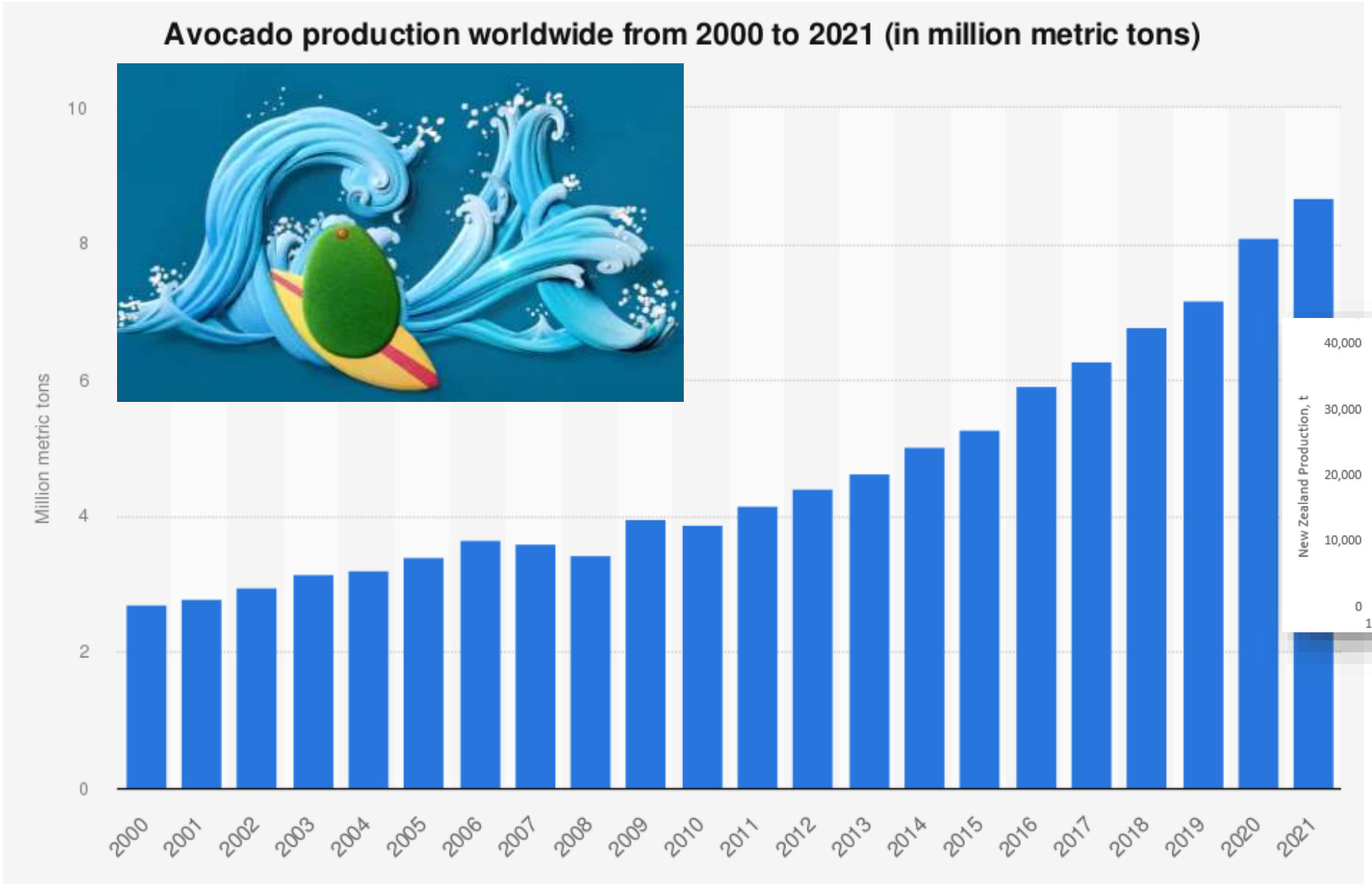
Plant & Food Research
Rangahau Ahumāra Kai

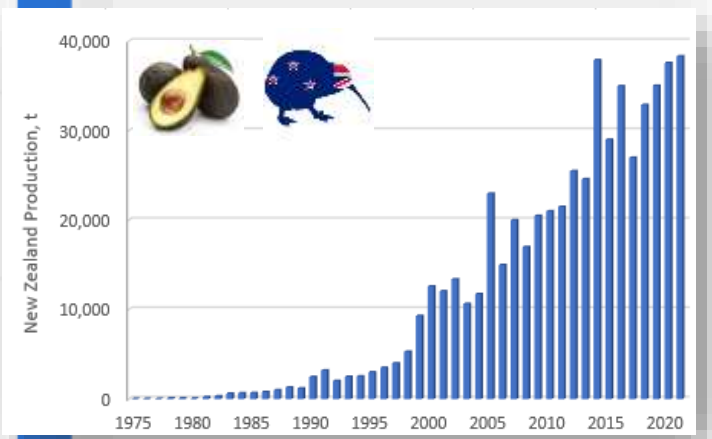
Sustainable Avocado Production:

A Green Future

Brent Clothier

Riding the Green Wave …





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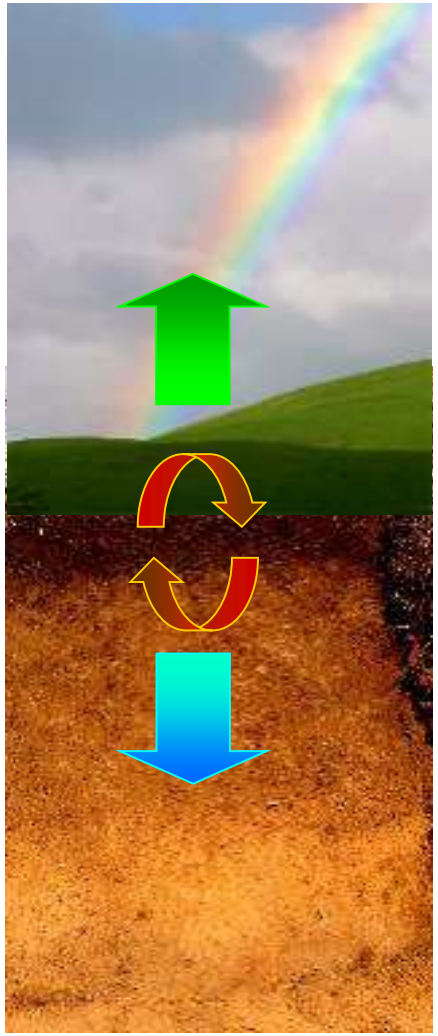
And now … Sustaining the Ride!

Back to Basics … Nature

Nature's Blessing: Capital & Interest

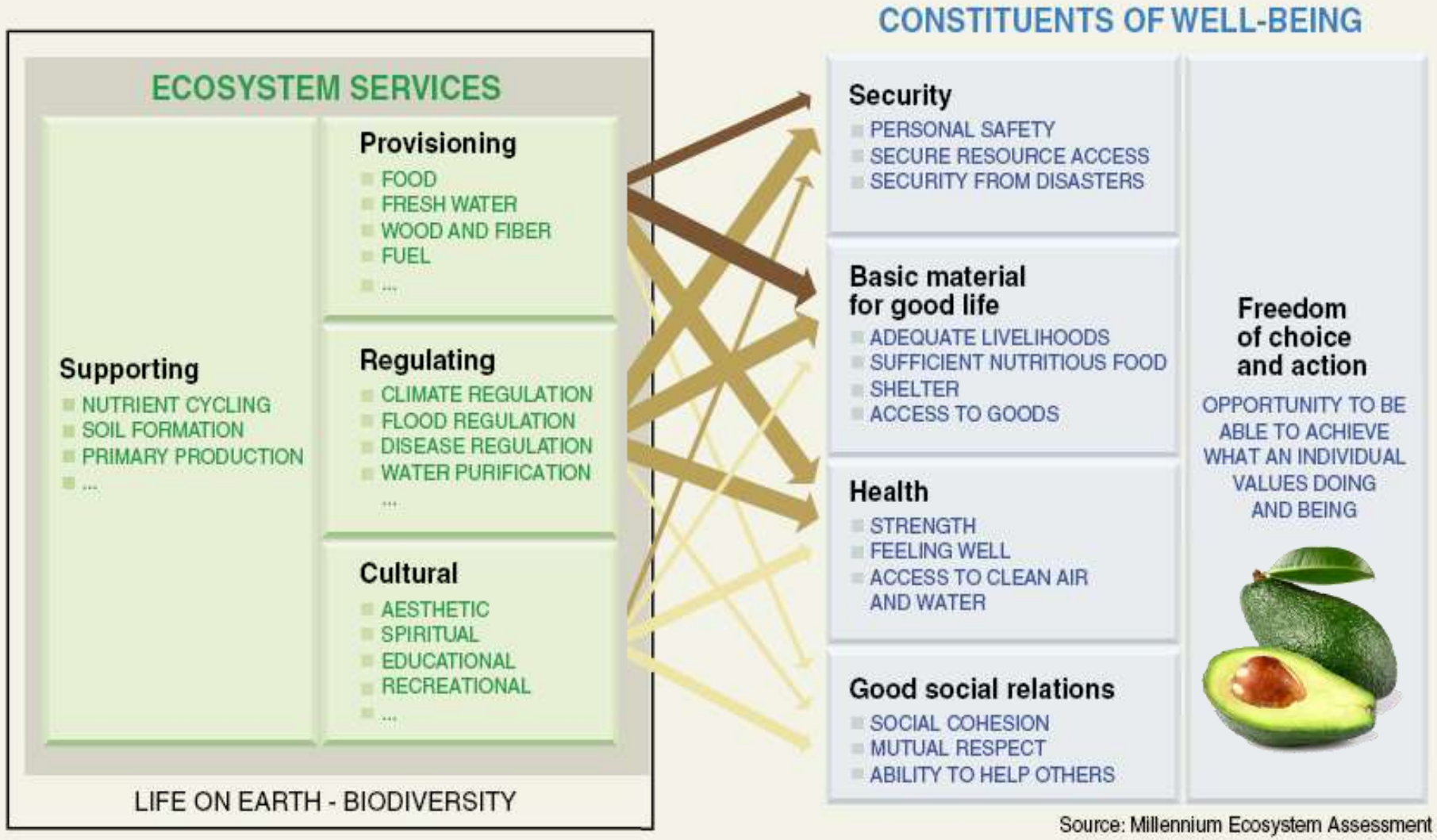


<u>Natural Capital</u>:

Our stocks of natural materials & energy

<u>Ecosystem Services</u>:

The beneficial flows of goods between natural capital stocks, or stocks & humans



Source: Millennium Ecosystem Assessment

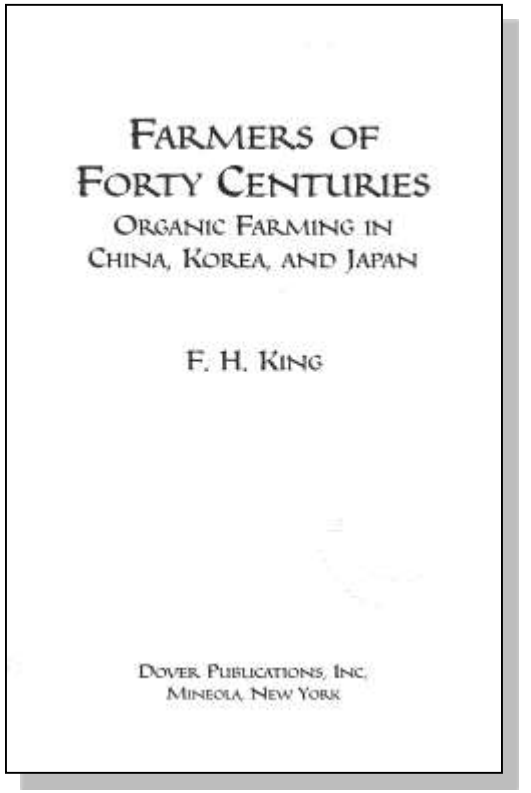
ARROW'S COLOR
Potential for mediation by socioeconomic factors

- Low
- Medium
- High

ARROW'S WIDTH
Intensity of linkages between ecosystem services and human well-being

- Weak
- Medium
- Strong

Metrics of Sustainability – Forty Centuries



We were amazed how these nations are conserving and utilising their natural resources and surprised at the returns they were getting from their fields

Franklin Hiram King, Professor of Agricultural Physics, University of Wisconsin, 1888-1902

Soil & Invested Carbon

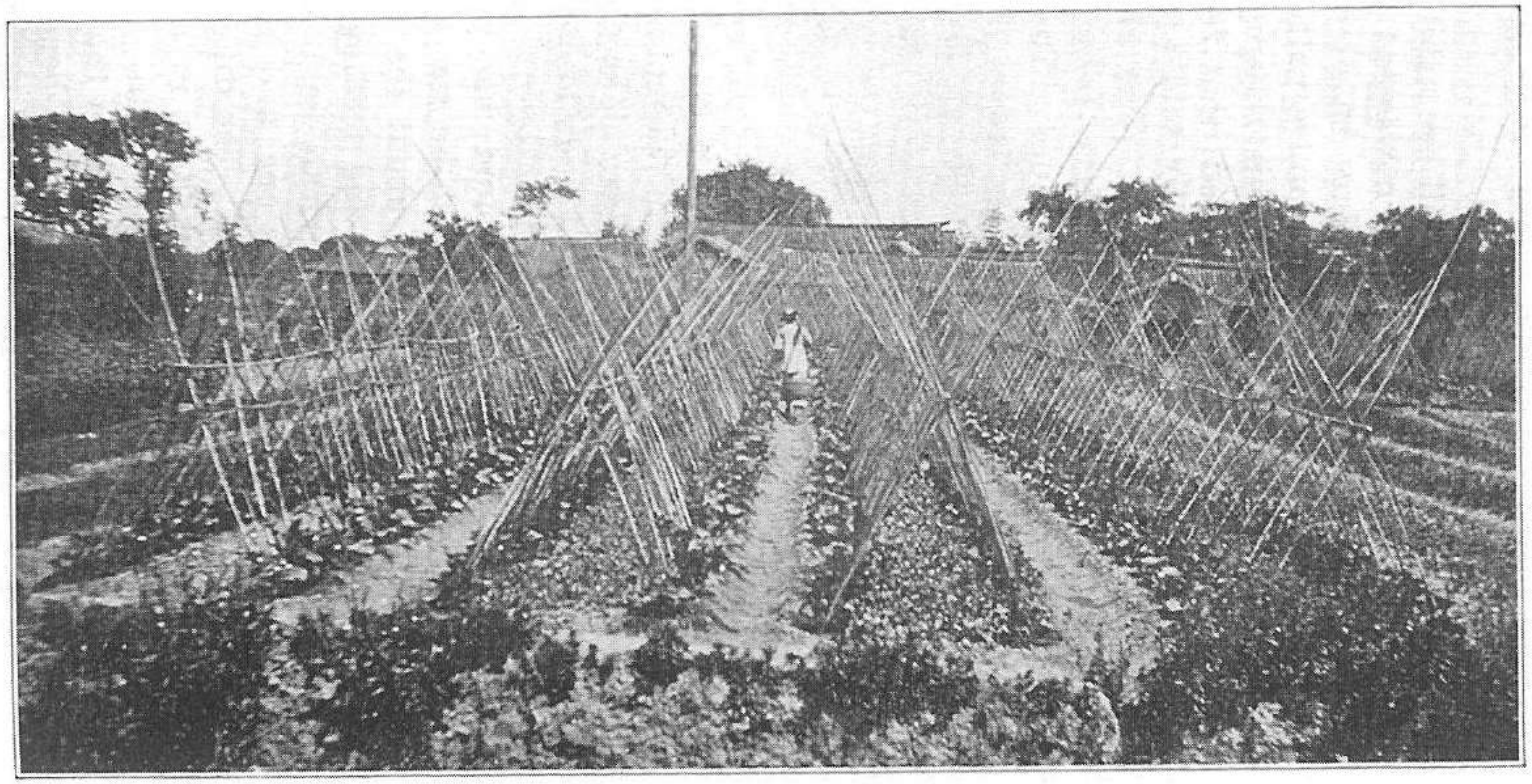


Fig. 113.—Where the yield is the product of brain, brawn and utilized waste.

Green manure and compost, and the ash of the fuel finds its way ultimately to the field.

Manure of all kinds, human and animal, is religiously saved and applied to the fields in a manner which secures an efficiency far above our own

F.H. King 1911

Carbon Investment, Water, & Tea

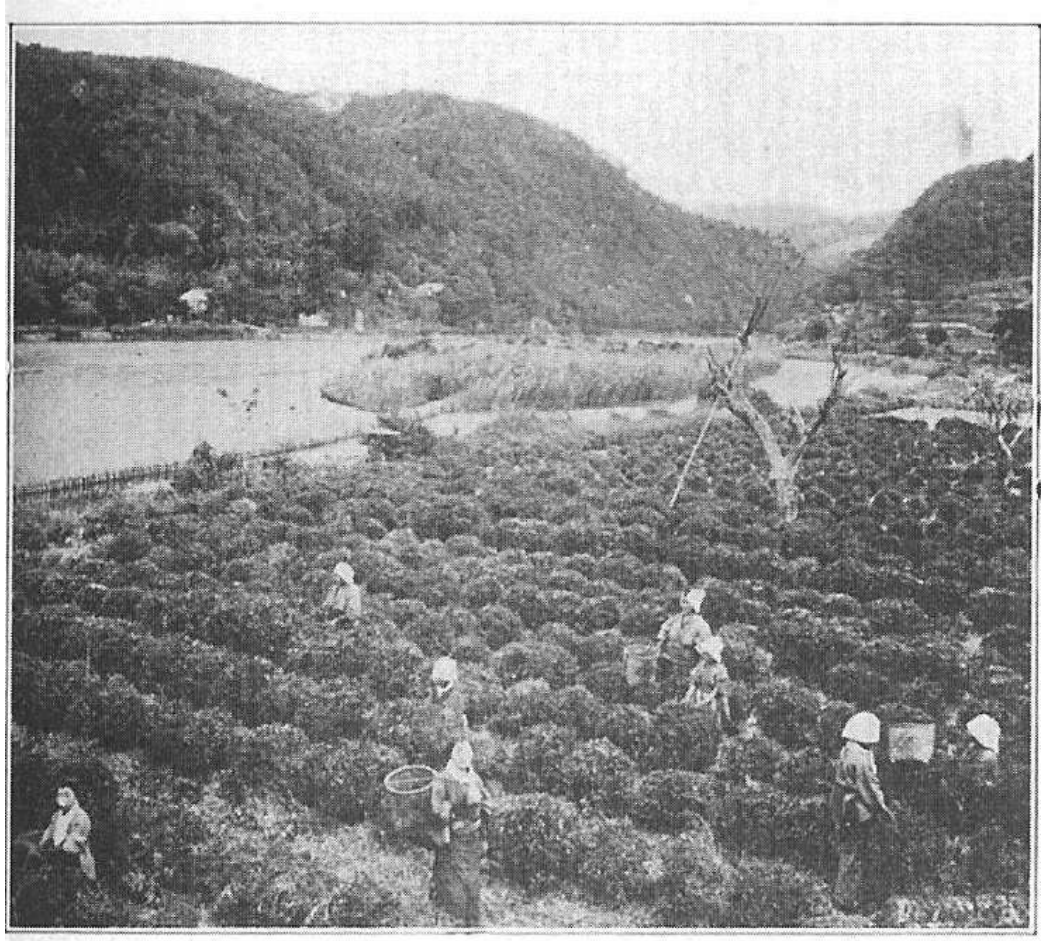
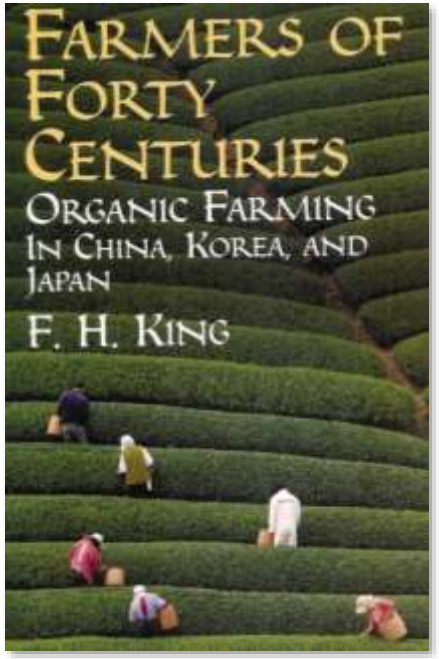


Fig. 194.—Group of Japanese women picking leaves of the tea plant.



Boiling water has been adopted to safeguard against deadly disease germs where the wastes of the body are taken back to the field

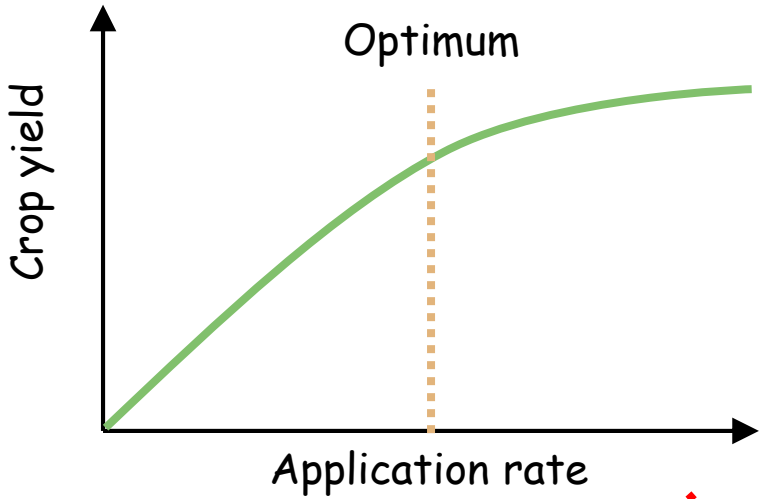
The tea industry had its foundation in the need for something to render boiled water palatable for drinking purposes

F.H. King 1911

What “sustainability” waves have we been riding?

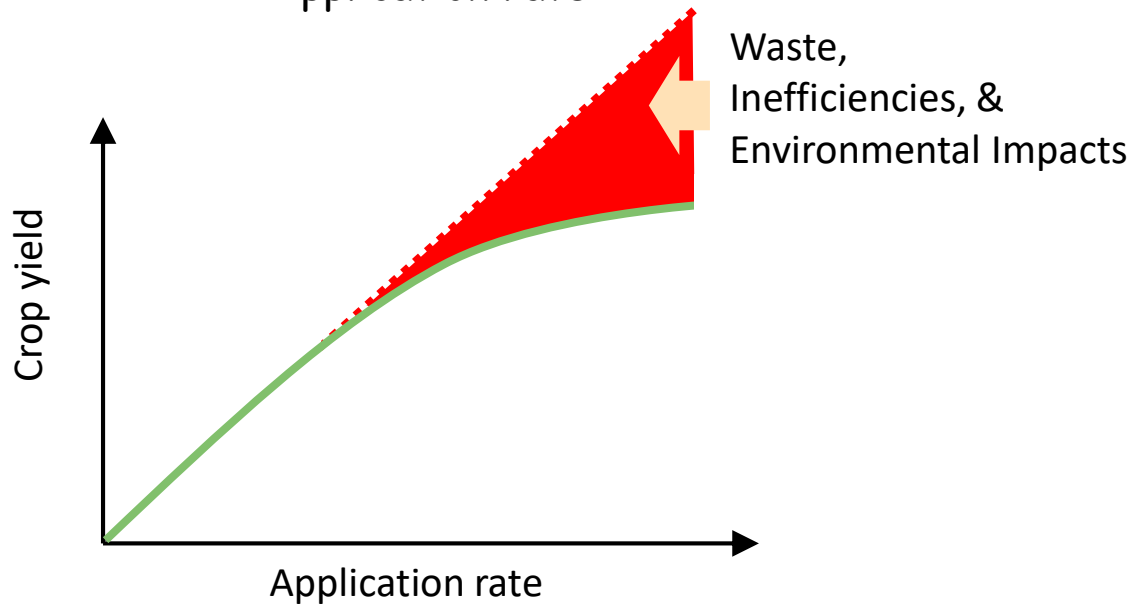
The 1970s : Productivity Goals for using

- Water
- Fertiliser
- Pesticides



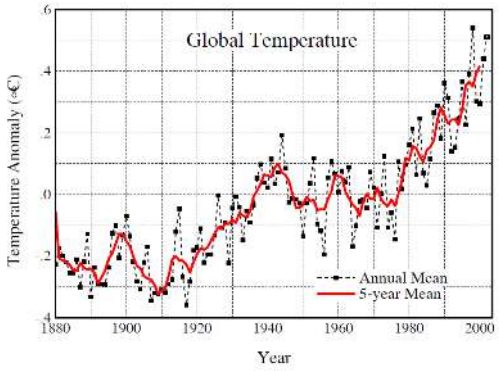
The 1980s : Sustainability Goals

- Law of diminishing returns
- Systems thinking
- Environmental consciousness



Sustainability Waves … continued.

The 1990s : Climate-Change - Beginning of Awareness (AR1)



The 2000s : UN Millennium Ecosystem Assessment

Back-to-the-Future: Investment into Natural Capital

Investment Actions

ECOSYSTEM SERVICES

Supporting
- NUTRIENT CYCLING
- SOIL FORMATION
- PRIMARY PRODUCTION
- ...

Provisioning
- FOOD
- FRESH WATER
- WOOD AND FIBER
- FUEL
- ...

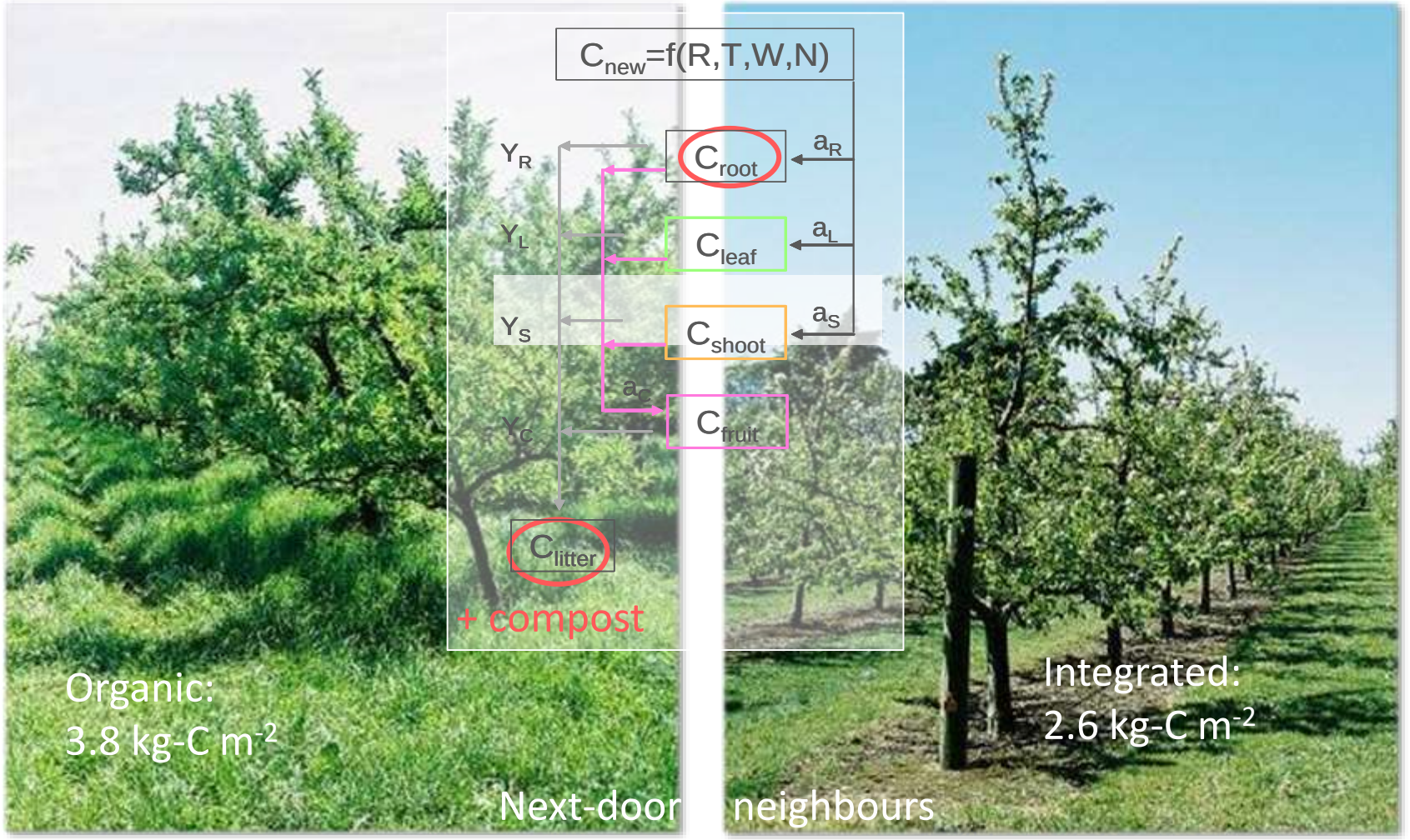
Regulating
- CLIMATE REGULATION
- FLOOD REGULATION
- DISEASE REGULATION
- WATER PURIFICATION
- ...

Cultural
- AESTHETIC
- SPIRITUAL
- EDUCATIONAL
- RECREATIONAL
- ...

Returns on Investment

Services

Investing Carbon into a Modern Orchard Soil

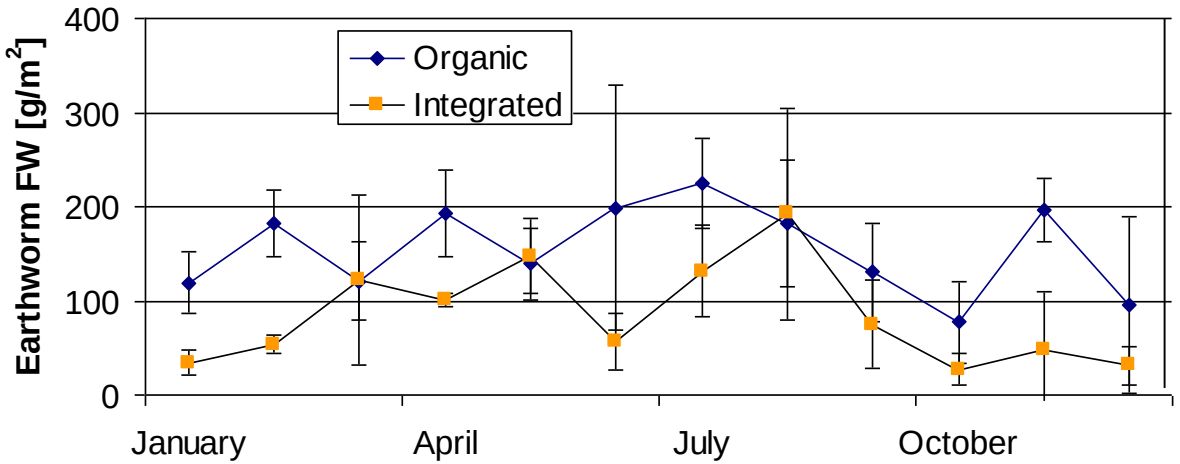


Changed Soil Carbon Stocks & Different Ecosystem Services

SIMBIOS Centre

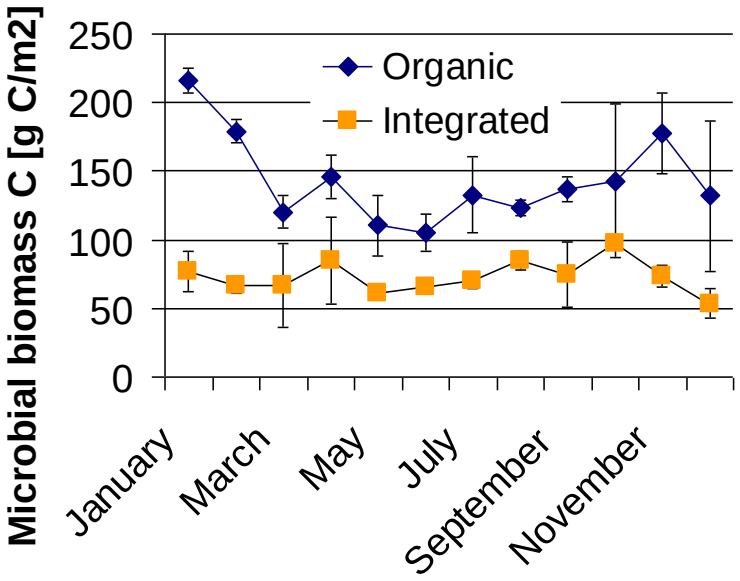
X-ray Tomography – Carbon Investment Changes Soil Structure

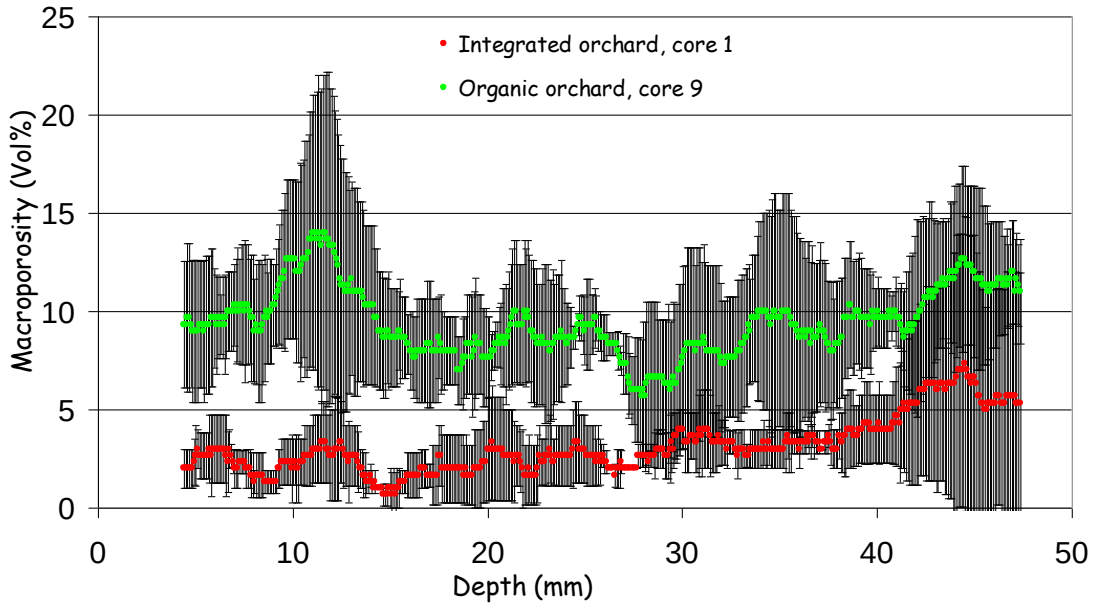
Macro & Microbiological Changes



Deurer *et al*. (2009)

... Lead to Soil Structural Changes. Soil Macropores & "Sponginess"



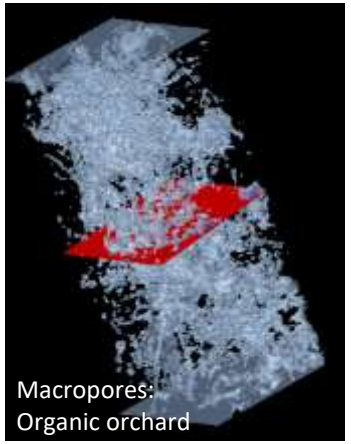


European Journal of Soil Science, February 2008, **59**, 2–13 doi: 10.1111/j.1365-2389.2007.00991.x

Preferential flow and transport in soil: progress and prognosis

B. E. CLOTHIER, S. R. GREEN & M. DEURER
Sustainable Land Use Team, The Horticultural and Food Research Institute of New Zealand Ltd, PB 11-030, Palmerston North 4442, New Zealand

The Value of Holes in Soil


Macropores:
Organic orchard

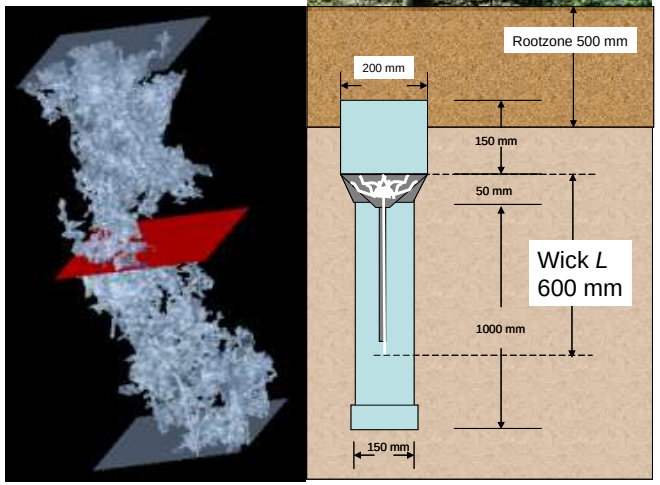
We identified 12 of 17 ecosystem services that benefit from macropores in soil.

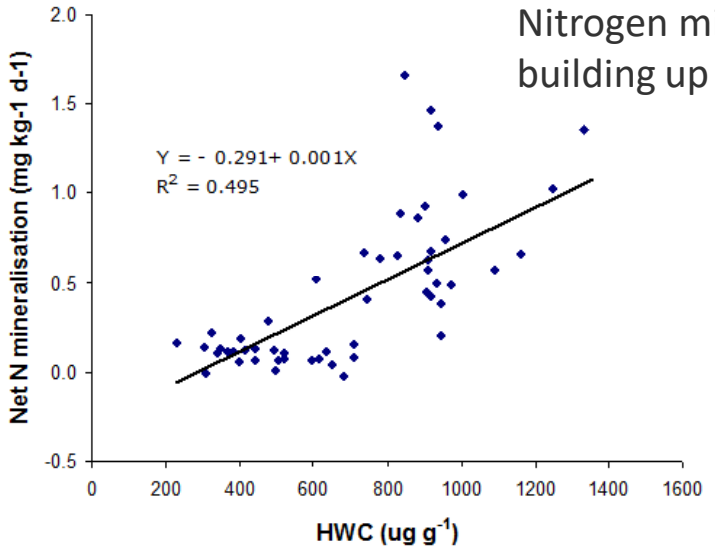
We calculated the global value of the ecosystem services from macropores to be US$304 billion yr^{-1}.

Table 1 The ecosystem services selected by Costanza *et al.* (1997). A tick indicates a positive role for macropores, a cross a negative impact, and a dash implies neutrality

Number	Ecosystem service including ecosystem 'goods'	Preferential flow impact
1	Gas regulation	√
2	Climate regulation	√
3	Disturbance regulation	√
4	Water regulation	√
5	Water supply	×
6	Erosion control and sediment retention	√
7	Soil formation	√
8	Nutrient cycling	√
9	Waste treatment	×
10	Pollination	√
11	Biological control	√
12	Refugia	√
13	Food production	×
14	Raw materials	—
15	Genetic resources	√
16	Recreation	√
17	Cultural	—

ROI into Soil Carbon: Supporting Services & Regulating Services



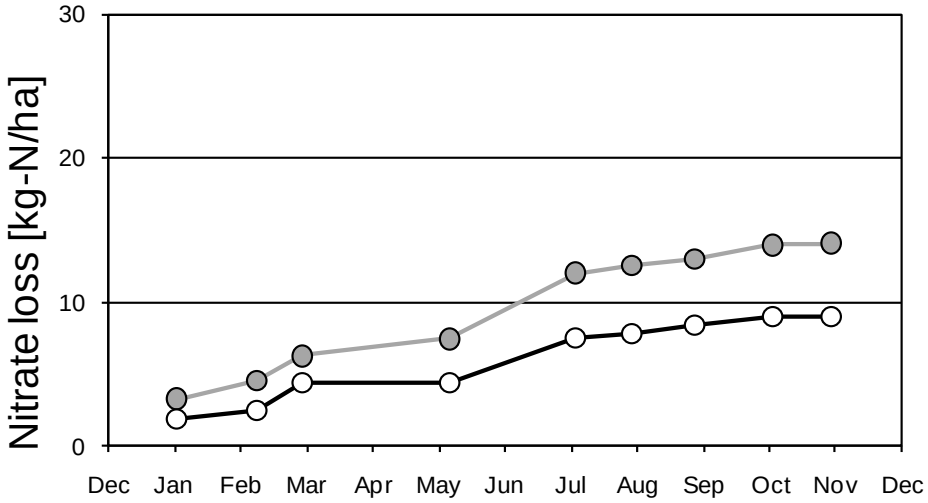


Nitrogen mineralisation (mg-N kg^{-1} d^{-1}) by building up the soil's labile carbon (HWC)

N generation: 105 kg-N ha^{-1} y^{-1}

That's \$20,000 ha^{-1} of N for 'free'

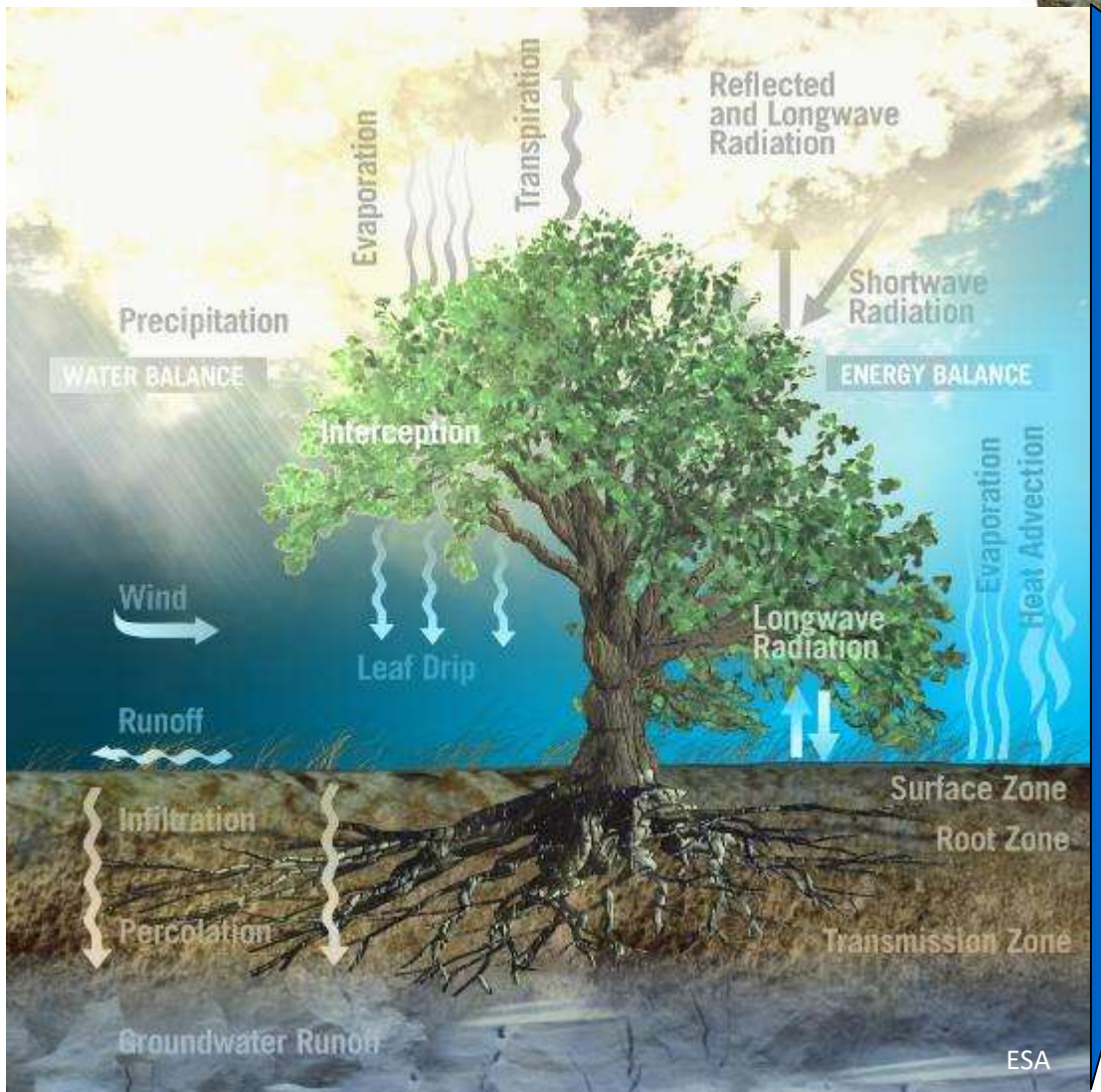
Kim *et al.* (2011)

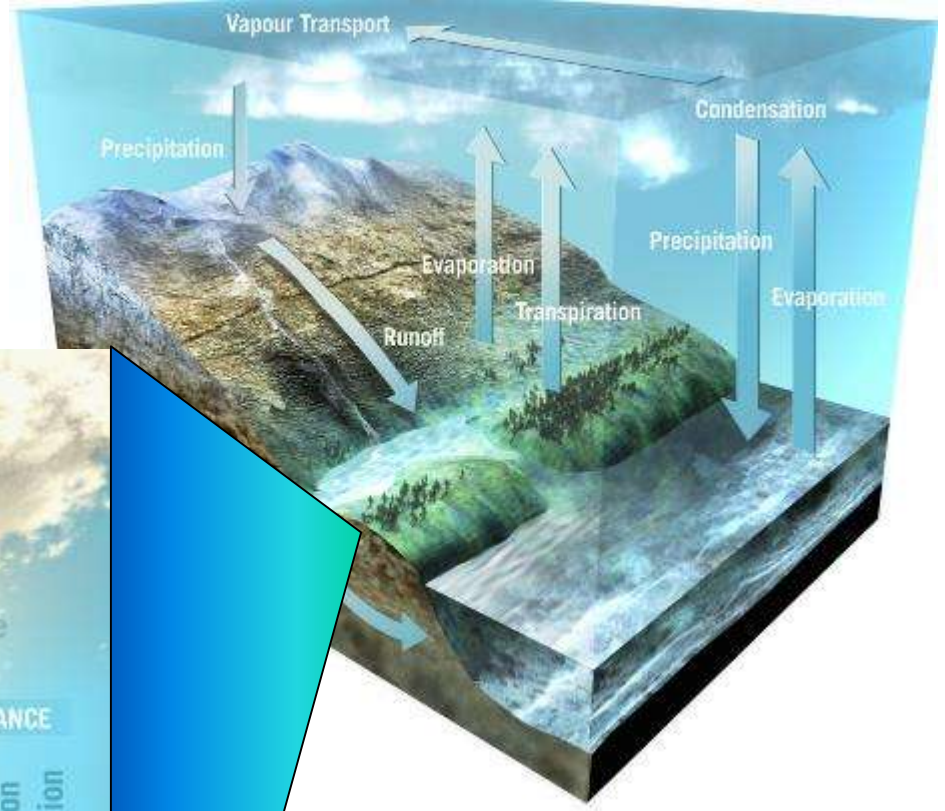


Low N Leaching: 90% retained

Green *et al.* (2010)

Soil:
A thin nexus teeming with service flows from natural-capital stocks of water, biota, carbon, & energy

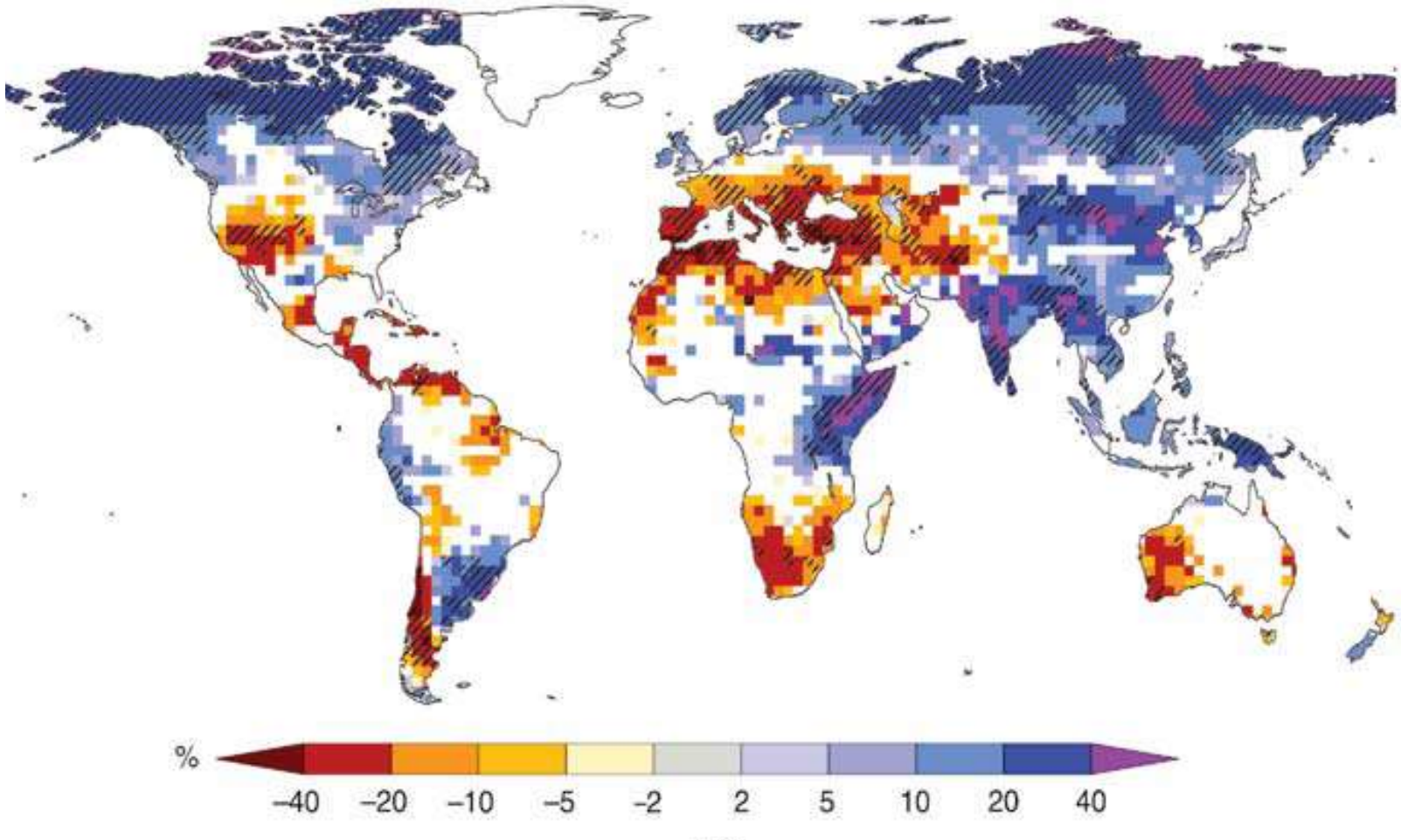




Water: The Prime Natural Capital Stock

Water: Future Pressures

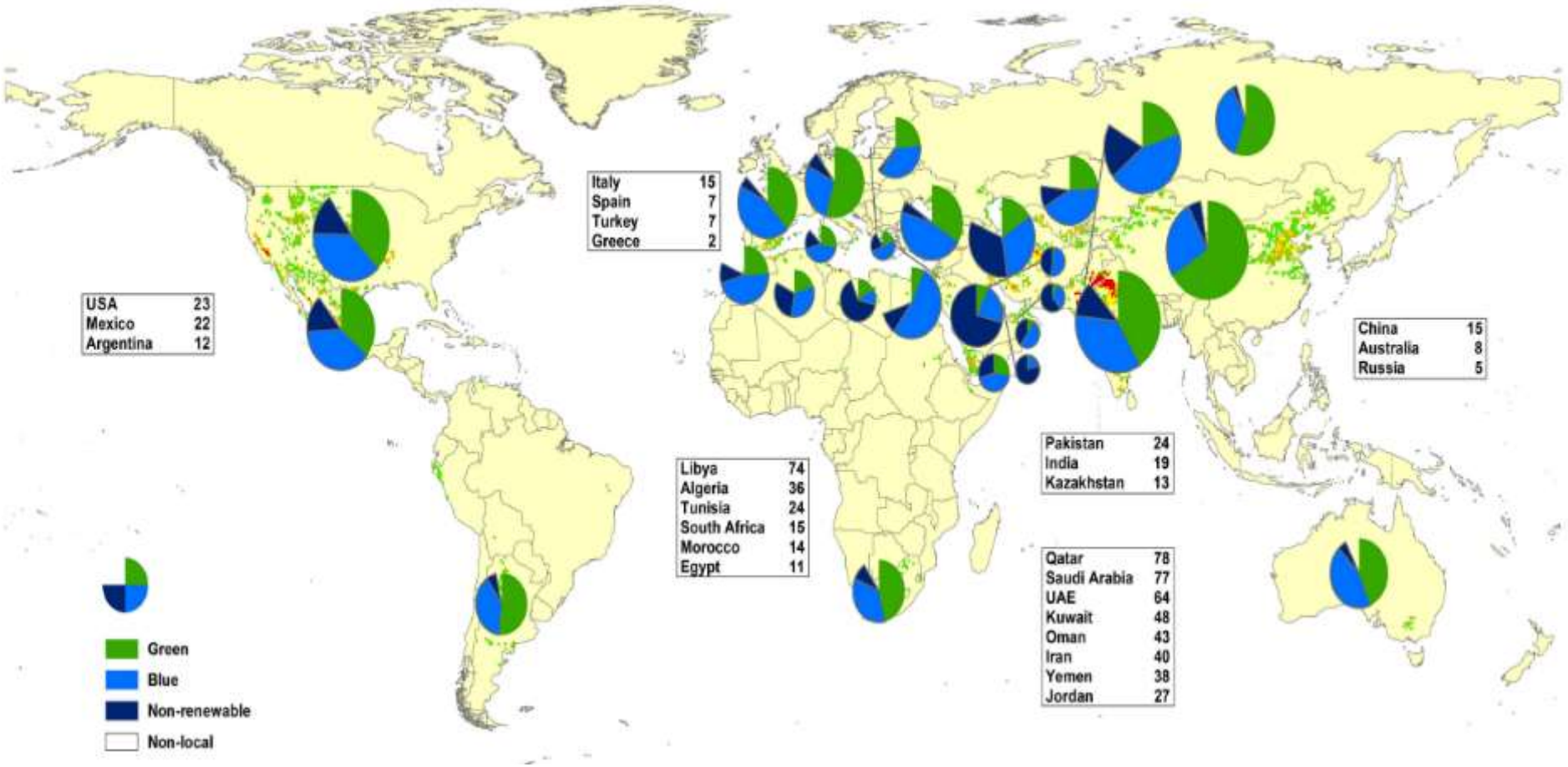
Predicted changes in water availability (%) by the end of the 21st century



IPCC AR4:Scenario A1B, 2090-2099

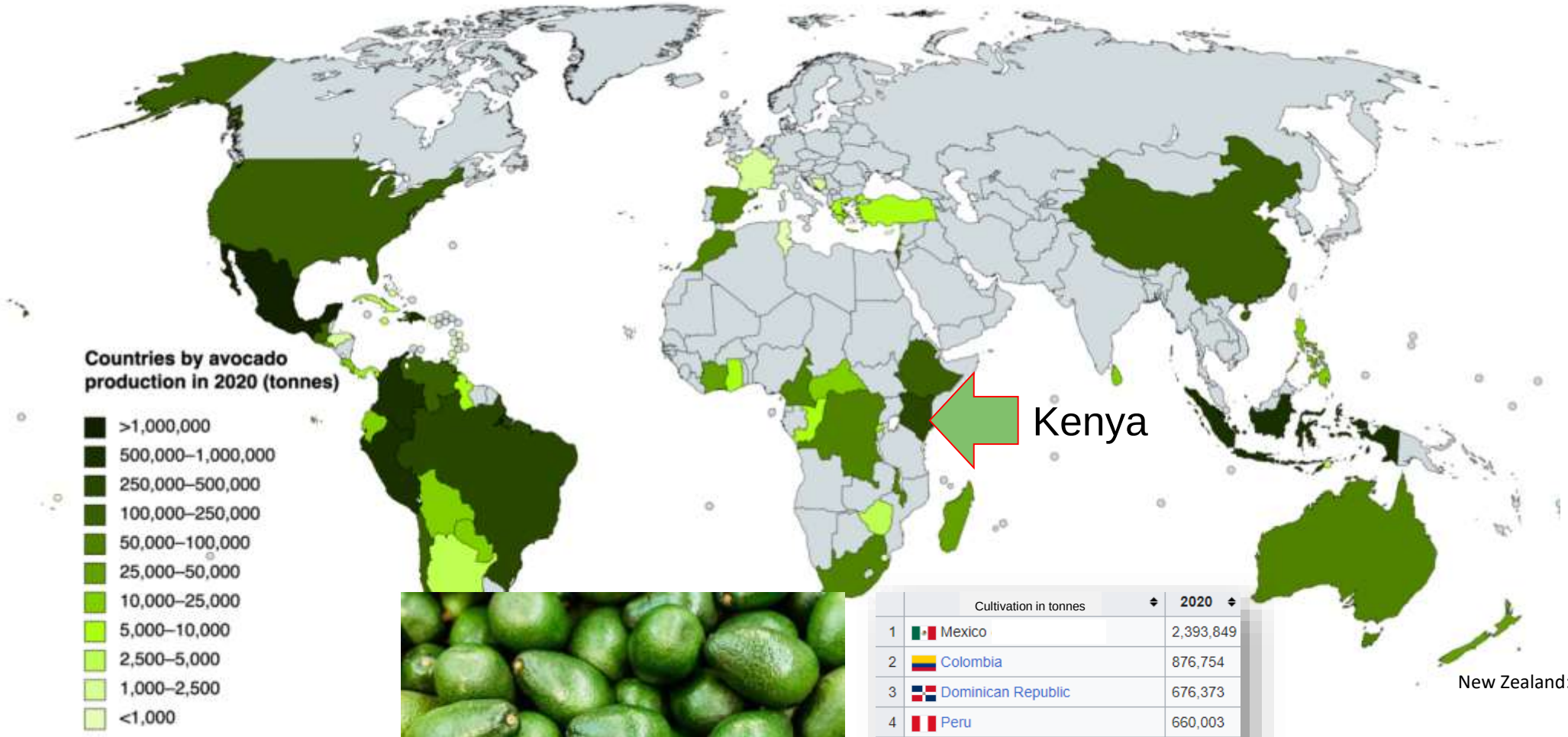
The Global Picture of Groundwater Over-Draft

*"Irrigation water from: rain (green water), renewable reserves (blue water) & non-sustainable groundwater (**dark blue water**)"*. Boxes are % unsustainable.



Non-sustainable groundwater sustaining irrigation: A global assessment
Wada *et al., Water Resources Research* 2012

World Avocado Production



	Cultivation in tonnes	2020
1	Mexico	2,393,849
2	Colombia	876,754
3	Dominican Republic	676,373
4	Peru	660,003
5	Indonesia	609,049
6	Kenya	322,556
7	Brazil	266,784
8	Ethiopia	245,336

New Zealand: 37,657 t (24th)

FAOSTAT

The African Water-Colour Challenge

Nature (519), 19 March 2015. pp 281-285

Terraced fields in the Simien Mountains, Ethiopia, help to conserve soil moisture.

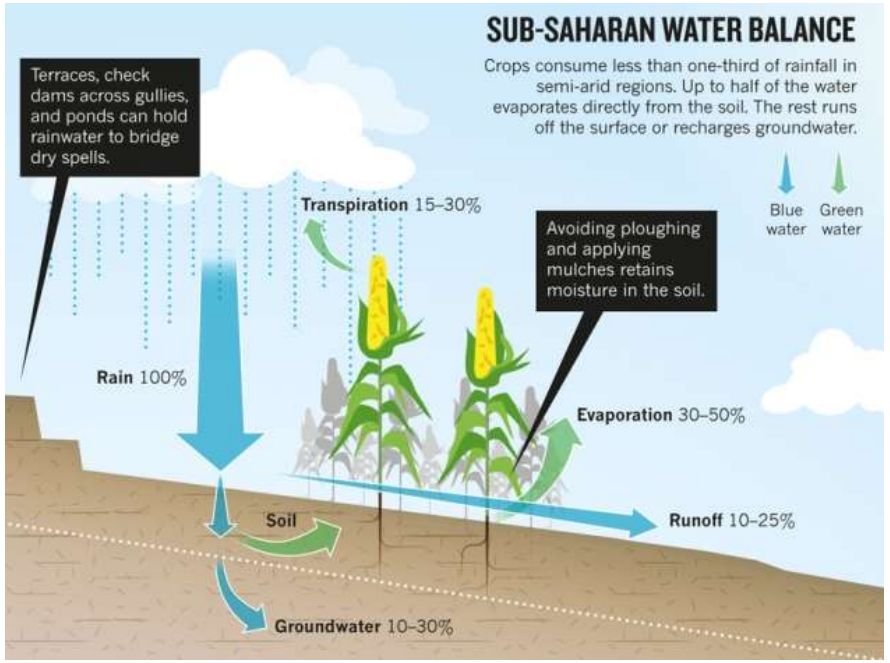
Increase water harvesting in Africa

Meeting global food needs requires strategies for storing rainwater and retaining soil moisture to bridge dry spells, urge **Johan Rockström** and **Malin Falkenmark**.

Ensuring that the world's food needs are met by 2050 will take a doubling of global food production[1]. To improve agricultural yields on that scale will require a radical rethink of global water-management strategies and policies.

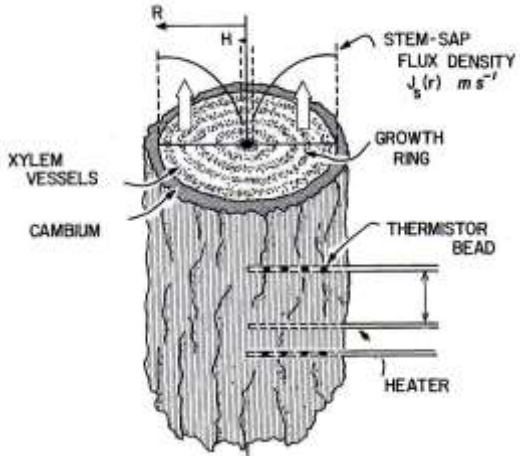
Sub-Saharan Africa is the epicentre of this challenge. The region's population is set to more than double by 2050 to almost 2.5 billion, or 25% of the world's projected population[2]. Half of its current one billion inhabitants lives in extreme poverty, one-quarter is undernourished, and one-fifth faces serious water shortages. Although almost two-thirds of the population are rural, agriculture on much of the land is limited by scarce, variable and unpredictable water resources[3].

Ninety-five per cent of sub-Saharan agriculture depends on 'green water': moisture from rain held in the soil. In large parts of the continent, most rain evaporates before it generates 'blue water', or run-off, so little of it recharges rivers, lakes and groundwater. Most farming communities are a long way from rivers[4] and cannot use irrigation. Arid deserts and semi-arid savannahs comprise 40% of the region's land area. These receive too little surface run-off (less than 100 millimetres a year) to grow maize (corn), rice, millet and sorghum (which requires at least 400 mm per year) using irrigation alone. Future rainfall will be more variable and could be 25% lower in many semi-arid regions if average global temperatures warm by 2 °C above pre-industrial levels[5]. ▸



- Maximize the value of transpiration of green-water (rain)
- Use of harvested green-water
- Tactical use of blue-water (irrigation). Little infrastructure!

Direct Measurements of Avocado Tree Water-Use: Sap Flow & Soil Water



- Four 6 year-old grafted-Hass trees instrumented
- Direct tree water-use measurements by sap-flow, plus soil-water monitoring
- A public-private partnership

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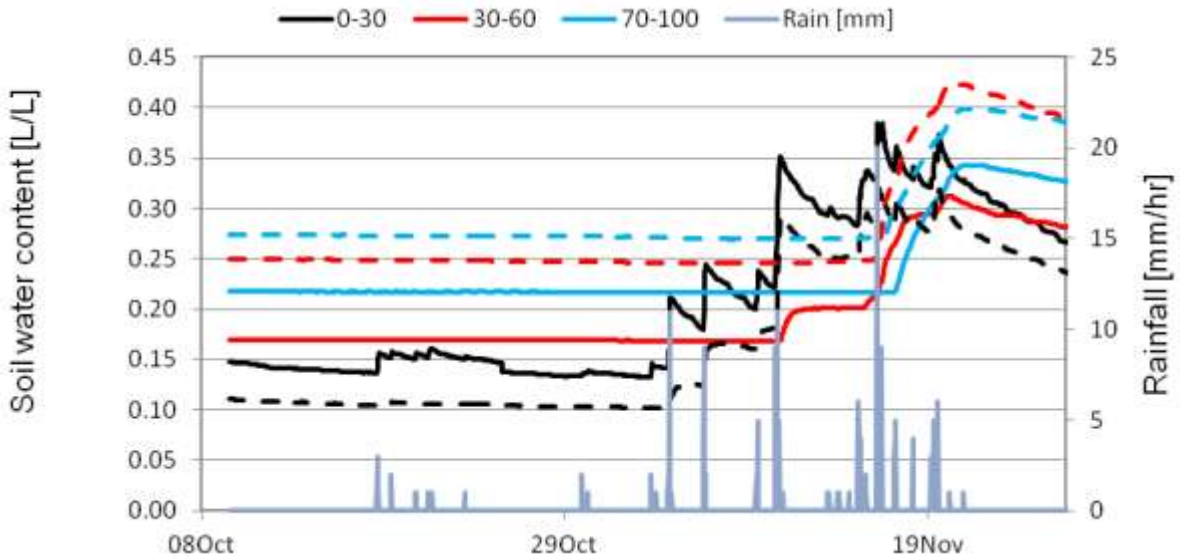
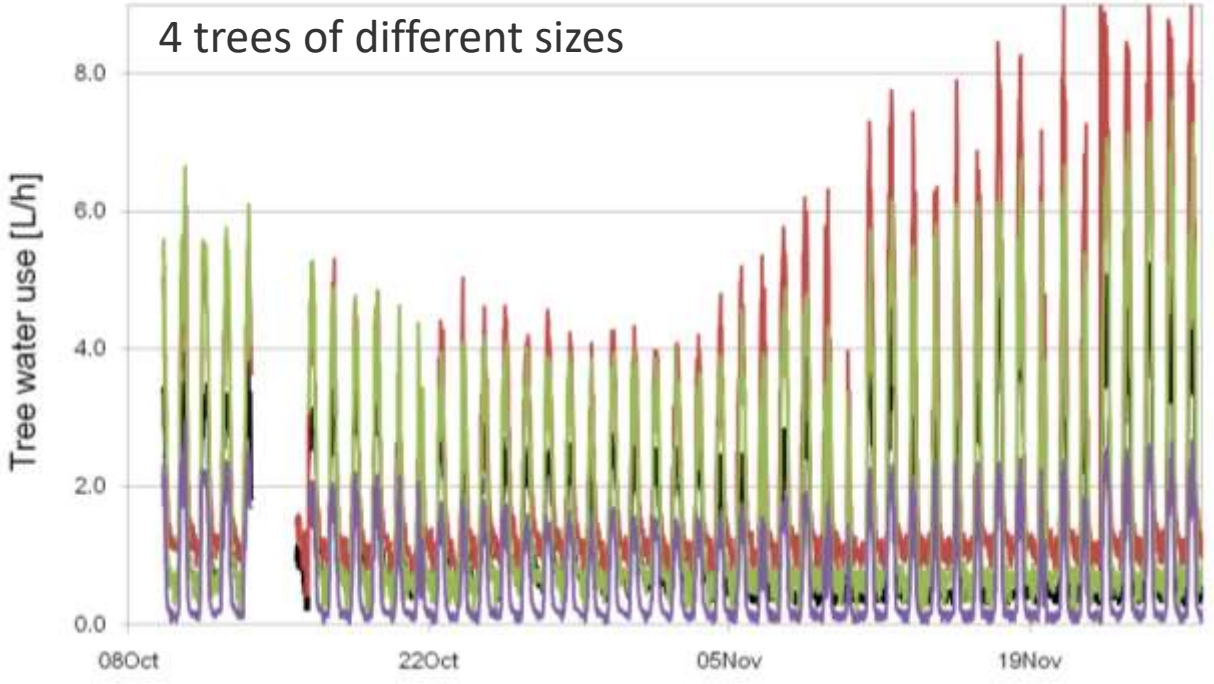
The soil was very dry until the Short Rains came …

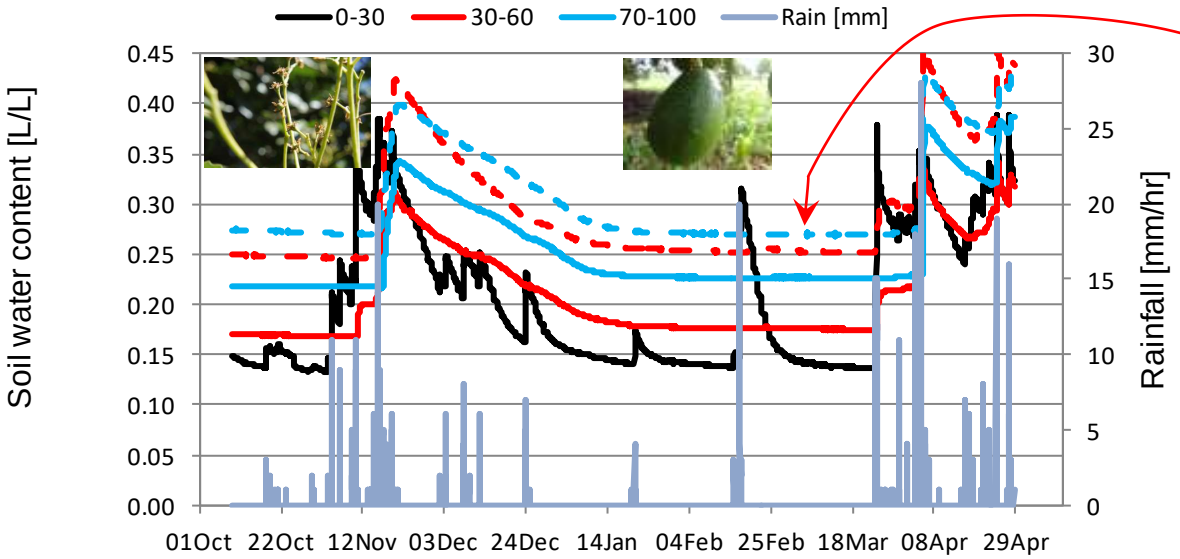


Tree water-use doubled with the arrival of the Short Rains.

Water-stress release …



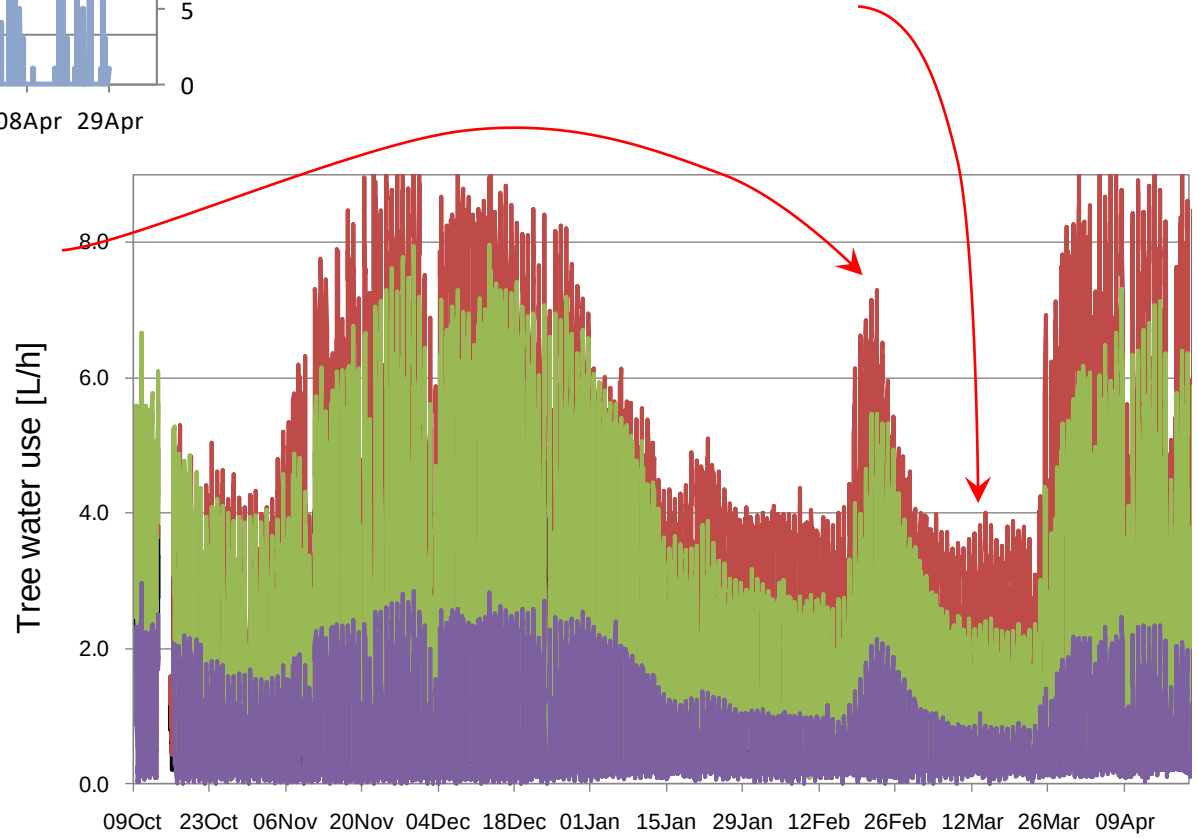
Flowering concerns before Short Rains & fruit filling before the Long Rains?



All supplied by roots below 1 m

The trees are using 10-40 L per day

One early rain. Only short-lived relief for tree water-use



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Managing ‘Green Water’ by Pruning

- New growth lower down
- Enhanced fruitfulness
- Harvest quality
- Safer harvesting

- Tactical management of green-water
- Lower leaf-area
- Reduced water use?
- Drought avoidance?

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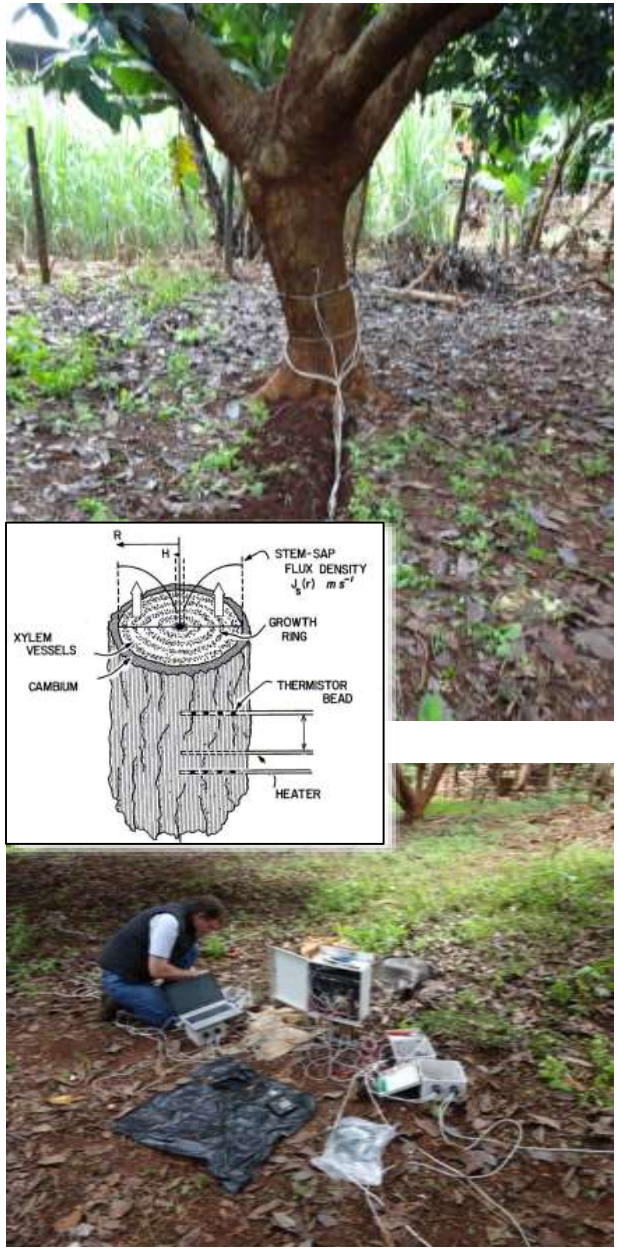
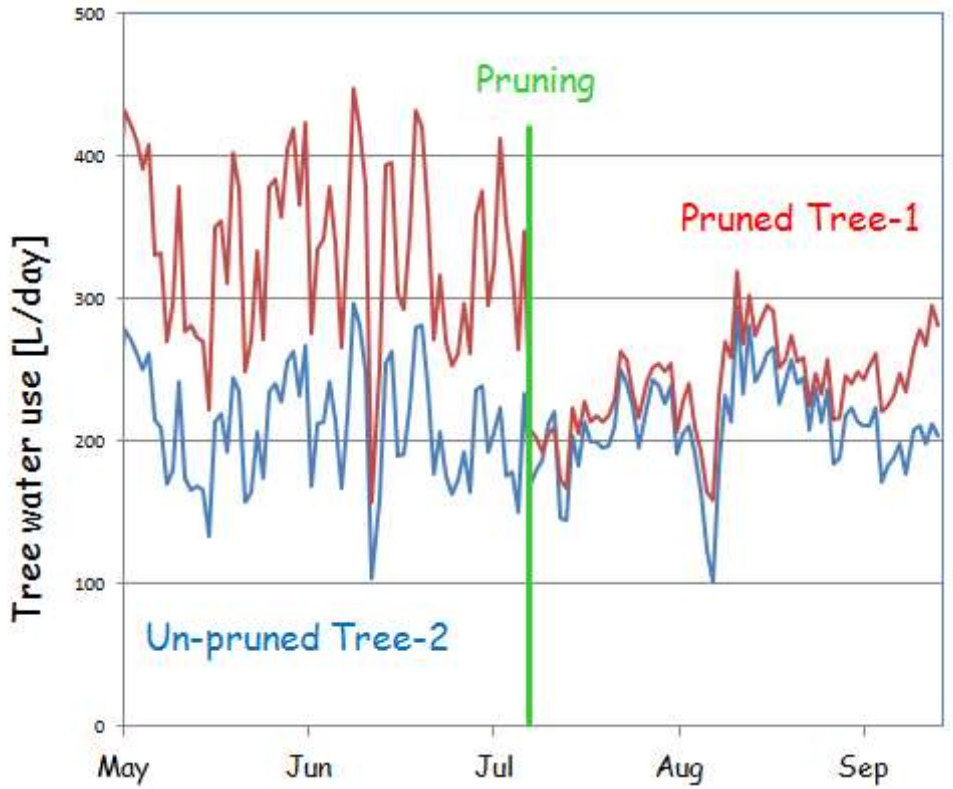
Pruned Tree Water-Use: Comparing Trees





- A water-use reduction of 37% by pruning
- A daily saving of ≈ 150 L per day
- More green-water (rain) left in the soil
- Drought avoidance
- Continuous canopy management

A Pilot:

- Using ‘recycled’ 20 L bottles as ‘portable drip-irrigators”
- Bottles drip @ 4 L per hour
- Five hours to discharge
- Especially for establishment & young trees
- Possible water sources: rain-water or wells


(The late) Mr Thomas

Thankfully irrigation development is now happening, here & across Africa.


Mr Wachira, Muruguru B Irrigation Scheme

Kenya’s National Irrigation Authority established 2019

National Irrigation Authority

Adapting to climate change

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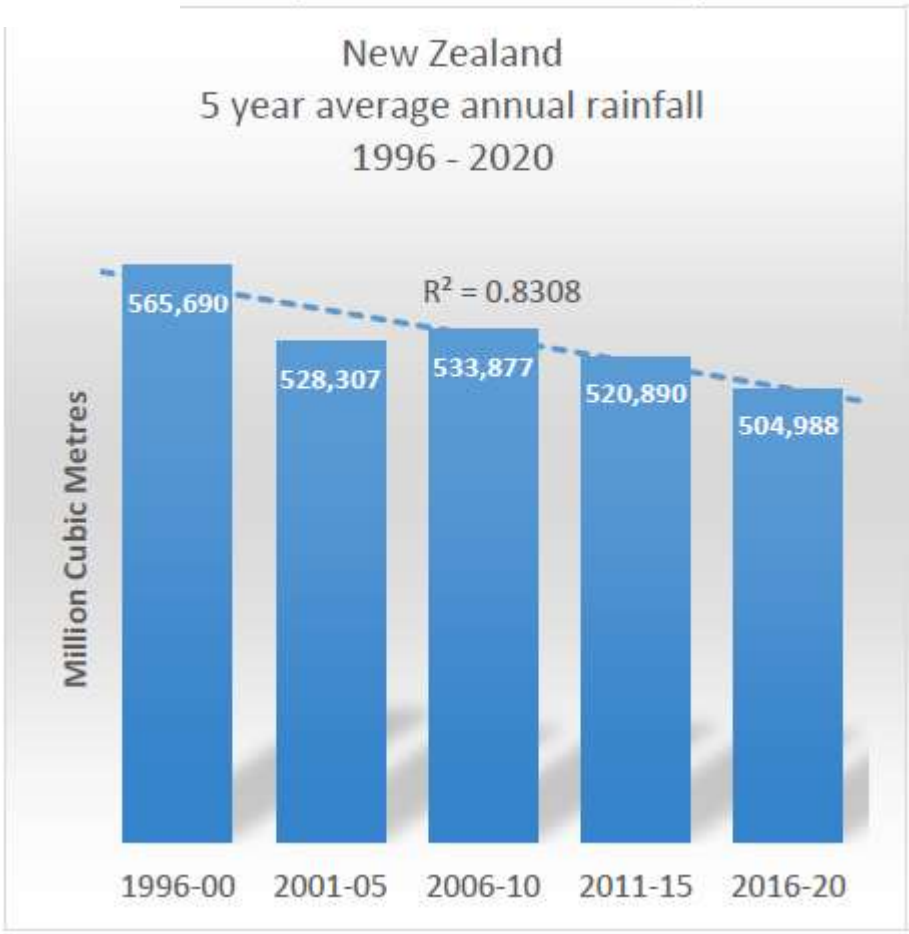
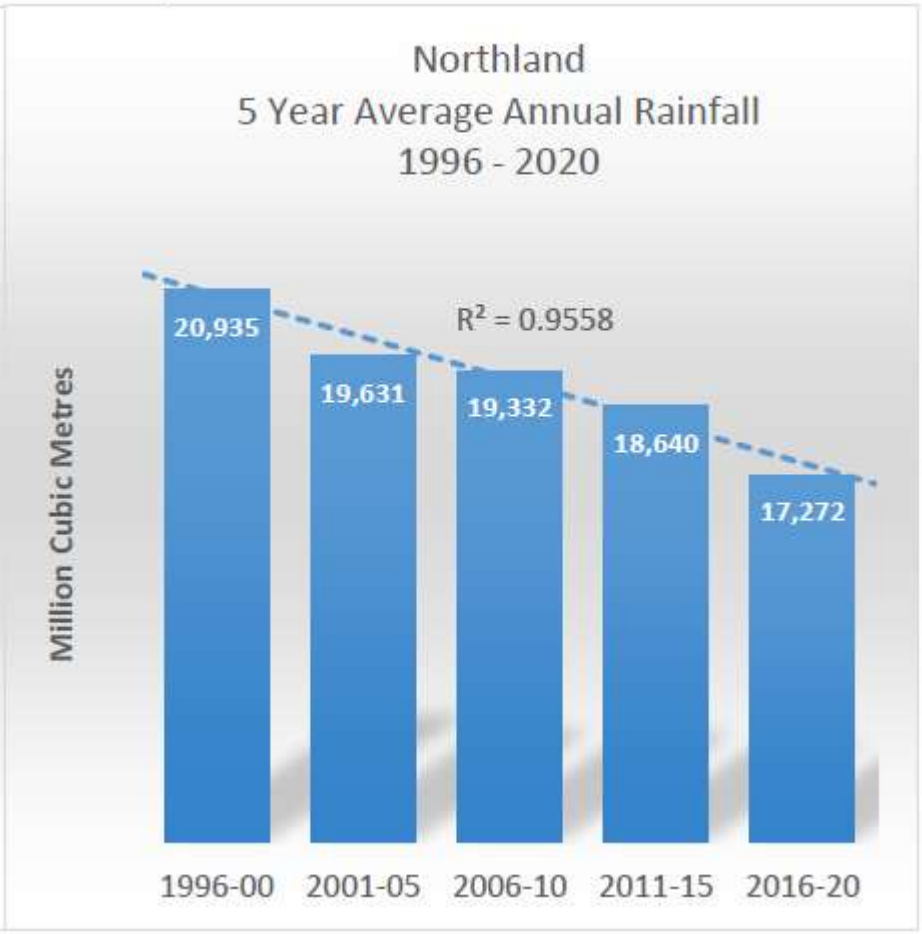
We’re drying out in New Zealand too … although it might not seem so of late!

Average Rainfall 1996-2020 (source Statistics NZ)



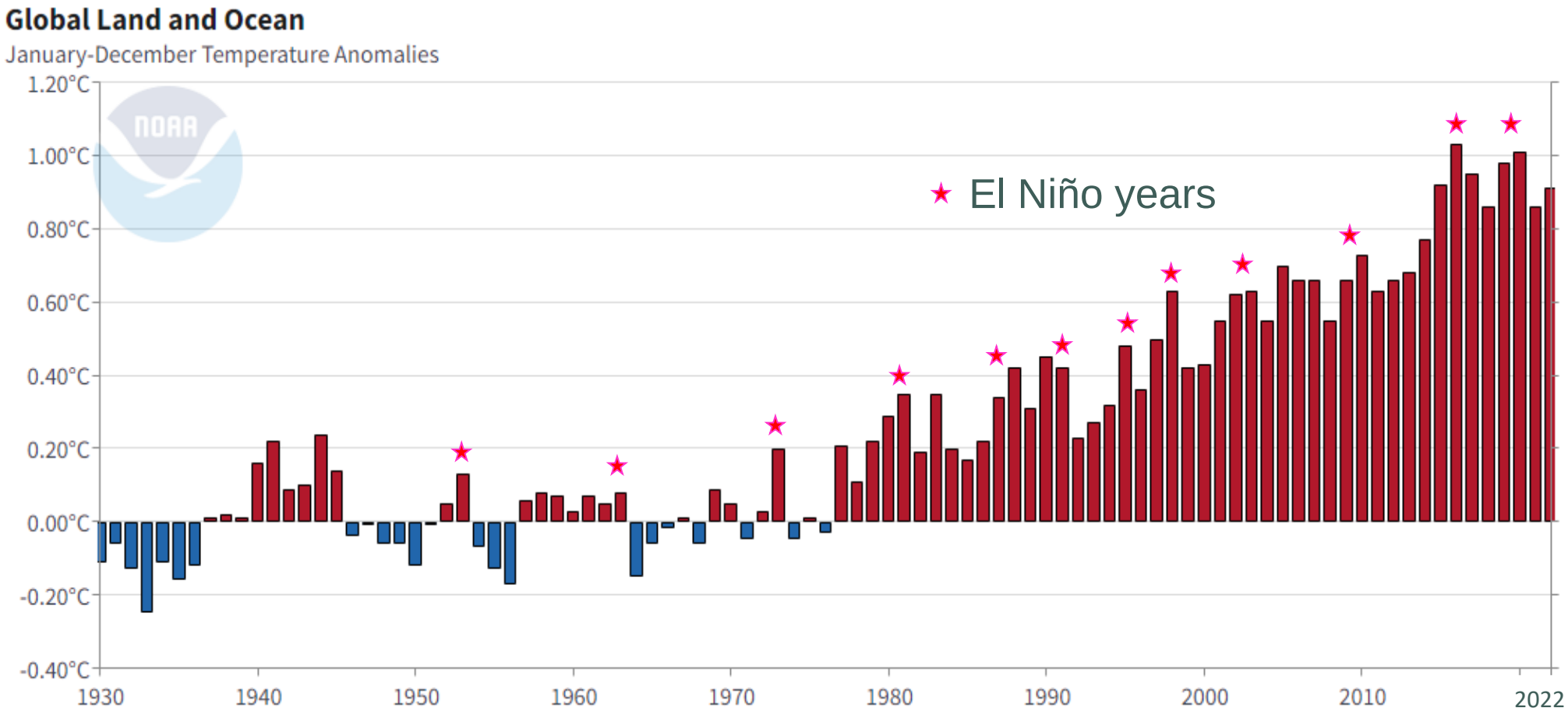
An 11% decline



A 17.5% decline

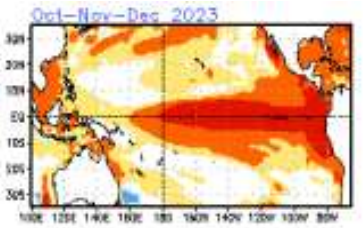
There’ll be increased pressure on our dwindling water resources

The Climate-Change Hockey Stick



It's happening … even after 3 years of the 'triple-dip' La Niña.

El Niño's coming … 2024 likely to be hottest-on-record



New Zealand's "Zero Carbon" Act (2019)

Climate Change Response (Zero Carbon) Amendment Act 2019

Public Act 2019 No 61
Date of assent 13 November 2019
Commencement see section 2

Contents

The Purpose of the Act (Section 3) is to …

provide a framework by which New Zealand can develop and implement clear and stable climate change policies that—

(i) contribute to the global effort under the Paris Agreement to limit the global average temperature increase to 1.5° Celsius above pre-industrial levels; and

… Mitigation

… at this stage we can probably ignore horticultural emissions (mitigations)

Figure 10.1 Indicative yearly biological emissions per hectare from different land uses

Source: Clothier et al. (2017); Reisinger et al. (2017); MAF (n.d.).

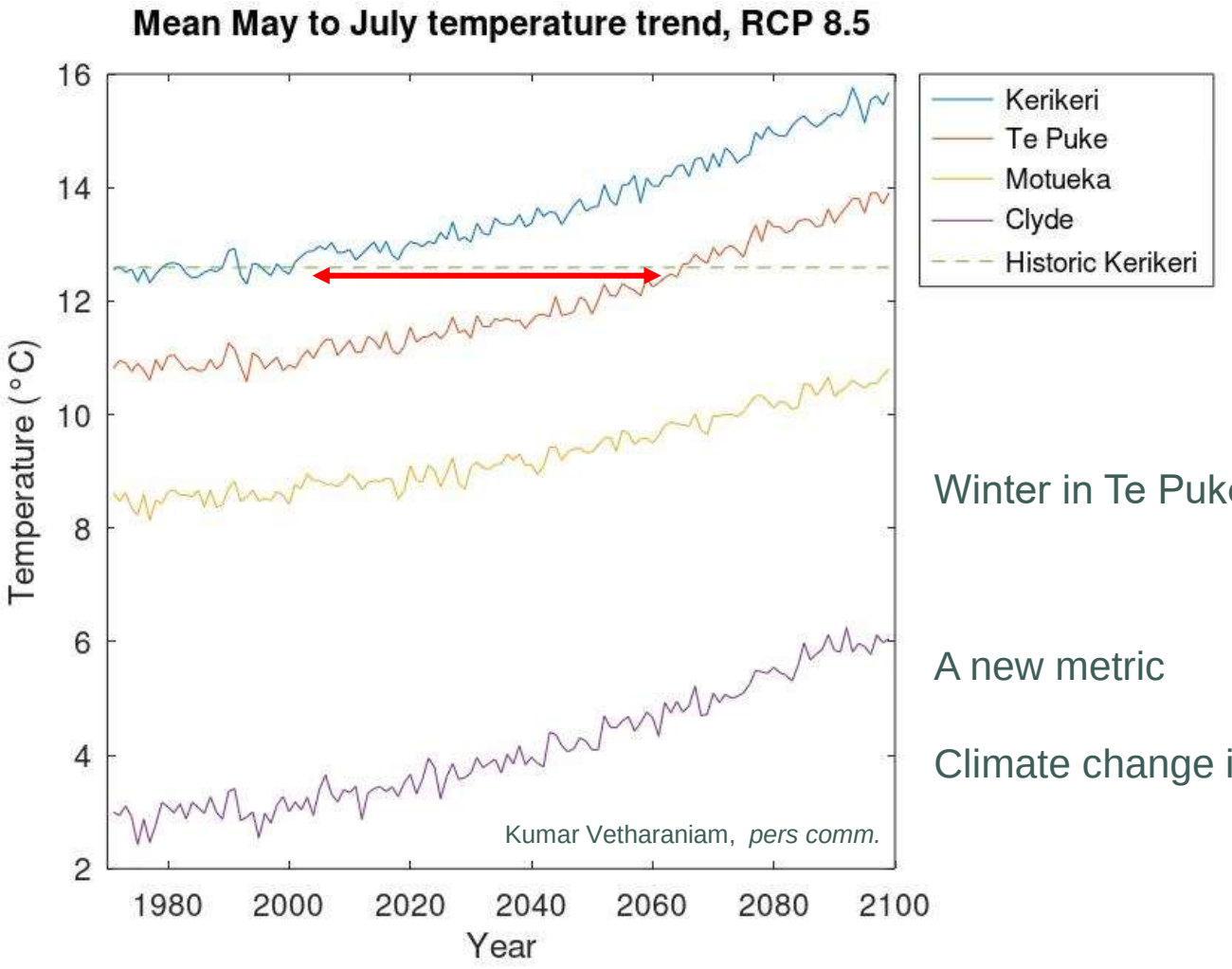
Hierarchy of Adaptation Options

Following Stokes & Howden (2010):

- **Tactical adaptation**: Modifying production practices within the current system.
- **Strategic adaptation**: A change to the current production system in a substantive way.
- **Transformational adaptation**: Involves adoption of a new production system, or a change in the location of the industry.

Add “extreme events” into strategic & transformational adaptations

Projected Climate Change: High-Emissions Pathway (RCP8.5)*



Winter in Te Puke will, in 60 years' time, be like it is now in Kerikeri

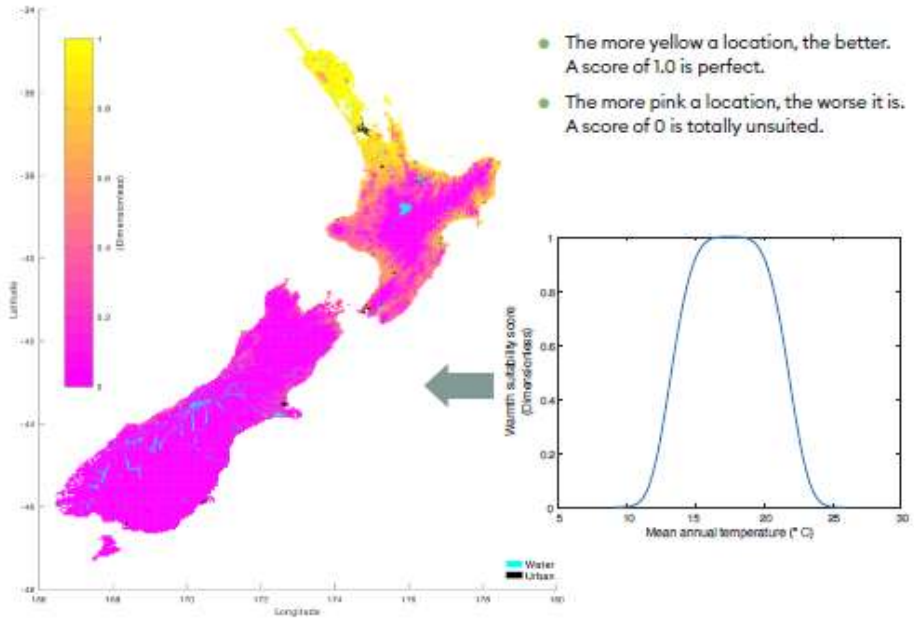
A new metric

Climate change is coming to you at a southward-velocity of 10 km y^{-1}

- Representative Concentration Pathway (RCP) 8.5 W m^{-2} of radiative forcing (net energy input)
  That's pretty much "business-as-usual"!

Today's Location Suitability for Avocado Growing: Tactical & Strategic Adaptation

Warmth Suitability Score for Avocado



Plus …

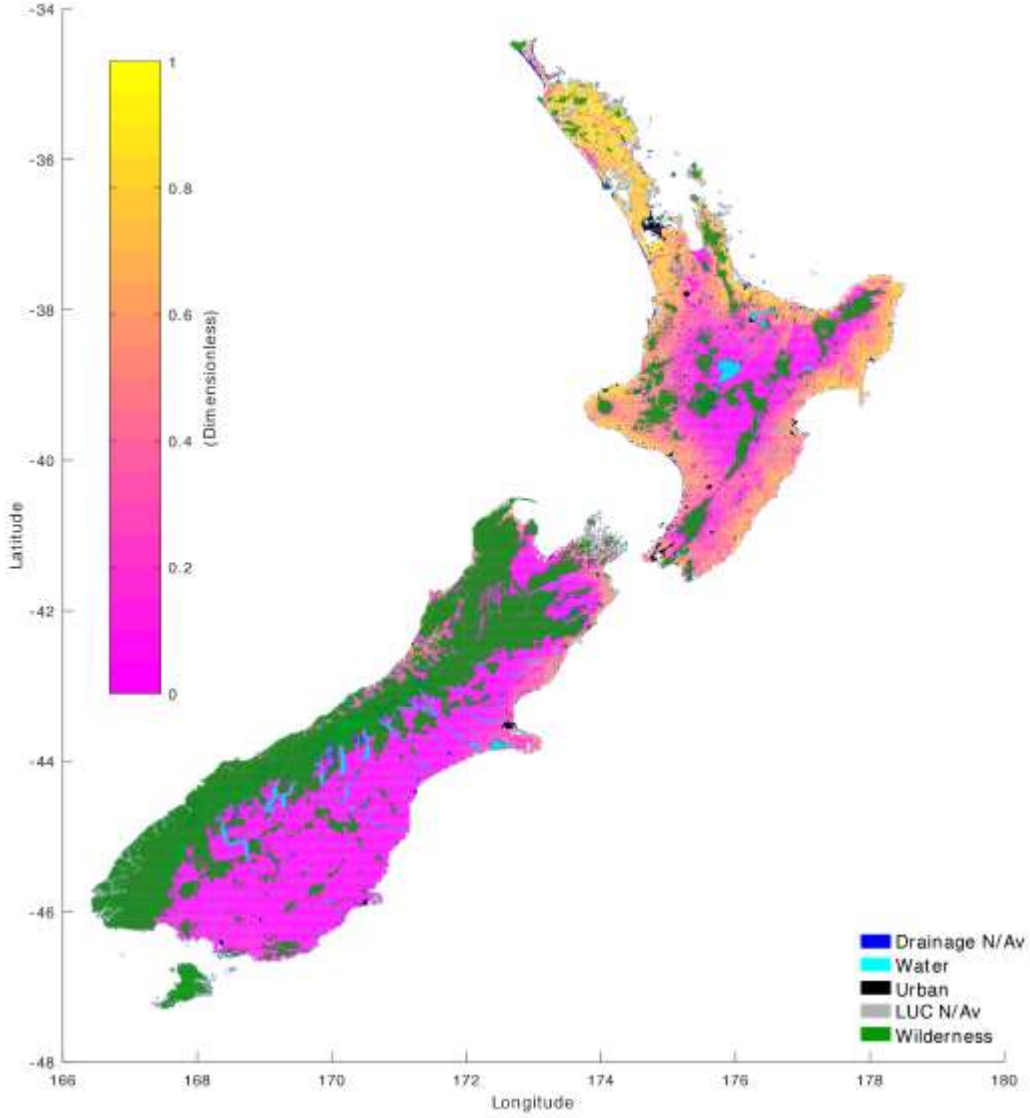
Criteria considered	Importance
Climate related	
Mean annual temperature	High
Low frost risk	High
Soil or land related	
Drainage	High
Potential rooting depth	Moderate
Land use capability class (LUC)	Moderate
pH	Moderate
Slope of land	Low


land

Modelling Continuous Location Suitability Scores and Spatial Footprint of Apple and Kiwifruit in New Zealand

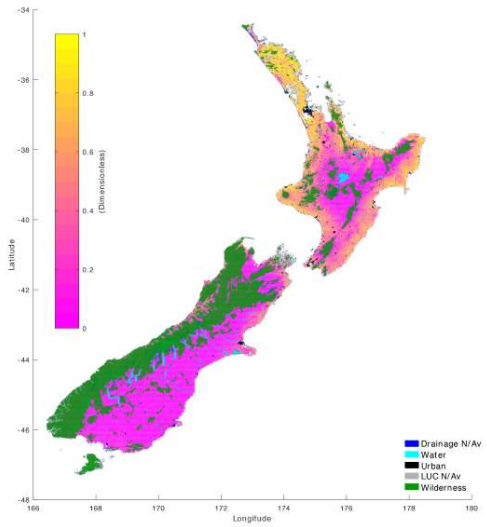
Based on Vetharaniam *et al.* (2022)

Overall suitability for avocado today (5 x 5 km)



Tomorrow's Location Suitability for Avocado Growing: Transformational Adaptation

Today



Area (km^2)

Suitability range	Historic (1972–2004)	Mid-century	Late-century
0.6–0.7	9,360	13,700 (12,300–15,300)	19,000 (17,900–20,100)
0.7–0.8	7,950	11,400 (10,600–12,700)	17,400 (16,100–18,900)
0.8–0.9	4,090	6,720 (5,630–7,830)	11,800 (10,400–13,000)
0.9–1.0	1,150	2,670 (2,230–3,340)	6,110 (5,360–7,340)

Ranges in brackets indicate prediction uncertainty

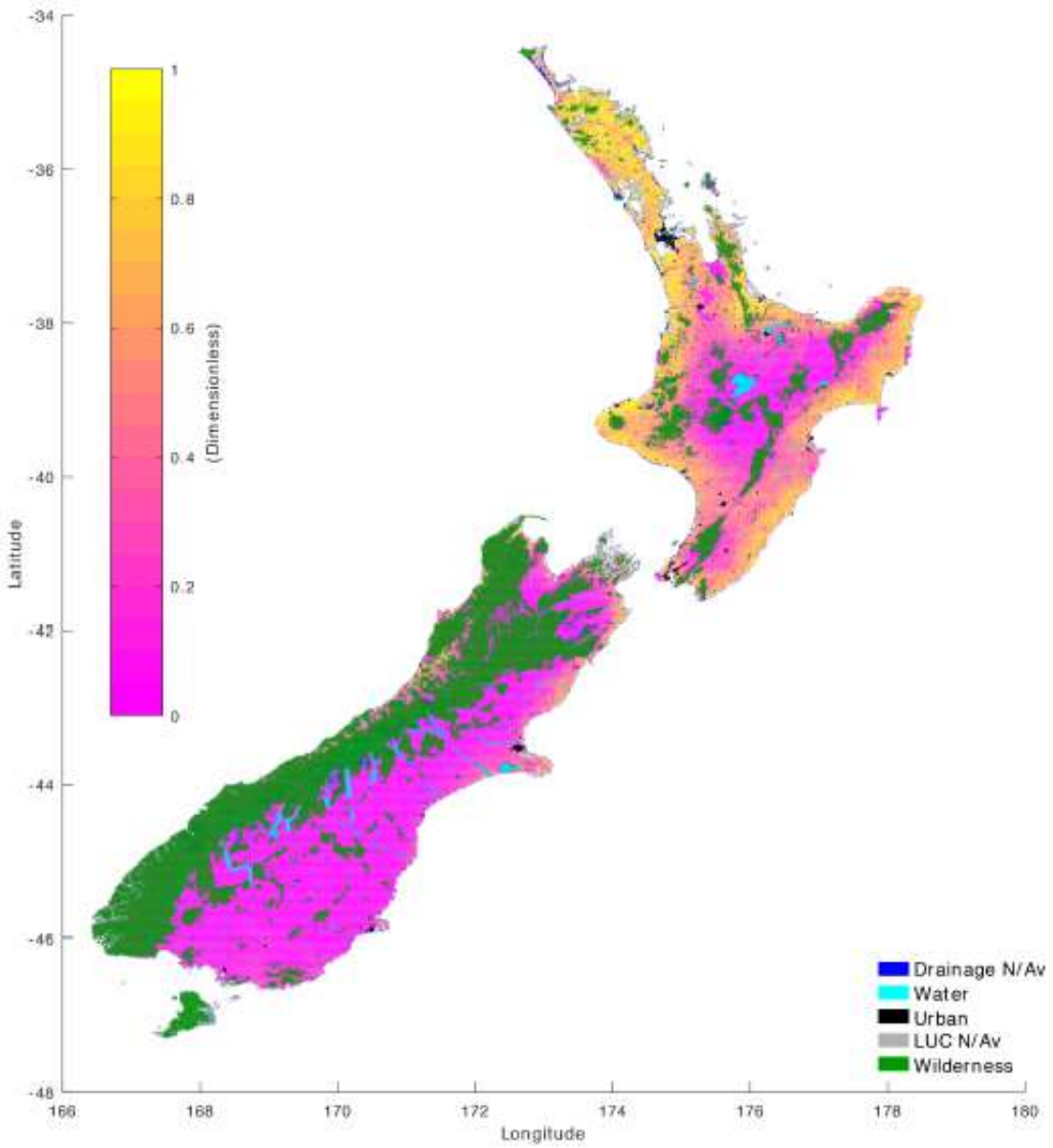
1 km^2 = 100 ha

≈ 2x

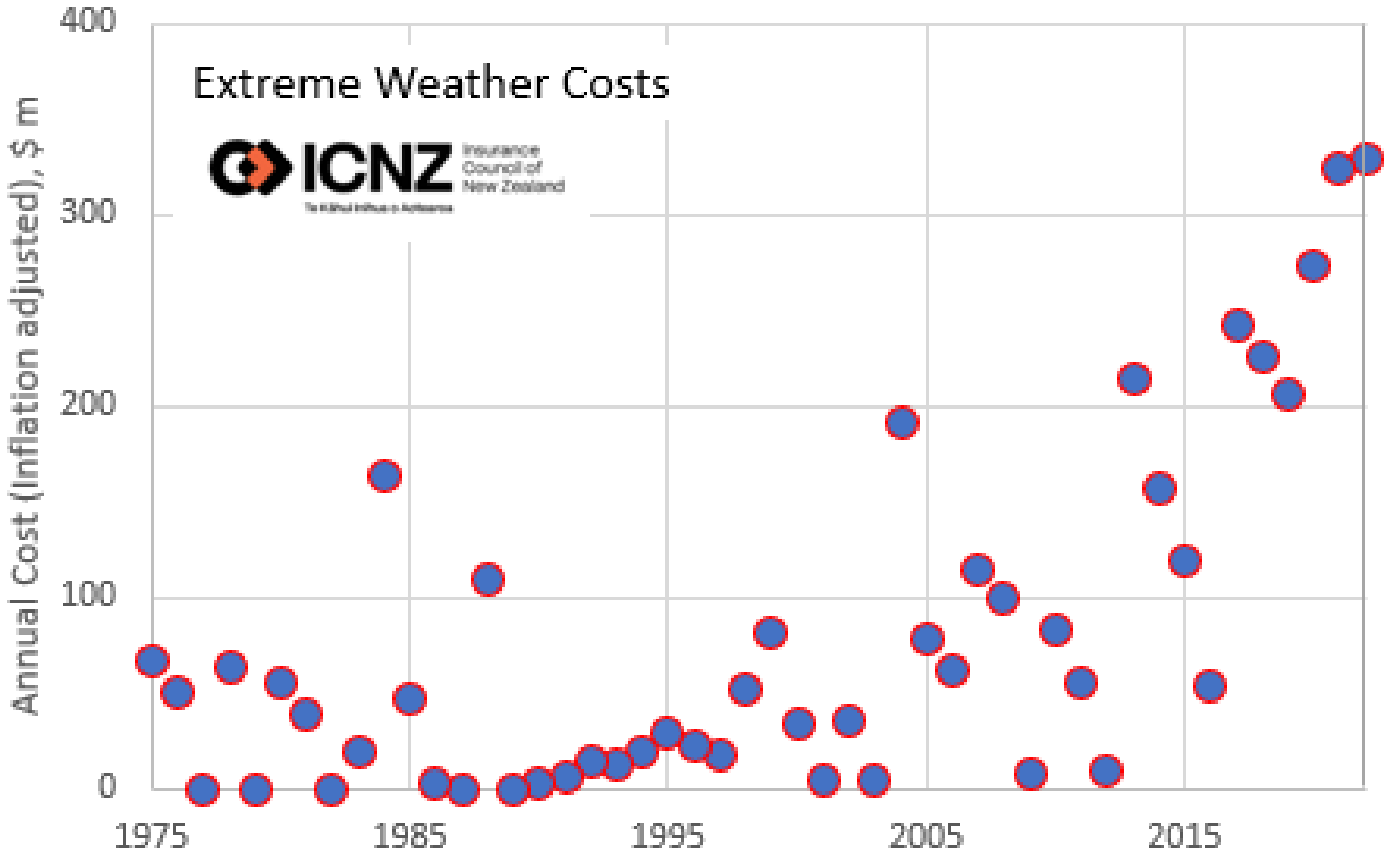
≈ 3.5x

Transformational change possible

Mid-century Suitability (RCP 8.5)

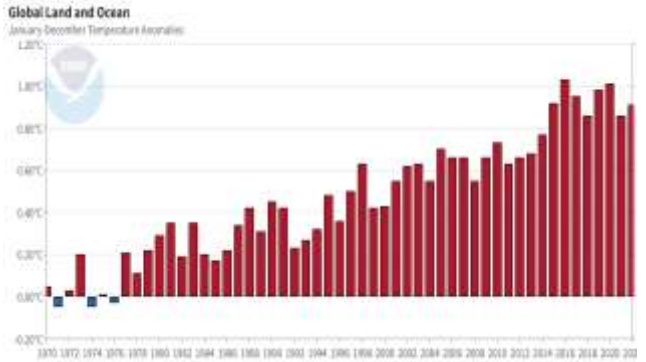


But extreme events. They're already hitting us in the pocket!



With rising temperatures the atmosphere has more energy & water to get rid of

Temperature



And that's even before the last two months …

Recent Extreme Rainfall Events in New Zealand:

Former Prime Minister Sir Geoffrey Palmer once called New Zealand an "***irredeemably pluvial country***".

Beware the Climate “Doom Loop”

The world is at risk of descending into a climate “doom loop”

Emphasising **adaptation** by simply coping with the escalating impacts of climate change

… could draw resources away from the need to slash carbon emissions through **mitigation**

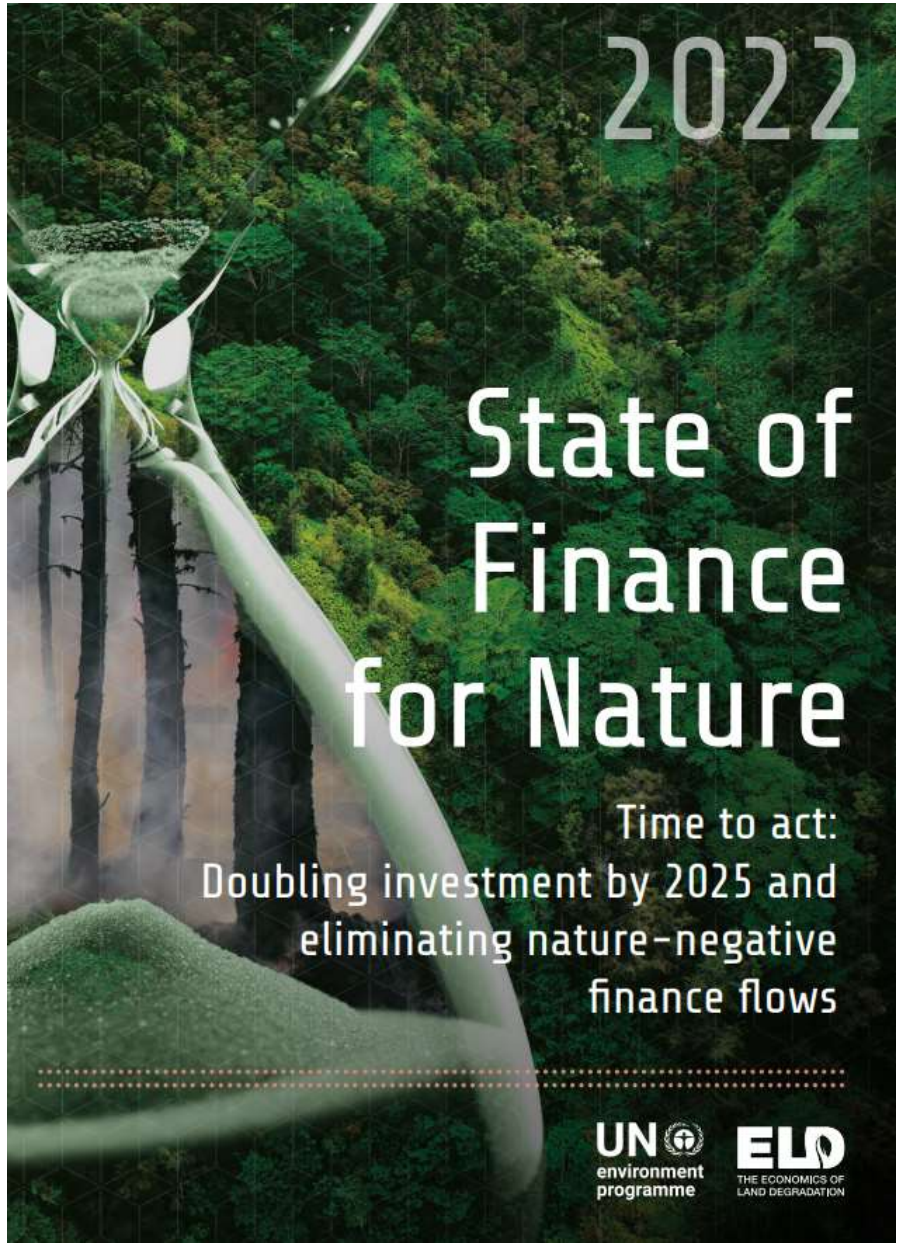
… making the situation even worse.

The Guardian

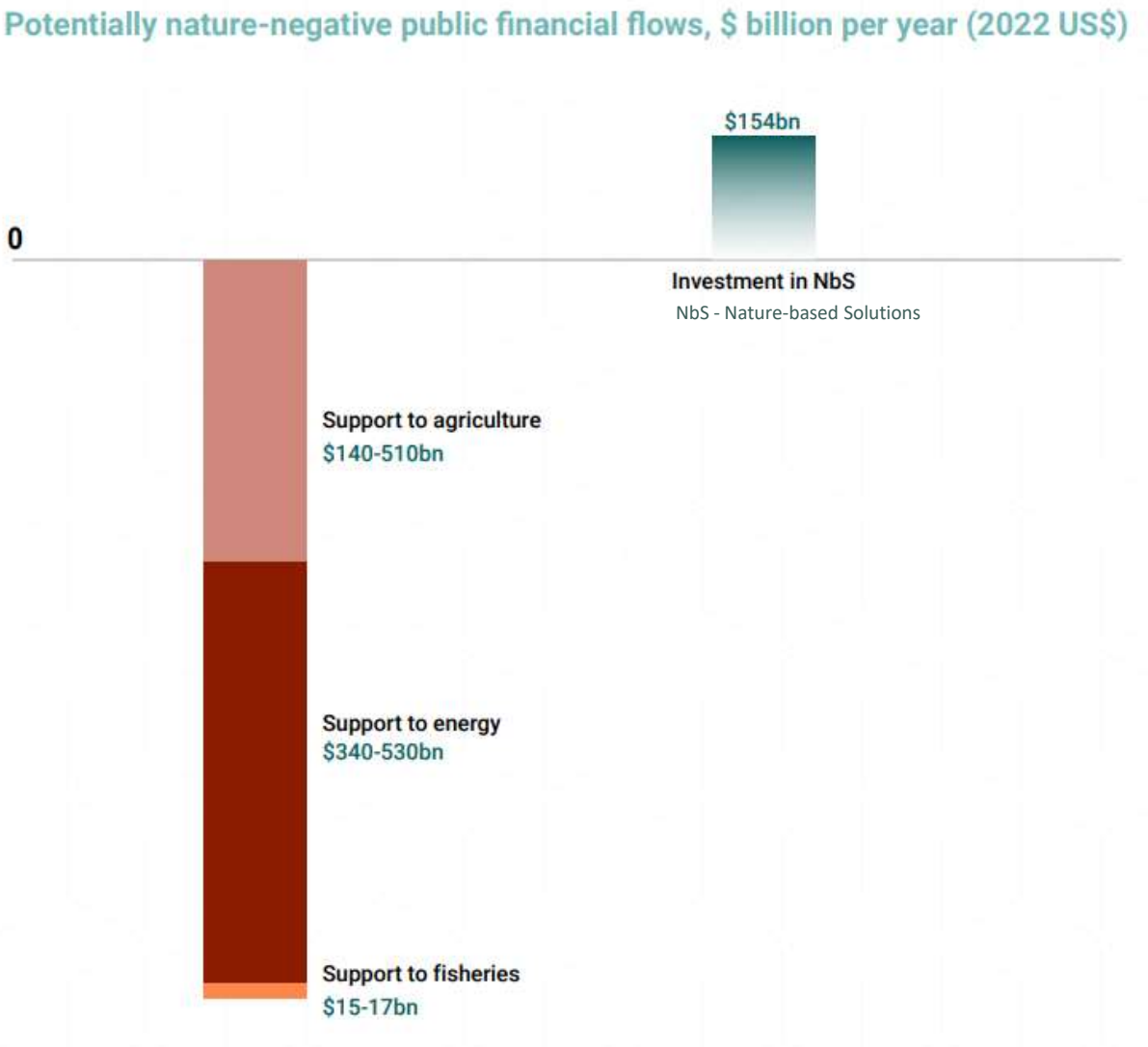
16th February 2023.

World risks descending into a climate ‘doom loop’, warn thinktanks | Climate crisis | The Guardian

Investing in Nature: The Benefits



Sadly, the Balance Sheet is in the Red

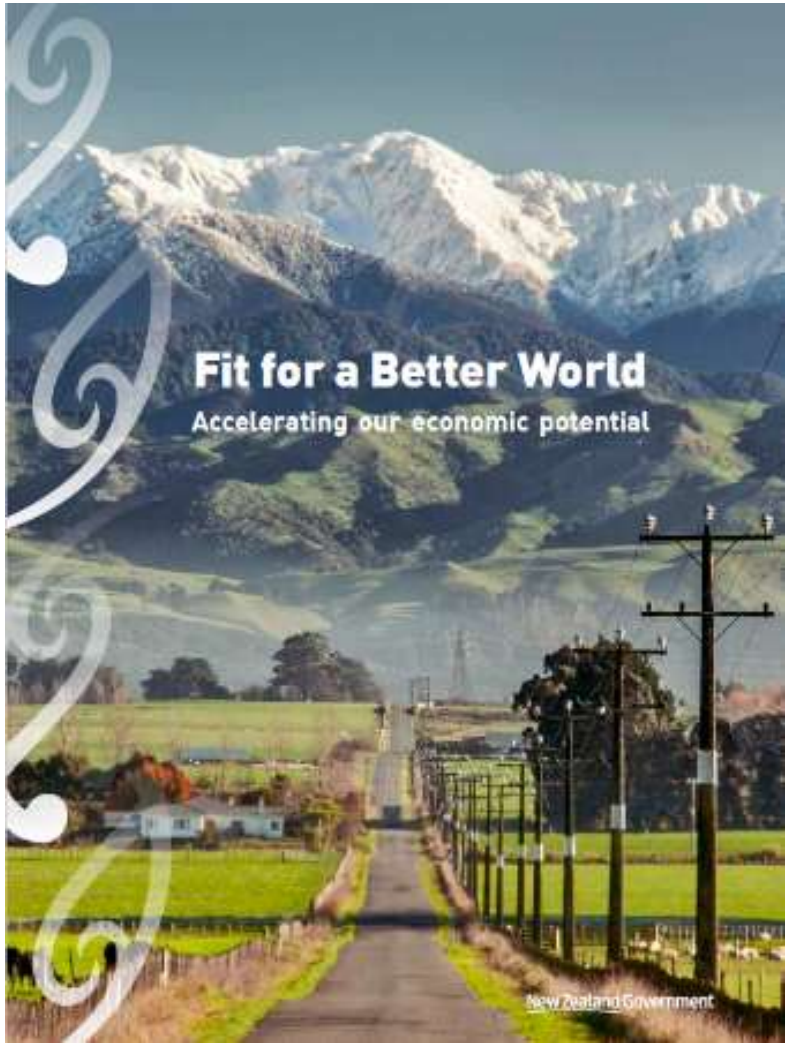


Commentary from Our Ministry of Primary Industries …

Achieving our sustainability goals requires a particular focus on the health of our soil, plants, animals and people.

There is an opportunity to design a New Zealand based regenerative farming approach, based on current sustainable practices and a mindset of continuous improvement, and the principles of Te Taiao (environment) and the mātauranga (knowledge) that underpins it.

Our approach will recognise the connection between the health of our land and the health and resilience of our communities, waterways, biodiversity and climate.



Nature’s Pots of Gold

- Our soils
- Our waters
- Our plants
- Our fruit
- Our people

The Return-on-Investment into Nature is High

Plant & Food Research
Rangahau Ahumāra Kai

Thank you

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A smart green future. Together.

plantandfood.co.nz