Manaaki Whenua
Landcare Research

Ecosystem-based solutions for climate change adaptation in rural landscapes of New Zealand

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Our Land and Water National Science Challenge & the Next Foundation

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‘Think piece’ on Regenerative Agriculture in Aotearoa New Zealand: project overview and statement of purpose

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Find the full project overview, white paper and topic reports at

ourlandandwater.nz/regenag and www.landcareresearch.co.nz/publications/regenag

This report is one of a series of topic reports written as part of a ‘think piece’ project on Regenerative Agriculture (RA) in Aotearoa New Zealand (NZ). This think piece aims to provide a framework that can be used to develop a scientific evidence base and research questions specific to RA. It is the result of a large collaborative effort across the New Zealand agri-food system over the course of 6 months in 2020 that included representatives of the research community, farming industry bodies, farmers and RA practitioners, consultants, governmental organisations, and the social/environmental entrepreneurial sector.

The think piece outputs included this series of topic reports and a white paper providing a high-level summary of the context and main outcomes from each topic report. All topic reports have been peer-reviewed by at least one named topic expert and the relevant research portfolio leader within MWLR.

Foreword from the project leads

Regenerative Agriculture (RA) is emerging as a grassroot-led movement that extends far beyond the farmgate. Underpinning the movement is a vision of agriculture that regenerates the natural world while producing ‘nutrient-dense’ food and providing farmers with good livelihoods. There are a growing number of farmers, NGOs, governmental institutions, and big corporations backing RA as a solution to many of the systemic challenges faced by humanity, including climate change, food system disfunction, biodiversity loss and human health (to name a few). It has now become a movement. Momentum is building at all levels of the food supply and value chain. Now is an exciting time for scientists and practitioners to work together towards a better understanding of RA, and what benefits may or not arise from the adoption of RA in NZ.

RA’s definitions are fluid and numerous – and vary depending on places and cultures. The lack of a crystal-clear definition makes it a challenging study subject. RA is not a ‘thing’ that can be put in a clearly defined experimental box nor be dissected methodically. In a way, RA calls for a more prominent acknowledgement of the diversity and creativity that is characteristic of farming – a call for reclaiming farming not only as a skilled profession but also as an art, constantly evolving and adapting, based on a multitude of theoretical and practical expertise.

RA research can similarly enact itself as a braided river of interlinked disciplines and knowledge types, spanning all aspects of health (planet, people, and economy) – where curiosity and open-mindedness prevail. The intent for this think piece was to explore and demonstrate what this braided river could look like in the context of a short-term (6 month) research project. It is with this intent that Sam Lang and Gwen Grelet have initially approached the many collaborators that contributed to this series of topic reports – for all bring their unique knowledge, expertise, values and worldviews or perspectives on the topic of RA.

How was the work stream of this think piece organised?

The project's structure was jointly designed by a project steering committee comprised of the two project leads (Dr Gwen Grelet[1] and Sam Lang[2]); a representative of the New Zealand Ministry for Primary Industries (Sustainable Food and Fibre Futures lead Jeremy Pos); OLW's Director (Dr Ken Taylor and then Dr Jenny Webster-Brown), chief scientist (Professor Rich McDowell), and Kaihāpai Māori (Naomi Aporo); NEXT's environmental director (Jan Hania); and MWLR's General Manager Science and knowledge translation (Graham Sevicke-Jones). OLW's science theme leader for the programme 'Incentives for change' (Dr Bill Kaye-Blake) oversaw the project from start to completion.

The work stream was modular and essentially inspired by theories underpinning agent-based modelling (Gilbert 2008) that have been developed to study coupled human and nature systems, by which the actions and interactions of multiple actors within a complex system are implicitly recognised as being autonomous, and characterised by unique traits (e.g. methodological approaches, world views, values, goals, etc.) while interacting with each other through prescribed rules (An 2012).

Multiple working groups were formed, each deliberately including a single type of actor (e.g. researchers and technical experts only or regenerative practitioners only) or as wide a variety of actors as possible (e.g. representatives of multiple professions within an agricultural sector). The groups were tasked with making specific contributions to the think piece. While the tasks performed by each group were prescribed by the project lead researchers, each group had a high level of autonomy in the manner it chose to assemble, operate, and deliver its contribution to the think piece. Typically, the groups deployed methods such as literature and website reviews, online focus groups, online workshops, thematic analyses, and iterative feedback between groups as time permitted (given the short duration of the project).

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[1] Senior scientist at MWLR, with a background in soil ecology and plant ecophysiology - appointed as an un-paid member of Quorum Sense board of governors and part-time seconded to Toha Foundry while the think piece was being completed

[2] Sheep & beef farmer, independent social researcher, and project extension manager for Quorum Sense

Ecosystem-based solutions for climate change adaptation in rural landscapes of New Zealand

Contract Report: LC3954-18

Sandra Lavorel, Gwen-Aëlle Grelet

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Introduction

Ecosystems and their biodiversity ('Nature', henceforth; Díaz et al. 2015) contribute to people's quality of life (or well-being). These contributions can be positive (e.g. pollination, crop pest control, carbon sequestration by plants and soils, flood mitigation) or negative (e.g. invasive pest species, diseases), sometimes depending on the context or people (Diaz et al. 2018). The positive contributions of nature to human quality of life have been referred to as 'ecosystem services'. Their multiple economic, social, and cultural values are promoted by current alternatives to conventional agriculture (Plumecocq et al. 2018).

As one of its contributions to people's quality of life, Nature can support the adaptation of agro-ecosystems and farming communities to climate change. Adaptation occurs through actions and decisions made in order to limit the occurrence, and reduce, buffer, and repair the impacts, of multiple climate change direct drivers (e.g. increased temperatures means and extremes, changed precipitation regimes) and indirect drivers (e.g. more frequent fires or floods, exotic species invasions) on farm systems.

We have defined Nature's contributions to Adaptation (NCA) as the ecological properties and functions that people can manage and govern to regulate risks from climate change and related hazards, and that provide options for sustaining Nature's material and non-material benefits to their livelihoods (Lavorel et al. 2015; Colloff et al. 2020). These contributions are inherently a co-creation of benefits between humans and Nature. These contributions to adaptation are typically derived from ecosystems in good condition, including through their biodiversity.

Nature's Contributions to Adaptation (NCA) can be considered across five categories (Lavorel et al. 2020):

- ecological resilience – the ability, often underpinned by greater biodiversity, to buffer impacts on ecosystems from extreme climate events and other climate-related disturbances (e.g. fire)
- ecological transformability – the ability of ecosystems to reconfigure under changing trends and extreme climate changes through biotic community reorganisation and dispersal
- latent regulating contributions, whose values are revealed or increased under climate change, such as reducing floods and erosion from extreme rainfall, or climate mitigation through carbon sequestration
- sustained current material, regulating and non-material contributions from resilient or transformed ecosystems
- novel contributions from transformed ecosystems, such as new crops and products from species for which climate suitability increases, or the creation of new cultural values for novel biota, ecosystems, and landscapes.

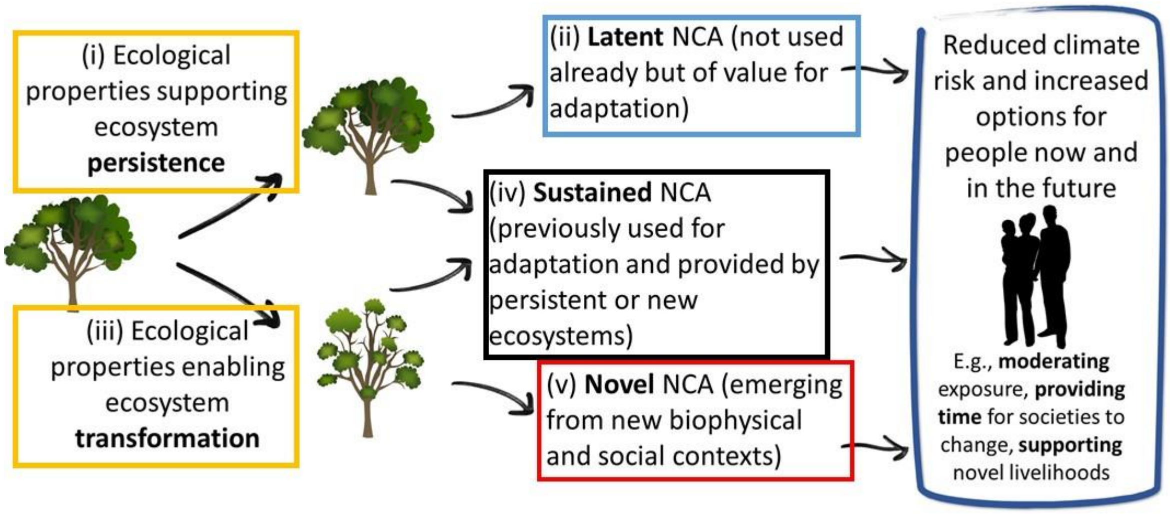

Figure 1. Typology of Nature's Contributions to Adaptation (modified from Lavorel et al. 2020).

This chapter exemplifies how the focus on Nature's contributions to adaptation can be synergistic with the objectives of Regenerative Agriculture (RA) in New Zealand.

1 Nature's contributions to adaptation in New Zealand rural landscapes

We are synthesising qualitative knowledge on Nature's contributions to adaptation to climate change in New Zealand rural landscapes to illustrate how these can align with the objectives and practices of RA (Figure 2**Error! Reference source not found.** and Figure 3).

1.1 Diversifying pasture vegetation

In RA, the incorporation of greater plant diversity in pastures, along with soil management that restores and conserves soil carbon and organic matter stocks, supports a set of interconnected NCA that can contribute to delivering sought-after outcomes from regenerative farming systems. This is shown in Figure 2.

First, pastures that are more diverse (which include a greater number of species and genotypes) promote plant communities that are more stable and resilient to climate extreme (e.g. droughts, sometimes accompanied by intense extreme rainfall events). This stability and resilience is driven by properties of individual species or cultivars (e.g. drought-resistant) and also by complementarity between the different species / cultivars (e.g. different complementary timing and rate of growth) (De Bello et al. 2021).

Increased adaptation potential in the long term is supported by a diverse species and gene reservoir, which allows the pasture community to reorganise in response to both trends in climate change and extreme events (Meilhac et al. 2019). This is enhanced by the set of principles being applied by practitioners of RA in New Zealand (see Lang 2021; Grelet, Lang et al. 2021), which promote the incorporation of more diversity in farm systems (principle

10: harness diversity) by increasing the number of species, or varieties, or both; and also promote adaptive management (principle 2: make context-specific decisions), whereby species mixes can change as climate and soil conditions change.

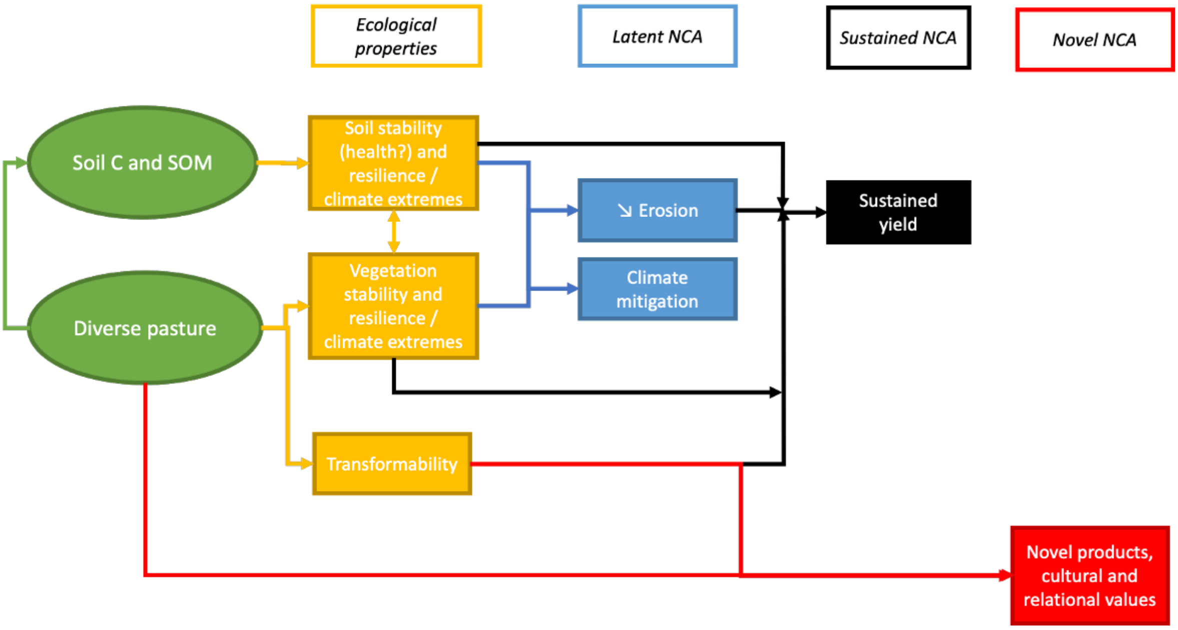

Figure 2. Multiple types of Nature's Contributions to Adaptation supported by pasture diversification and soil management in RA. NCA typology and corresponding colours are explained in Figure 1 (SOM – soil organic matter, C – carbon, NCA – Nature's Contributions to Adaptation).

Likewise, RA principles 9 and 10 (minimise disturbance, maximise photosynthesis year round – see Grelet et al. 2021, Lang et al. 2021) seek to increase soil carbon and organic matter stocks, which in turn support the stability of the physical, chemical and biological properties that underpin soil health (see Schon et al. 2021) and their resilience to climate extremes (see Donovan et al. 2021).

Second, soil health and a stable/resilient, diverse vegetation are critical for the provision of latent regulating contributions from agro-ecosystems, whose value to farmers and society increase under climate change. The first of these contributions is mitigation of climate change through carbon sequestration in soils, reduced nitrogen oxide emission, and methane consumption by soils (see Laubach et al. 2021). Reduction of erosion is another contribution provided by healthy, stable soil and diverse plant communities, whose importance to sustaining production will increase under expected changes in rainfall regimes, with more frequent, intense rainfall events, sometimes following droughts (see Donovan et al. 2021).

Third, the properties of ecological resilience and transformability, along with erosion reduction, are essential for sustaining yields in the face of climate variability and change. Better soil structure and organic matter content increase water infiltration and water holding capacity. This maintains soil moisture during drought, and hence primary plant production. Note that this also feeds back to supporting plant community stability (though not added on the diagram to avoid making it over-complicated). Also, adapted species/varieties and species complementarity in phenology, root morphology and plant physiology increase water use efficiency, thus supporting production through drier periods. In turn, the performance of individual species / varieties and the manner with which they interact as part of a diverse community of plants can inform breeding of novel agronomical mixtures that include genetic diversity as a key property (Litrico & Violle 2015). Finally, transformability towards species and varieties continuously adapted to changing climate ensures yields are sustained over time.

Fourth, as climate changes and novel species and varietal mixtures self-organise and/or are promoted by farmers' practices, so do novel productions become part of a diversified and resilient production portfolio. This includes, for example, native or naturalised medicinal and veterinary beneficial plants (Johnson 2015), or melliferous species. Evolving plant communities and their soils also support relational values among farming families and communities as learning and capabilities for climate change adaptation are built.

1.2 Indigenous and planted woody vegetation and wetlands on farmland

Regenerative farming systems often include woody vegetation and wetlands as part of the farm design. Woody vegetation, in particular, can occur as an integral part of the productive area for those RA operations that include agroforestry or silvopastures. Woody vegetation is also nurtured in most sheep & beef operations, including merino sheep. Regenerative arable farming systems can also include trees and shrubs, such as diversified hedgerows, to promote integrated pest managements, climate control, etc. The semi-natural elements support multiple contributions to climate adaptation. These contributions were reviewed in Easdale et al. (2021) and are shown in Figure 3.

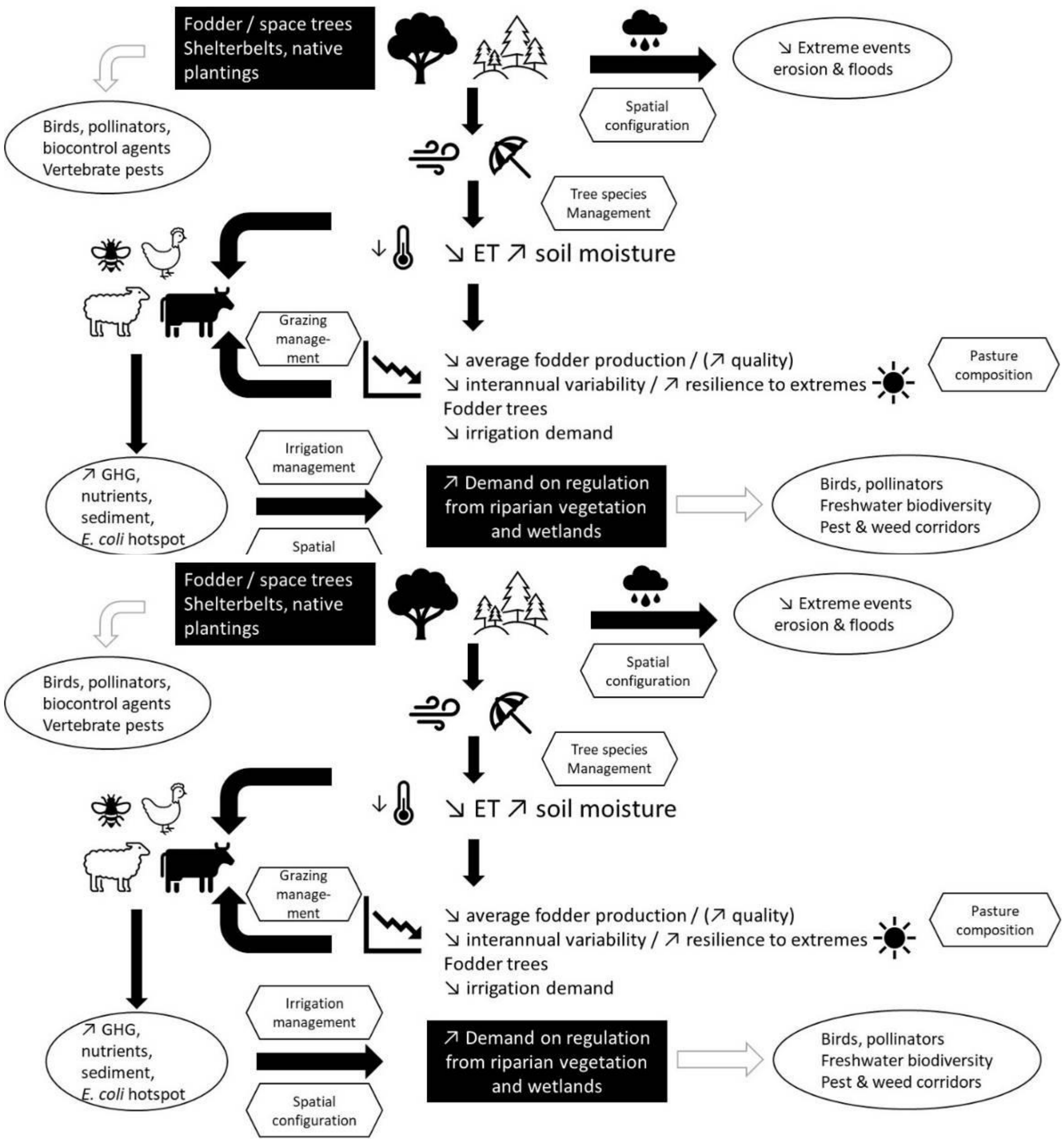

Figure 3. Multiple contributions to adaptation to climate change supported by indigenous and exotic woody vegetation and wetlands on farms (ET – evapotranspiration).

The main findings from the Easdale et. al. (2021) review are further explained below:

Planted, regenerating, and remnant trees, shrubs, and grasses regulate microclimate in pastures and fields by intercepting winds and sun and are used by farm animals for shade and shelter. This reduces hot temperatures and evapotranspiration, and increases soil moisture (Thomas et al. 2018). While in many places around New Zealand this may decrease average total annual fodder production, it also buffers interannual variability and increases its resilience to drought and heat extremes. The demand on irrigation for buffering production is thereby also reduced. Planted exotic trees (e.g. poplars, willows, tree lucerne) and native trees (e.g. pukapuka) can also provide critical complementary fodder for stock during drought periods. Such resilience of fodder production compounds with direct beneficial effects on animal health and behaviour to sustain animal production.

Net production benefits can be increased at four levels of management. First, the selection of planted tree species (deep-rooted versus more shallow roots, fast versus slower growing, and possibly also preferred type of mycorrhizal associates) and the success of planting protocols will determine the likelihood of successful erosion mitigation / control of mass movement erosion (see next paragraph). Second, the selection of planted tree species (e.g. deciduous vs evergreen, canopy density, suitability for coppicing) and their management (e.g. planting density, pruning, pollarding) determines their microclimatic effects. Third, yield sensitivity to shading and cooler early/late-season temperatures depends on pasture species composition. Fourth, choice of animal breeds and grazing management enables greater benefits for livestock production.

However, the congregation of animals beneath trees and bushes for shade and shelter, also called camping behaviour, creates hotspots of soil compaction, greenhouse gas emissions, and nutrients and pathogens deposition. These can be somewhat reduced by strategic placement of trees across slopes and away from watercourses (e.g. contour planting). However, managing herd densities and movements across the landscape will be key to control nutrient transfer across the wooded landscape, and also to prevent adverse unintended effects on catchment water quality. On plains, possible adverse impact on freshwater reservoirs can be mitigated or reduced by implementing precision irrigation. Inevitable increases in effluxes can then be mitigated by strategically located riparian vegetation and wetlands.

Woody vegetation placed at strategic locations on farms also mitigate mass movement erosion (e.g. spaced plantings for soil conservation, contour planting, etc.) and flood risks from intense rainfall events through their interception of rainfall and surface water flows, greater soil water infiltration, and capture by roots, and physical stabilisation of slopes by tree roots.

The network of woody vegetation and wetlands on farms is essential as habitat for native wildlife, pollinators, and natural biocontrol agents. Along watercourses and in wetlands, water quality and temperature regulation mitigate climate change effects on freshwater biodiversity. Woody network connectivity will be essential for helping native species migrate through farming landscapes as climate changes. This, however, trades off with facilitating the movement of weeds, and vertebrate and invertebrate pests.

2 Conclusions

2.1 Climate change adaptation as managing trade-offs and synergies across multiple adaptation services

As shown by the two examples developed here, there are ecological synergies, co-benefits and trade-offs across multiple contributions of nature to climate adaptation. Adaptation thus entails co-producing these multiple contributions and managing these interactions (Lavorel et al. 2020). This can only take place at the scale of the landscapes or catchments within which farms and rural communities operate.

Adaptation thus integrates responses to the multiple impacts of multiple climate-related drivers, where bundles of contributions to adaptation are co-managed within landscapes. Such adaptation is underpinned by the agency of multiple actors, who are engaged in ecosystem management, harvesting, or physically accessing their benefits (e.g. crops, fodder, timber, non-timber forest products, valued landscapes), and appreciating, appropriating or distributing their material and non-material values (e.g. value chains, constructing individual and collective cultural and relational values) (Lavorel et al. 2020).

Interestingly, some of the 'regenerative' outcomes identified by the sector working groups (see Grelet, Robson-Williams et al. 2021) emphasised the importance of having the farm business and biophysical ecosystem integrated in its surrounding (community, catchment, region).

2.2 Eco-centric contributions of nature to climate adaptation

Nature co-production – includes humans

The Nature's Contribution to People framework (Diaz et al 2018), on which the NCA framework is anchored, acknowledges that Nature's contribution is both generalisable but also defined on a place-by-place basis, and hence inherently dependent on people's prevalent culture and values at any one location (Hill et al 2021). The Nature's Contribution to People framework holds indigenous and local knowledge at the centre stage of both its creation and implementation.

One of the opportunities for the NCA framework in New Zealand, and with RA, is to explicitly include in its premise the diversity of contributions by Nature for Nature, and by humans for Nature. Indeed, Te Ao Māori, the Māori world view, is place-based (see Selai, 2021), but also acknowledges humans as a part of ecosystems/nature rather than separated from ecosystems/nature (Harmsworth & Awatere 2013), and so do most RA practitioners (see Lang 2021 – RA principles: the farm is a living system, make context-specific decisions & harness diversity).

This world view is conducive to acknowledging the rights of nature to its own social, economic, and environmental well-being. In fact, New Zealand became the first country in the world to grant legal personhood to a natural feature. In 2014 Te Urewera, a mountain range in the North Island, gained the same legal status as an individual person (Te Urewera Act 2014). Later in 2017, the Whanganui River also became a legal person (Te Awa Tupua Act 2017), and shortly after that, the government ('the Crown') and Taranaki iwi signed a Record of Understanding to state their shared intention that legal personhood will be granted to Taranaki Maunga (Mount Taranaki) as well.

This extended eco-centric version of Nature's Contributions would also presumably promote an adaptive and healthy whenua (Land, placenta, landscape), where mauri (life force, essence) from mountain to sea is in balance through time as climate changes – and this balance is place-specific.

RA practitioners see the farm as a living system (RA principle 1, see Lang 2021; Grelet al. 2021), which altogether has its own unique set of properties (context) (RA principle 2), of which humans are an integral part, and where the well-being of all parts of the system is valued, including the business, the farming family and any employees, but also the quality of life of animals, plants, water ecosystems, soil biota, and so on. Can RA farming systems provide a testing ground within which the concept of eco-centric, place-based Nature's contributions to adaptation of both people and nature might be applied, and its usefulness and impact assessed?

2.3 Adaptation services and Regenerative Agriculture: knowledge gaps

The key knowledge gaps in Nature's Contributions to Adaptation for RA are:

- Do RA farming system promote more effective Nature's Contributions to Adaptation, compared with other farming systems in comparable biophysical contexts (climate, soil type, topography, business type, etc.)?
- What novel adaptations, if any, might evolve in the near future from RA farming systems in New Zealand as climate change pressure increases?
- Can RA contribute to promoting pluralism and diversity of place-based solutions into climate change adaptation strategies for New Zealand farming, and build synergies with or support Māori-led initiatives?
- Can RA guide / contribute to identifying the steps required to the development of eco-centric Nature's Contributions to Adaptation, in the wider context of New Zealand farming?

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