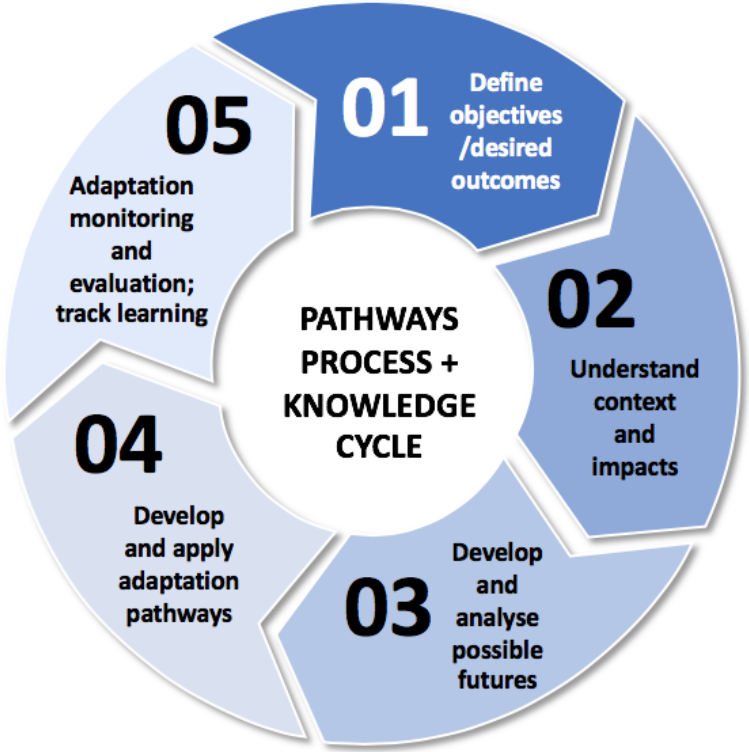
Farm systems are able to adapt, self-organise, learn and increase adaptive capacity to buffer against shocks and stresses (coping)



Climate resilience escalating demand for information about the future impacts of climate change to guide resilience in practice.

Cradock-Henry, N.A., Fountain, J., 2019. https://doi.org/10.1016/j.envsci.2019.01.015

What information is needed to enable adaptation?



Cradock-Henry, N.A., Frame, B., Preston, B.L., Reisinger, A., Rothman, D.S., 2018. https://doi.org/10.1007/s10584-018-2270-7

Adaptation knowledge cycle

IMPACTS
Direct impacts of higher Ts, lower P, extremes.

How, where, and what will the impacts of climate change be?

IMPLICATIONS
Impacts have implications for management.

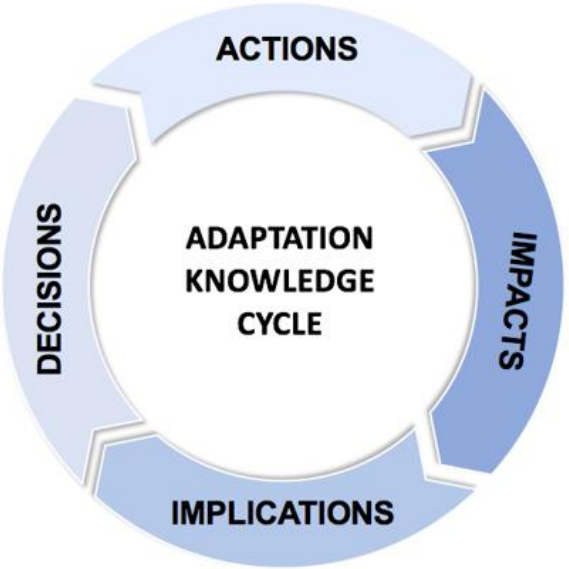
What is at risk? In what ways?

DECISIONS
Capability and capacity to make informed risk decisions.

What decisions need to be made? And when?

ACTIONS
Appropriate actions to prevent or minimise damage.

How is change enabled?



(Cradock-Henry et al., 2018a)

What do we know?

- **New knowledge and enhanced understanding of effects of climate change on primary industries.**

- **Effects**
  - Drought
  - Biosecurity
  - Climate variability and extremes
- **Sector-specific knowledge**
  - Pastoral farming
  - Cropping and arable
  - Horticulture and viticulture
  - Cross-sector science

- **Published literature (2007-2017)**
  - 224 NZ-papers on GHG mitigation
  - 22 NZ-papers on adaptation

- **MPI SLMACC Research**
  - 32 projects (139 projects)
  - Clark & Nottage, 2012 ($1.5M) pan-sector
  - Three projects >$500,000
  - Smaller, short-term (1-2 yrs.) projects ~$150-200K

Drought

SLMACC

IIDA	Lead author	Year	Sector	Location
Impacts	Tozer	2011	Pastoral	National
Implications	Clark	2008	Cross-sector	National
Decisions	Burton	2008	Cross-sector	Regional; North Otago, South Canterbury
	Cradock-Henry	2013	Dairy	Regional; Bay of Plenty
	McCusker	2015	Pastoral	National
Actions	-	-	-	-

LITERATURE

IIDA	Lead author	Year	Sector	Scale/Location
Impacts	Sylvester-Bradley	2008	Horticulture	National
	Zhang	2007	Pastoral	National
Implications	Lee	2013	Dairy	National
Decisions	Cradock-Henry	2008	Dairy	Regional; Bay of Plenty
	Gray	2011	Dairy	Regional; Hawke's Bay
	Hopkins	2015	Cross-sector	National
Actions	-	-	-	-

Pastoral farming

SLMACC

LITERATURE

IIDA	Lead author	Year	Sector	Scale/location
Impacts	Newton	2011	Pastoral	Regional; Canterbury
	Tozer	2011	Pastoral	National
	Dodd	2011	Pastoral	National
	Lieffering	2008	Pastoral	National
	Fowler	2008	Pastoral	Regional; Canterbury, Hawke's Bay
	Guo	2008	Pastoral	National
	Crush	2014	Pastoral, Arable	National
	Zhang	2007	Pastoral	National
	Keller	2014	Pastoral	National
	Fowler	2013	Pastoral	Regional; Hawke's Bay
Implications	Renwick	2013	Cross-sector	National
	Lieffering	2016	Pastoral, drystock	Regional; Hawke's Bay, Southland
	Lee	2013	Dairy	National
Decisions	Rosin	2015	Pastoral	National
	Cradock-Henry	2015	Pastoral	National
	Gray	2011	Dairy	Regional; Hawke's Bay
Actions	-	-	-	-

IIDA	Lead author	Year	Sector	Scale/location
Impacts	Fowler	2013	Pastoral	Regional; Hawke's Bay
	Keller	2014	Pastoral	National
	Lieffering	2016	Pastoral; drystock	Regional; Hawke's Bay, Southland
	Zhang	2007	Pastoral	National
Implications	Lee	2013	Dairy	National
Decisions	Gray	2011	Dairy	Regional; Hawke's Bay
Actions	-	-	-	-

Horticulture and viticulture

SLMACC

IIDA	Lead author	Year	Sector	Scale/location
Impacts	Beresford	2012	Horticulture	National
	Sturman	2015	Viticulture	Regional; Marlborough
Implications	Clark	2012	Cross sector	National
	Kenny	2008	Horticulture	Regional; Bay of Plenty, Hawke's Bay
Decisions	-	-	-	-
Actions	-	-	-	-

LITERATURE

IIDA	Lead author	Year	Sector	Scale/location
Impacts	Sturman	2013	Viticulture	National
Implications	-	-	-	-
Decisions	Cradock-Henry	2016	Horticulture	Regional; Bay of Plenty
Actions	-	-	-	-

What do we not know? Empirical gaps

- Regions and industries affected due to biological, socio-cultural, economic characteristics.
  - Climatic and topographic diversity, regional variation in climate and soil.

- Identify and evaluate multiple adaptation pathways, as well as their limits and barriers, throughout our agri-food systems.
  - Requires the social factors defining these pathways to be at the forefront of research.

- Industry-specific, regionally based options and pathways.

Adaptation is local.

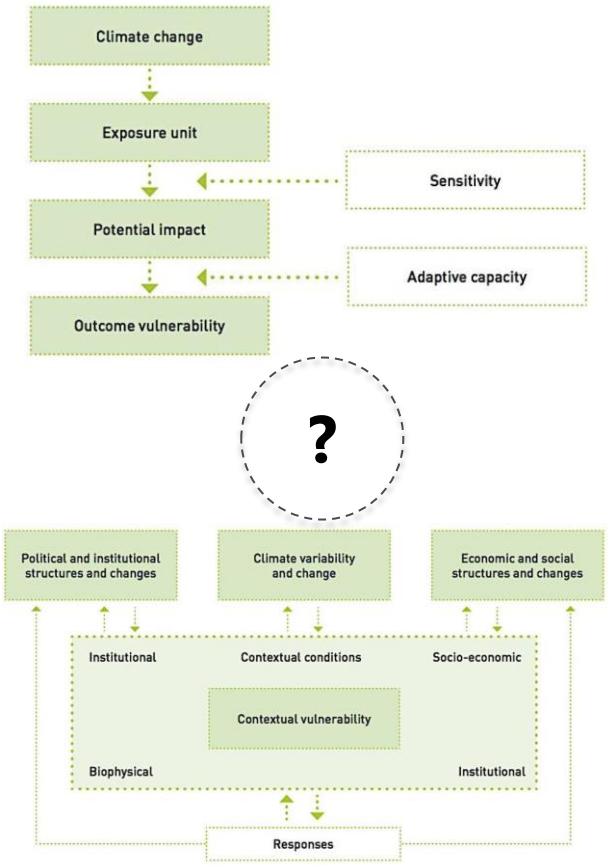
Scale/Region		Impacts	Implications	Decisions	Actions
National	National	15	4	2	1
North Island	Northland	1			
	Auckland				
	Waikato	1			
	Bay of Plenty			2	
	Gisborne	1			
	Hawke's Bay	1		1	
	Taranaki				
	Manawatu				
	Wellington				
South Island	Marlborough	1			
	Tasman				
	Canterbury	3	1	1	
	West Coast				
	Otago				
	Southland				

Methodological gaps

- Research has either been top-down or bottom-up.
- Systems thinking and resilience science can provide conceptual and methodological tools.
- Need to identify robust adaptation options.

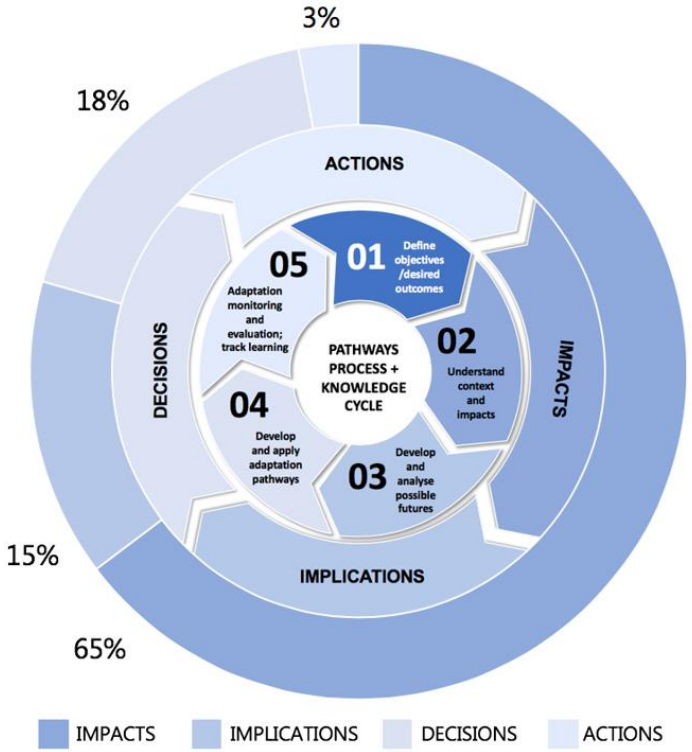
Adaptation strategies and behaviours are still skinny. We need better regionally-based adaptation strategy development."

- Workshop participant



How do we know we are doing the right thing?

How do we take action?



Is it real?

Does it matter?

Can we do anything about it or its impacts?

- Adaptation research is needed to support adaptive planning
  - **Decisions** and **Actions**
  - Novel adaptation: options beyond the norm
  - Explore new long term options
- Sector specific knowledge necessary.
- Factors that lead to adaptation intention, decision and action.
- Need for adaptation in face of uncertainty
  - Robust decision support systems, tools, processes and practices for resilient climate futures.

Barriers and enablers

- Uncertainty, resources, and psychosocial factors are the greatest impediments to more effective adoption.
- Greater integration and coordination across primary industries for adaptation is needed.
- Tools and policy measures for decision making under conditions of uncertainty.
- Bespoke information to meet end users' needs:
  - T-shape, breadth and depth

Conclusions

- There is no “silver bullet”; no single knowledge type needed.
  - Complex systems perspectives
  - Modelling insights with practitioners’ experiences, values and attitudes as well as governance perspectives
- Understand underlying structures of decision-making and behaviour
- Relationships between mitigation, adaptation and sustainable development
  - Adaptation pathways for Hawke’s Bay (MPI)

Thank you

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