Regenerative agriculture in Aotearoa New Zealand– research pathways to build science-based evidence and national narratives.

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Contents

Executive summary

CONTEXT:

- Regenerative agriculture (RA) is proposed as a solution to reverse climate change, biodiversity loss, declining water quality and health of freshwater ecosystems, wellbeing crisis in rural and farming communities and food system dysfunctions. RA may also open overseas premium and niche markets. However, there is a lack of clarity about what RA actually is, scepticism about its claimed benefits, and uncertainty as to whether the concept is even relevant to Aotearoa New Zealand (NZ).
- This white paper is the result of an intensive collaboration and consultation during June to November 2020. More than 70 NZ-based organisations and 200 people participated, collaborators including farmers and growers, researchers, private consultants, industry levy bodies, banks, retailers, not-for-profit organisations, overseas researchers and educators.
- The research underpinning this paper aimed to: (1) better understand what RA means for NZ and (2) develop a scientific framework for guiding RA research in NZ. It involved qualitative and quantitative online surveys, focus groups and literature/website searches, and focused primarily on what happens within the farmgate.
- Te ao Māori – the Māori worldview – is aligned to and important in the context of RA. However, whakapapa and mātauranga constitute a uniquely Māori knowledge system that is held by experts and collectively enacted by tangata whenua. From our discussions with Maori practitioners and researchers, it is clear that cultural concepts must remain grounded in te ao Māori and be guided by tikanga to ensure their integrity, including in their businesses. For tangata and whenua to benefit collectively from system transformation such as the one proposed by RA protagonists, an overview and insight into the diversity of Māori knowledge and practices for food and fibre production is needed first and also needs to be guided by tikanga. Tangata whenua and their diversity of enterprises cannot meaningfully engage in a conversation about linkages with RA until the time, space and resource for collective thinking has taken place. This work needs to be undertaken in the first instance by Māori experts and practitioners and is currently underway elsewhere.

FINDINGS:

- A small group of NZ RA farmers and practitioners, considered to be leading innovators by their community, informed the development of 11 principles for RA within the farmgate: (1) The farm is a living system; (2) Make context-specific decisions; (3) Question everything; (4) Learn together; (5) Failure is part of the journey; (6) Open and flexible toolbox; (7) Plan for what you want; start with what you have; (8) Maximise photosynthesis (year-round); (9) Minimise disturbance; (10) Harness diversity; (11) Manage livestock strategically. Collectively these principles embody a 'regenerative mindset', focus on attitudes and behaviours important for working with complex living systems, and provide targeted guidance on farm systems and practices.
- Discussions about "regenerative farming systems" with representatives from four NZ agricultural sectors (dairy, sheep & beef, arable, viticulture) focused on aspects such as social wellbeing, soils, integrated circular systems and marketability of regenerative produce. The top sought-after outcomes included achieving pride in farming, decisions based on long-term outcomes, increasing profitability and financial expertise rather than merely increasing production, continuous learning and positioning NZ as a world leader in RA.
- Our high-level review highlighted that the NZ agricultural sector is performing well and demonstrating leadership in some respects but with regard to water, soils, and native biodiversity, agricultural activities are contributing to NZ environmental and social challenges. Parts of the country are ill-equipped to cope with predicted frequent/intense drought and flooding. Such challenges will likely need to be addressed if NZ is to claim to deliver "regeneratively-produced" food and fibre.

- There is no hard and fast distinction between mainstream and RA systems and practices. There is instead a continuum of practices with significant overlap between mainstream and RA. However, some practices commonly employed by RA practitioners in NZ are RA-specific and some mainstream practices are inconsistent with RA principles.
- Various biophysical aspects of NZ are highlighted that sets it apart from other countries: its carbon-rich soils, the extreme contrast between NZ native biodiversity and the species supporting its agriculture, and its high propensity to soil erosion. NZ should evolve its own RA narrative based as much on soil carbon retention as on its increase and functionality, elimination of sediment losses, and the development of its RA farming systems to foster both 'total' and native biodiversity. Examination of domestic and overseas consumers' preferences and their willingness to pay extra for specific environmental outcomes suggest RA could increase the export value/overseas marketability of NZ food and fibre produce.
- Research needs are varied. Representatives of four NZ major ag sectors are asking for research on how RA impacts (1) Freshwater outcomes; (2) Food quality and safety; (3) Farmer empowerment and mindset; (4) Long-term viability of whole systems; (5) Animal welfare; (6) On-farm all taxa (total) biodiversity; and (7) Soil carbon. They also asked researchers to assess how RA might increase (8) resilience; (9) accountability in our food systems and (10) access to premium/niche markets. In addition to the above, RA practitioners highlight the need for scientific studies on how RA affects (11) soil health; (12) profitability and production; and (13) whole-of-system environment, social and economic outcomes at farm-scale. Finally, professionals in the wider agri-food system further want (14) data to de-risk investment and transition to RA; (15) 'conventional-style' practice guides for RA, customised for different sectors and NZ contexts; (16) an understanding of the 'RA continuum" and (17) clarity around the need for a definition/certification for RA (or the lack thereof).
- A consortium of 50+ scientists and independent experts examined the claims made by RA protagonists to highlight key knowledge gaps for RA in NZ and to propose sets of indicators and experimental approaches suitable to close these gaps. Topics addressed were: farmers' wellbeing; RA economics and marketability; productivity; produce quality and safety; animal welfare; reduction of greenhouse gas emissions; soil health; resilience to extreme weather events; freshwater outcomes; biodiversity; adaptation to global change; and an integrated one whenua one health framework.

RECOMMENDATIONS FOR RA RESEARCH:

We recommend that RA research be designed to not only test and/or explain RA claims, but also to inform/support the transformation of NZ's agriculture and food system, enabling direct data-based feedback between scientists, producers and consumers, which can in turn inform NZ's own RA narrative. To achieve this, we recommend that:

- In relevant contexts, mātauranga Māori-led research approaches be prioritised.
- RA research be focused on (i) established RA farms, that have been successfully managed under RA principles for multiple years and (ii) transition case-studies, which should whenever possible be located where the most gains can be made from RA, should its claims be proven true.
- Suitable experimental approaches:
    - To investigate biophysical attributes: (i) pairwise comparative approaches with sufficient replication, (ii) large-scale time-series (preferentially 5+ years) across a network of unpaired sites following adequate baselining of both control and RA sites; .
    - To investigate socio-economic attributes: large representative samples of population or businesses for the investigation of socio-economic attributes using large-scale methods (e.g. surveys), or smaller, carefully selected, representative exemplars of individuals or businesses when using other methods (e.g. interviews)
- Farm system research can be used to assess the impact of RA on farm-level productivity and resource use, and to understand the impact of individual RA practices in the context of a whole system management change.

- Life cycle analyses (not covered in this paper) are essential to assess farm carbon and greenhouse gas footprints.
- Economic assessments offer limited insight if they do not account for increase or decrease in natural capital (e.g. using natural capital valuation/true cost accounting).
- Many outcomes (e.g. biodiversity, freshwater health, food quality, some economic outcomes) can be assessed by combining farmer-led data capture and remote/proximal sensing with scientists-led in-field measurements and modelling/machine learning to ground-truth and increase accuracy and precision of sensing technologies. This in turn can be used to (i) create a direct data-based feedback loops between farmers/growers, scientists, and consumers and (ii) contribute to a national effort on environmental monitoring.
- RA research projects need to (i) collectively maximise synergy and complementarity of topics and methodologies, (ii) include a combination of benchmarked metrics of significance to producers (RA and others) and scientists.

PERSPECTIVES AND OPPORTUNITIES:

The success and impact of RA research on the NZ agri-food system can be accelerated by it being undertaken in an adaptive, transparent and agile manner in genuine partnership with iwi, successful RA practitioners and the wider farming community, industry and decision makers, scientists, and representatives of market/brands – to enable the rapid uptake of research findings by both consumers and producers, and inform NZ's own RA narratives.

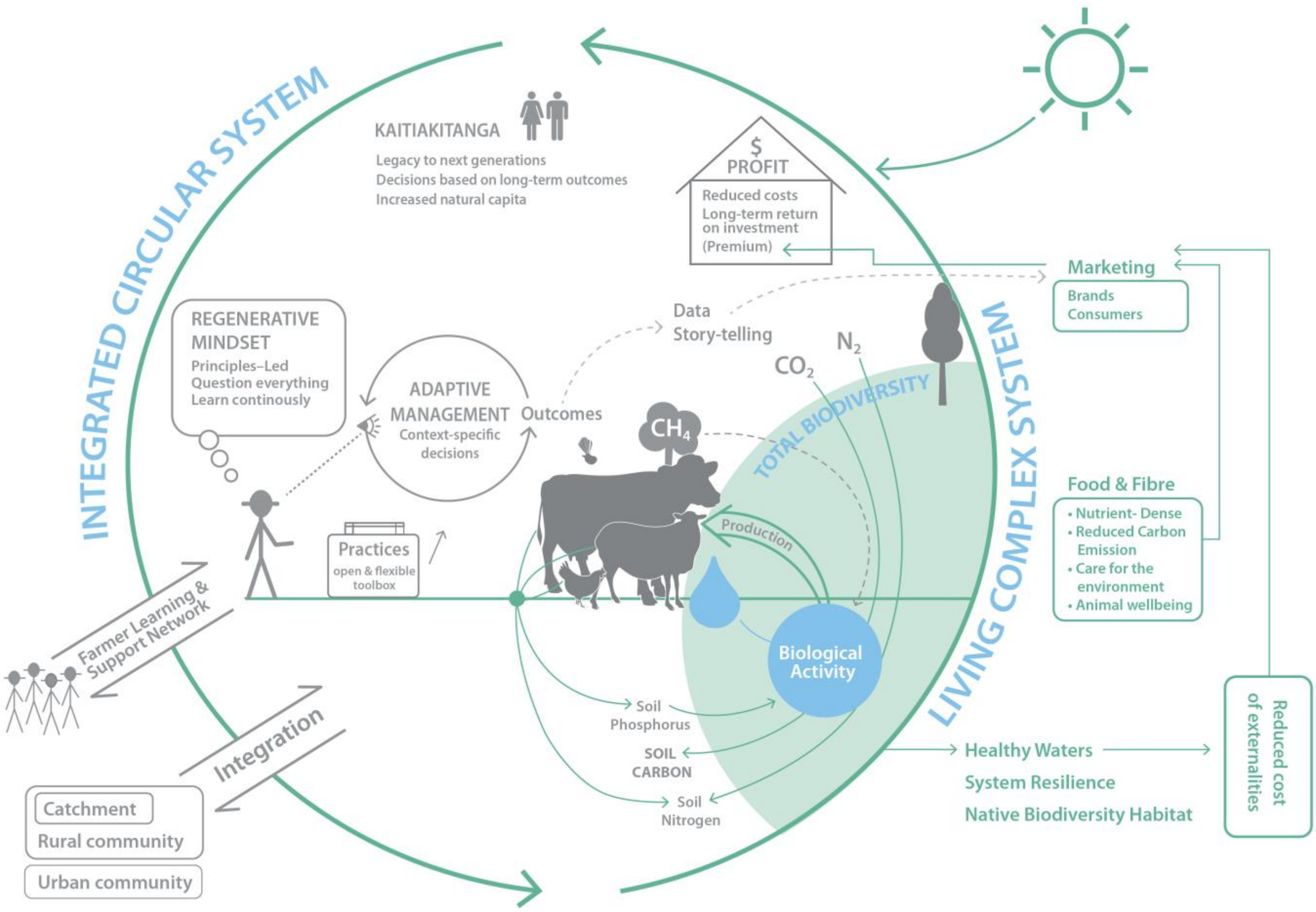
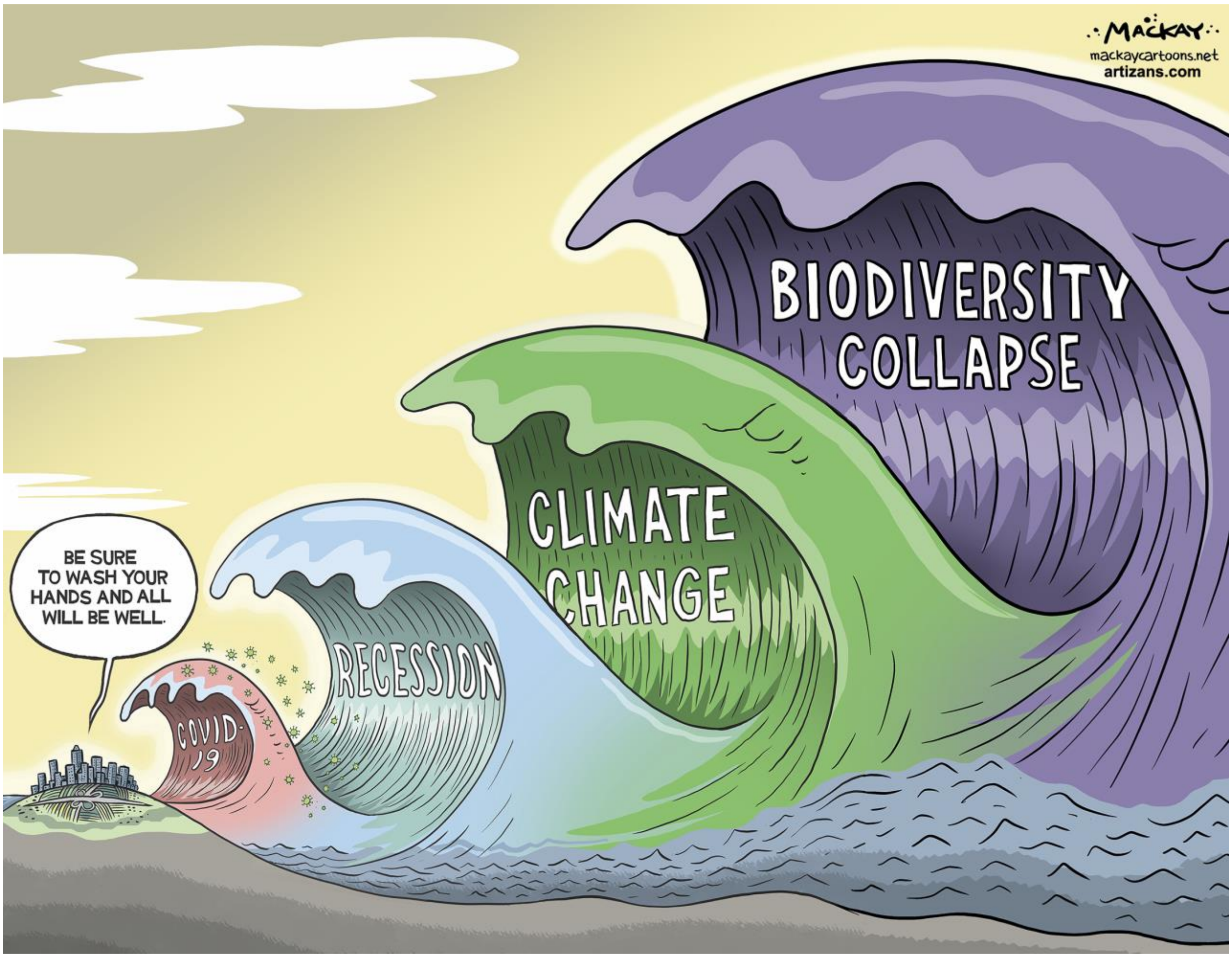


Figure A. A western science view of a regenerative farming system in New Zealand. *Infographics artwork by Marion Millard-Grelet and Nicolette Faville.*

Introduction



https://mackaycartoons.net/2020/03/18/wednesday-march-11-2020/ (with permission).

> By 2050, our planet will need to feed close to 10 billion people. **It is vital that we transform our agricultural and food systems so they work with and not against nature**. This is the only way to ensure people everywhere have access to a healthy and nutritious diet.
> (Inger Andersen, Executive Director, UN Environment Programme)

This is the context for the debates on 'regenerative farming' or 'regenerative agriculture' (RA). Its proponents claim that RA can reverse climate change and lessen or even mitigate the environmental impacts arising from food production while delivering social and economic benefits. Its critics question these claims and point to the lack of scientific evidence.

On a wider scale, many see in RA the potential for a much-needed transformation of the global agri-food system. RA is attracting increasing interest, both internationally and in Aotearoa New Zealand (NZ) – from producers, retailers, researchers, consumers, the financial sector, impact investors, social and green entrepreneurs, as well as from politicians and the media [51; 57; 79; 122; 125; 134; 153; 162; 173].

So, what is RA? Which aspects have substance and which are just hype? And how relevant is it to NZ?

This white paper presents information and perspectives on what being regenerative might mean for NZ farming systems and highlights a possible pathway for building scientific evidence on RA that is relevant to NZ.

In NZ there is a groundswell of farmers transitioning to RA e.g., [5; 105]. Many see RA as a solution for some of NZ's most acute environmental and societal challenges, such as the declining health of our waterways, the widespread loss of topsoil, the increasing threats from more frequent and severe droughts, and the pervasive wellbeing crisis of rural farming communities.

RA may also offer opportunities to secure overseas premiums and to niche markets. These aspirations are also reflected at a national level, including the NZ Primary Sector Council's 'Fit for a Better World' vision and strategy, in which developing a 'regenerative mindset' underpins calls for change and futureproofing of food and fibre production

RA is a global, grassroots, farmer-driven movement founded on an ecological paradigm addressing failings in our current global food system. The RA movement acknowledges that farmers can become part of the solution to mitigate or reverse the negative environmental impacts of our current food production systems.

However, RA is much more than a system of farming: it is a mindset that questions the status quo [178], and instead of becoming defeatist sees opportunities for different ways of living, working and farming [85; 105]. RA aligns with growing worldwide societal and consumer demands for safer, healthier, environmentally sound food systems, and engages in innovative processing and marketing.

Some argue that NZ farming systems are already regenerative, and do not see an urgent need for a change in the way NZ farmers manage their farms [6; 29; 41; 59 and other articles in this issue; 146; 161]. They are also concerned about the unintended consequences that RA might trigger. So, there are divergent views about RA in NZ. At one extreme some are calling for transformation [12; 51; 79; 153; 162; 173], while others claim that many of the negative environmental impacts of farming are the consequences of practices not employed in NZ (e.g. broad-acre monoculture, and large-scale feedlots) [101]. Therefore, any examination of what it means to be regenerative needs to include multiple perspectives and actors.

This paper represents the collaboration of over 200 people from a wide range of research institutions, the private sector, government departments, finance, farming communities, agricultural levy bodies, and large corporates, as well as marketers and retailers [54].

We don't offer a definition of RA for two reasons: the benefits of defining RA are disputed (as we subsequently discuss), and in NZ any such definition would need to be anchored in te ao Māori, the Māori worldview, and the goals, visions, priorities and aspirations of whānau, hapū, iwi and Māori corporations for how kai (food) is produced, and how whenua (land), wai (water), and rangi (sky) interact with tangata (people). While the potential relationship between te ao Māori and RA is acknowledged here [95], it is not explored in detail. Māori agribusinesses, landowners, and tangata whenua generally (the Māori people of NZ) need more time to determine their goals and priorities. There are currently ongoing Māori-led conversations e.g., [3; 62; 68; 176].

A collaborative approach with multiple perspectives also applies to the task of building scientific evidence for RA. RA has polarised the scientific community in NZ and elsewhere. There is a plethora of peer-reviewed studies on individual RA practices investigated in isolation, but only a few scientific studies reporting outcomes from RA *systems*, and these are mostly overseas studies. While some technical experts and researchers see RA as an opportunity to advance socio-ecological knowledge and improve NZ's productive landscapes, others argue that the gains seen overseas will not translate to NZ due to its distinctive features, such as younger, carbon-rich soils and world-leading farming systems. Both perspectives need to be included in future RA research.

The anecdotal evidence for the benefits of RA in NZ is rapidly growing. RA farmers are recording their observations and communicating them to other farmers via social media and on-the-ground, farmer-led events. However, these observations, processes and reported benefits have not been tested by researchers. This creates tension between farmers and scientists, adding to the systemic decoupling of the NZ science system from the extensive knowledge base of NZ farming communities. This the unfortunate result of a three-decade legacy of public fund withdrawal (see [19; 171]), which, despite current government reinvestment in extension services, continues today.

We have designed the research and consultation work underpinning this white paper with all of the above in mind. We have included representation of a wide range of attitudes towards science, scientific institutions and farming systems of NZ, and we hope the recommendations for building scientific evidence will satisfy all parties with an interest in RA.

We start by examining what RA is, and what 'regenerative' might mean for NZ farming systems. Although we don't provide a NZ definition for RA, we do offer an insight into what outcomes are important, and the principles and practices being implemented by some leading RA practitioners in NZ. We also examine what distinguishes NZ from the overseas countries leading the global RA movement. In doing so, we point towards areas where NZ could evolve its own narratives of RA.

We then provide an insight into the RA research needs that are specific to NZ. We consulted or collaborated with influential key actors in the NZ primary sector – a small but representative group of people involved in each of the four main NZ agricultural sectors – and took into account research needs expressed by the RA farming community. We also summarise the in-depth exploration of key RA knowledge gaps identified by researchers and technical experts.

Finally, we provide a high-level summary of the most relevant research designs for building the scientific evidence on RA in NZ.

While we have endeavoured to be as inclusive and holistic as possible, we acknowledge that the work carried out to inform the writing of this paper was limited in scope due to limited timeframe, the limited resources available, and the project coinciding with national disruptions related to Covid-19. Our approach has delivered many lessons, which are embodied in the research designs suggested in this paper.

1 What is regenerative agriculture in Aotearoa New Zealand?

An overview of the definitions of 'regenerative agriculture' (229 journal articles and 25 practitioner websites) showed that they are mostly based on processes, outcomes, or both [125]. Users should hence "define it comprehensively for their own purpose and context" [125]. Here we don't define RA, but rather examine, from different perspectives, what it might mean for NZ.

1a An introduction to regenerative agriculture

We start by acknowledging the history and whakapapa of RA – the other movements and traditions that have inspired and energised it [111]. In 1979 Medard Gabel made the first written reference to "regenerative agriculture". In 1983 Robert D. Rodale, son of the founder of the Rodale Institute in the USA, led the creation of the Regenerative Agriculture Association. The Rodale Institute remains a key organic research and extension organisation, promoting the concept of RA as "regenerative organic agriculture". RA has, from the early 1980s, been recognised as one of the alternative sustainable agricultures [21; 47]. Until recently Rodale was alone among the organic agriculture associations in adopting the term 'regenerative', but a growing number of organic groups are using both terms, possibly to maintain their visibility and relevance.

The term 'regenerative agriculture' is sometimes used as equivalent to 'sustainable agriculture', while including concepts akin to 'restoration ecology'. As such, it denotes a range of farming systems aiming to reverse the harm caused by intensive agriculture and continuously improve the farm system. Some RA proponents avoid the use of 'sustainability', pointing out that some systems can be sustained at a degraded level. But for the proponents of sustainable agriculture, the idea that this may imply 'maintaining in a degraded state' is nonsense.

For example, the new (April 2020) EU taxonomy for sustainable activities requires farms to "do no harm" for each aspect of environmental sustainability included in the taxonomy *and* to significantly progress one aspect [2]. However, the taxonomy does not encompass the concept of 'continuous improvement' that is inherent in RA. One of RA's distinguishing features is the holistic pursuit of continuous improvement, not only on environmental but also on social, economic, and cultural outcomes, both within and beyond the farm gate. It thereby strives to positively influence agri-food and politico-social systems [30; 125; 152].

While RA is informed by the many predecessors of alternative agricultures, unlike them it does not preclude any particular practice if it is needed to facilitate the transition of the agroecosystem to a state of increased health. In other words, the means are less important than achieving the ends. Therefore, a defining attribute of RA is that it is 'outcomes-focused' (Figure 1).

The current level of development of RA is comparable to that of organic agriculture in the 1940s: "a loose but coalescing group of like-minded people, mostly farmers and growers", when "the first formal associations are starting to be formed and the message is spreading globally." [110]. RA is building a slightly different hierarchy of values in that it is outcome-focused and strives to continuously improve. In Aotearoa and elsewhere RA is still evolving, and this contributes to its vibrancy and, for some, its appeal. But it can be difficult to grasp because it lacks a crystal-clear definition [152].

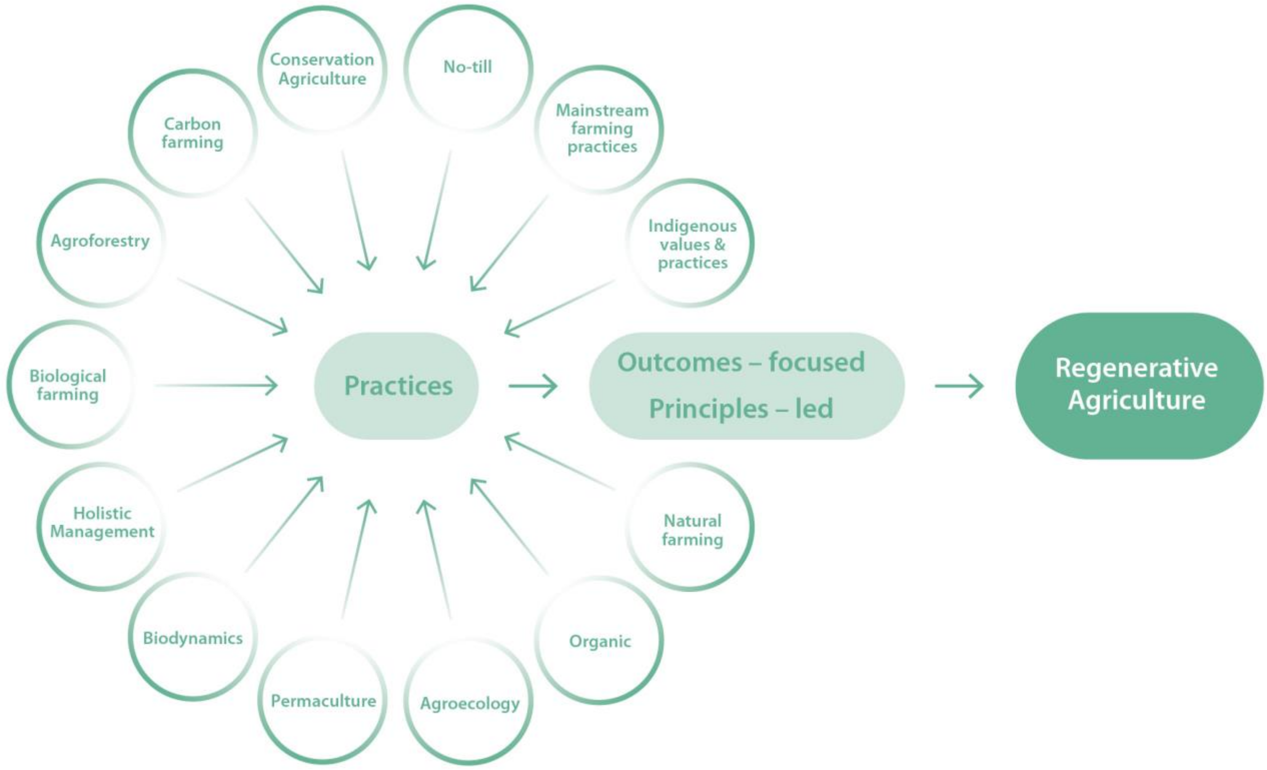


Figure 1. Regenerative agriculture draws upon many alternative agricultures and is outcome-focused and principles-led (see section 1d).

1b Te ao Māori and regenerative agriculture: tangata ahu whenua (nurturing our landscapes) [95]

In te ao Māori, the universe and our world, including humanity, extend back hundreds of generations through a series of genealogical webs to the time of enlightenment (te ao mārama). This genealogical sequence (whakapapa) relates humanity to the natural world [56]. Based on this relational understanding, the wellbeing of humanity is reciprocally bound to the viability and vitality of the natural world. To ensure our collective wellbeing, cultural experts (e.g. tohunga, kaitiaki, rangatira) use deeply encoded systems of mātauranga, tikanga and kawa to guide tangata whenua as kaitiaki or caretakers of this balance in their tribal territories [109].

For a range of reasons linked to a settler agenda (see [180 for context]), the ability of tangata whenua to listen to the land, read the signals in the world around them, and enact their responsibilities as kaitiakitanga has diminished [63; 74; 75]. However, a rekindling of whakapapa, mātauranga and tikanga is occurring across social, cultural, environmental, and economic platforms.

Te ao Māori bases enterprise and trade decision-making on relationships and values (e.g. kaupapa Māori outcomes, [9], and balances profitability and asset growth with the reconnection of its peoples and revitalisation of ancestral landscapes [9; 63; 75; 76]. While there is diversity in the application of customary values and principles according to enterprise type, scale, governance maturity, capability, and capacity [65], Māori entities (MEs), underpinned by whakapapa and customary values, share several common characteristics:

- diversified portfolios, to spread risk, manage complex system interdependencies, and achieve holistic outcomes
- holistic and intergenerational decision-making – building multiple capitals for short, mid- and long-term benefits

- multi-purpose landscapes, including cultural and environmental relationships and exchanges with landscapes alongside economic and aesthetic/social aspects
- collectivisation by smaller MEs to achieve economies of scale and aligned outcomes.

While a relational world view is pervasive in MEs, what tikanga-led practice 'looks like,' and the impacts of such practices, particularly at scale, is poorly known. In the agri-food and fibre sector, tikanga-led practices have been maintained over the past decade by a core of small- and medium-scale verified hua parakore and te waka kai ora – Māori organics practitioners and producers [24; 64-66]. They differ from US-based models of organics and RA in that they are free of GMO and synthetic inputs, which, from a te ao Māori perspective, disrupt the vitality of the natural world.

Te ao farming and gardening practices strengthen the relationships between tangata and whenua through methods and materials suited to a particular place and cultural narrative, rather than a particular system. Community and local-scale kai māra (gardens/orchards) have proliferated recently [65]. These community-led initiatives, as well as tertiary-level courses offering customary practice and management qualifications [40; 165], are helping to reinstitute whakapapa and pass on the mātauranga and tikanga on customary crops (e.g. kūmara and taro), as well as heirloom species (vegetables and fruits).

An emerging group of large and medium MEs scaled for large export markets are exploring ways to embed tikanga-led practices into their farms, orchards, and forests. These are some of the 'next steps' for many MEs in enacting duties as kaitiaki. While alternative agricultural systems may offer tangata whenua some tools and practices to achieve more holistic outcomes, they do not address the deep cultural and relational shifts needed for Māori collective wellbeing. To know what authentic, tikanga-led practice 'looks like,' it is important that sharing unique on-farm practice empowers tangata whenua to be the owners of their unique and shared knowledge.

Overall, the diversity of farming practices is contributing to a rekindling and growing knowledge about what tikanga-led practice can look like in different places, scales and contexts. The systems and practices arising will be unique to Māori entities. To engage with emerging systems such as RA, and to establish a collective understanding of tikanga-led practice, Māori entities and tangata whenua will require the resources and time to consolidate a diverse, often invisible, landscape of activities. Te ao Māori enterprises led by whakapapa and customary knowledges are an opportunity to rethink norms underpinning food and fibre systems in NZ [63].

1c Consultation with representatives of four major NZ agricultural sectors to determine regenerative farming outcomes

We consulted with sector working groups, including 60 participants from the arable (17), dairy (15), sheep & beef (20), and viticulture (9) sectors [55]. These groups spanned the continuum of professions engaged in those sectors – from farmers to financiers (banking), to scientists, consultants and retailers (supermarkets). They represented a diverse array of perspectives, particularly with regard to RA. Tangata whenua were not well represented from these groups, but separate initiatives, inquiring into what 'regenerative' outcomes might look like in tikanga-led agricultural initiatives, are being led by Māori for Māori, as explained in section 1b. We used a range of approaches to gather participants; thoughts/opinions on regenerative farming systems. Those approaches and resulting findings are described in the following sections.

Most popular topics

Our first approach was to solicit and analyse written and oral perspectives from each participant on their opinion about "what makes farming systems regenerative". We asked participants to answer questions such as: "What does a regenerative farming system look like to you for a given outcome? What should a farming system achieve or deliver in your opinion for it to be regenerative in this particular aspect?" When participants did not know what RA is, they were invited to base their answers on what the word "regenerative" meant to them. We then coded their answers according to major themes. Figure 2 shows what themes were most frequently discussed (note that a controversial theme can register just as high on this list as those representing consensus.) Table 1 provides a summary of the topics included in each theme.

Social wellbeing was a particularly frequent theme, demonstrating RA's tendency to ask broad questions about wider systems rather than focusing narrowly on input/output/practice. Soils were the second-most-discussed theme, further emphasising the focus of RA on soil health [152].

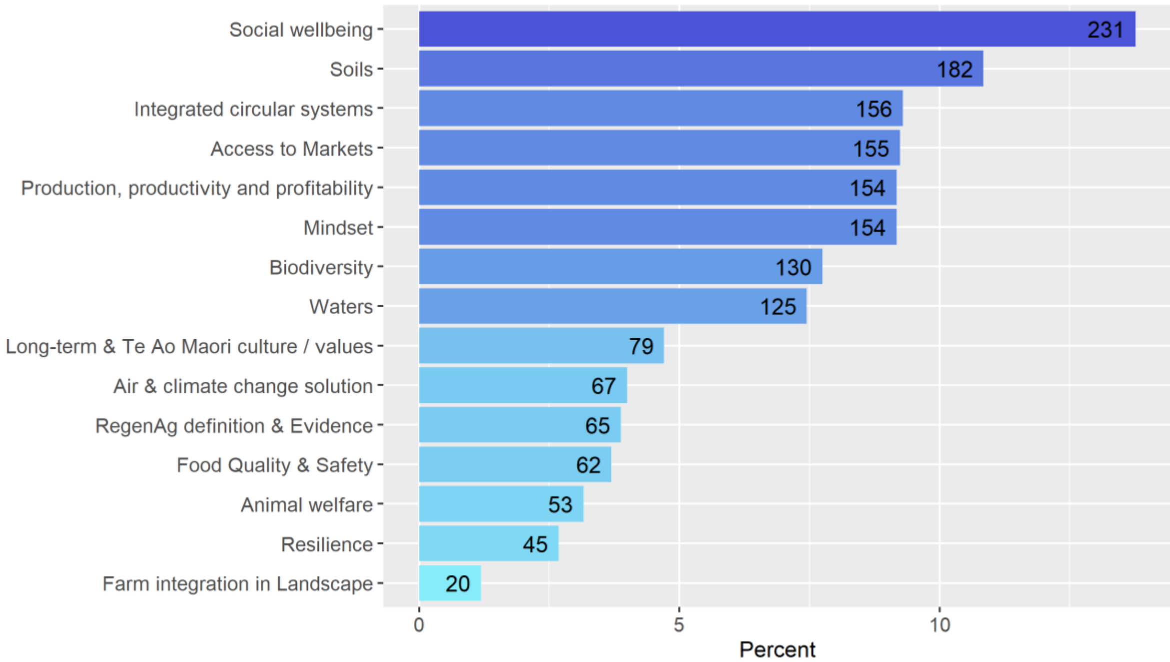


Figure 2. The number of times conversations were coded to each of 15 themes (n = 1,671).

There were 60 participants in total, drawn from four different agricultural sectors (arable, dairy, sheep & beef, and viticulture). The number of times each theme was coded also relates to its universality across the four sectors. *In: Grelet GA, Robson-Williams M et al. 2021* [55]

Table 1. Summary of the topics included in the 15 major themes discussed by participants of our four sector working groups. *In: Grelet GA, Robson-Williams M et al. 2021* [55]

Theme	**Examples of participant descriptions of regenerative outcomes**
Social wellbeing	Good physical and mental health of farmers and employees. Enjoyment and fulfilment from work. Healthy food. Thriving rural communities and jobs. Urban and rural communities engaged with farming. Consumers connected to food.
Soils	Improved soil physical health e.g. improved structure, organic matter levels, water holding capacity rooting depth, and decreased compaction and soil disturbance and erosion. Improved soil chemical health, increased soil C, Total N, and increased nutrient cycling. Improved biological health e.g. increased biological activity, more worms, more fungi. Increased soil resilience to floods and drought, relationship of soil health with biodiversity, plant function and animal function.
Integrated, circular systems	Farms managed as a system, recognising interconnections between on farm practices and ecosystem health, and dependencies between environmental, animal, social, cultural and economic dimensions. Tight nutrient cycles resulting in fewer nutrient inputs and losses and reducing imported and non-renewable inputs. The stocking intensity of the farm is no more than can be supported from the surrounding area all year around. Organic matter recycling, e.g. through composting and farm wastes reconceived as resources e.g. for organic matter, nutrients, energy. Mixed systems, such as animals integrated into crop or vineyard.
Access to markets	Greater emphasis on local - Local customers, profits kept local, supporting local communities and businesses. NZ regenerative agriculture has a strong brand, a compelling and evidenced story and NZers are proud of the way the food and fibre is produced. Regenerative produce should command a premium. Payments received for other values/services produced on farm, such as ecosystems services and carbon sequestration. High trust relationship with financial sector and financial sector valuing multiple values, not just economic. Some participants highlighted a tension between producing a premium product and ethos of healthy food being available to all. Other participants questioned whether regenerative principles should underpin all of NZ agriculture, or just certified 'regenerative' farms.
Productivity and profitability	Whole of system productivity measures used. Less impact for unit of yield. Profitable while internalising externalities and paying living wage and maintaining good conditions for employees. Businesses are not just for profit, and profitability is balanced with quality of life. Profits shared at all stages of the value chain. Businesses moving away from commodity markets. Multiple sources of income. Financial freedom to experiment.
Mindset	Work with nature for holistic outcomes, not trying to control nature and not just for production. Proud and happy to be a regenerative farmer. Curious, open-minded, experimental with a drive toward continual improvement underpinned by learning and adaptation. Confident to take responsibility for the farm's impacts, to make decisions for now and the future, and with a sense of empowerment. Collaborative with peers and connected to community. Observed desired shift in mindset towards regenerative agriculture, where farming expertise is valued, and there is a high trust relationship between farmers and regulators that also allows for experimentation.
Biodiversity	All parts of the faming environment are biodiverse, for example, microbial, insects, plants, birds, genetic, and in soils. Taonga species and native biodiversity are protected. There is structural and functional biodiversity. Regenerative farmers consider biodiversity beyond the farm boundaries and support biodiversity at landscape and ecosystem scales. Diversity considered more generally such as moving from monocultures to polycultures and strategic use of trees in the landscape.
Waters	Reduced contaminant loss from farm. Planting critical source areas and gullies. Improved water quality and ecological health in waterways. Stock out of waterways and improved wintering of stock. More efficient use of water on farm.
Long-term and te ao Māori culture/values	Long-term outcomes inform planning and goal setting. Future needs recognised and accounted for. Next generations have a connection with the land. Next generations want to farm and can farm profitably. Farming for environmental outcomes. Stewardship demonstrated to the public. Improved mauri of the land and water. Respect for cultural values and those values protected. Taonga acknowledged and protected.
Air and climate change solutions	Improved air quality. Reduced greenhouse gas emissions. Reduced methane emissions through grazing practices and reduced animal N intake. Sequestration and deep storage of carbon in soils. Measuring and monitoring in place.
RA definition and evidence	Regenerative farming claims need to be verified and practices audited. Outcome measures as opposed to input measures suggested as a way to build evidence but allowing flexibility in practice. Ongoing monitoring and evaluation processes in place. Differing views on how to define regenerative agriculture from black and white definition that is easy to certify and provide the evidence needed to secure a premium, through to continuous improvement nature of regenerative agriculture means that the definition should be more about the journey, or the trend. How do we know at what point on the journey we become regenerative? Outcome measures as opposed to input measures suggested as a way to build evidence but allowing flexibility in practice. Some arable farmers noted that going fully regenerative is more difficult for arable systems, and that pastoral systems may have more to gain from regenerative practices.
Food quality and safety	High quality, verifiably nutrient-dense foods. Reduced or no chemical usage, leading to verifiably residue-free foods. Although participants from all sectors thought reduced chemical usage was an important outcome of regenerative farming, some in the arable and viticulture sectors indicated the challenges of managing resistance and producing clean seed lines without agrochemicals and suggested that the emphasis should be on different inputs not no inputs, such as exploration of alternatives to chemical biocides.
Animal welfare	Year-round high standards of animal health and welfare, including good nutrition, good husbandry, good disease surveillance, resulting in reduced disease and mortality rates. "Not pushing animals so hard". Diverse swards used provide the opportunity for stock to "self-medicate". Decreased need for chemical and therapeutic treatments as health and welfare increase.
Resilience	Ecological and economic resilience. Ability to deal with change, especially systems and crops that can cope with extreme weather. Resilience is considered not only at an individual farm level but at multiple farm level.
Farm integration in landscape	Farming in the context of the landscape, such as planting out Critical Source Areas and fragile land, maintaining ecological corridors or regenerating natural landscape functions. Integrated catchment management with others' farms and catchment communities. Collective management of landscape scale concerns such as cross-contamination of clean seed lines from biodiverse cover crop mixes.

Most important topics, and statements participants agreed with most

Our second approach was to ask participants to either rate the importance of the 'regenerative' outcomes they had previously discussed, or to indicate their opinion on the veracity of particular statements about some of these outcomes [55]. We used Likert scale surveys [96] with an even number of choices [58].

We focused the surveys on outcomes relating to soil health, social wellbeing, mindset, the financial success of farming businesses and the marketability of regenerative farm produce. Approximately 80 questions were included. To obtain data on importance ratings, participants were asked to rate the importance of particular outcomes with four possible answers: 1 (not so important), 2 (quite important), 3, (very important) or 4 (extremely important). To gain insights on participants' opinions about the marketability of NZ's regenerative produce, we asked the participants to rate the veracity of approximately 20 statements derived from earlier conversations about access to markets (see Figure 2 and Table 1). Participants were asked to choose between the following four answers: 1 (not true), 2 (unsure), 3 (possibly) and 4 (yep, I agree).

Figure 3 presents a highlight of the most contrasted or interesting answering patterns. The answers for the full set of questions are provided in the full study report [55]. Pride in farming (but not necessarily joy in farming), making decisions based on outcomes sought in the long term, increased profitability and financial expertise (as opposed to increased production), continuous learning (but not necessarily acknowledging farmers' expertise) and positioning NZ as a world leader in RA were collectively the highest rated outcomes. The aspiration to become a world leader in RA whilst suggesting NZ farming systems are not yet 'regenerative' represents a willingness to create rapid and meaningful change. Additional answers (not shown here) shows that participants valued long-term over short-term returns [55].

As regards social wellbeing, farmer empowerment and community support are significant. Aspirational and attitudinal aspects of farmer behaviour/belief were ranked higher than operational matters. Soil priorities related to soil structure, function (carbon and microbes) and water capture/retention, more so than carbon sequestration (data not shown).

Lastly, our data highlighted differences in perceptions about the certification or verification of regenerative produce: participants from all but viticulture (data not shown) believed verification was unnecessary, because story-telling works well. However, they thought science-based verification is possible and is needed for traceability.

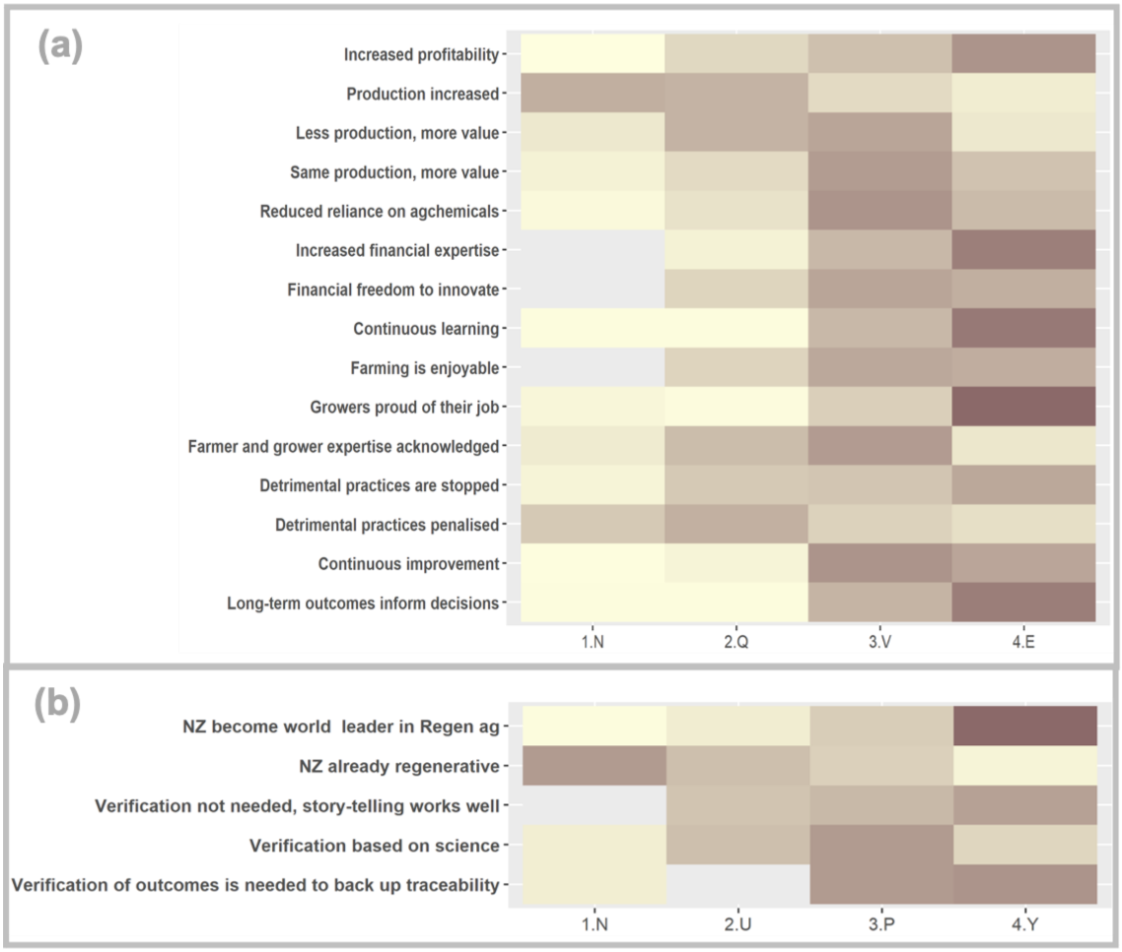


Figure 3. Importance ratings given to 20 different outcomes relating to the financial success of farming businesses, soil health, social wellbeing, mindset) in the context of regenerative farming systems (a) and veracity of statements made about marketability of RA produce (b).

Panel (a) shows the relative distribution of answers to questions about the importance of particular sought-after farming outcomes. Participants were asked to rate the importance of a range of outcomes using a Likert-scale survey. The figure shows the relative proportion of participants having chosen option 1 (not so important), 2 (quite important), 3 (very important) or 4 (extremely important). Panel (b) shows the relative distribution of answers to questions about the veracity of statements about marketability and the extent to which participants agreed with any given statements. Participants were given the choice between 1 (not true), 2 (unsure), 3 (possibly) or 4 (yep, I agree). For both panels, the colour intensity is proportional to the number of participants choosing that option: from grey (no participants selected that choice) to dark brown (most participants selected that choice). *Adapted from Grelet GA, Robson-Williams M et al. 2021* [55]

1d Principles of RA in NZ

RA is principles-based. This has a bearing on everything from the mindset of the individual farmer to the care of the farm system, to the stewardship of the larger ecology in which the farm sits, and the surrounding community. RA is not just a number of core practices, farming strategies or prohibitions. Before we focus on some of the RA principles, we look at some of the context for RA.

Differences between practices-focused and principles-led systems

The industrial approach that defined the 20th century strove to maximise efficiency by prescribing and enforcing certain practices. The formal education systems, manufacturing, large corporate structures, and indeed the industrial farm are examples.

Figure 4 illustrates how living systems differ from industrial systems. Industrial approaches focus on 'best practices' and rely on high energy inputs. The regenerative approach is centred on principles and optimised for flexibility and self-maintenance, and it requires less non-renewable energy. It is democratising, fit for living systems, and encourages perspective shifts and learning.

This focus on living systems also encourages holism and recognises interdependence. It is perceived as being better suited to systems requiring agility. Box 1 provides two examples where a shift of focus from practices to principles has been implemented at a global scale for increased operational learning, agility, and transparency.

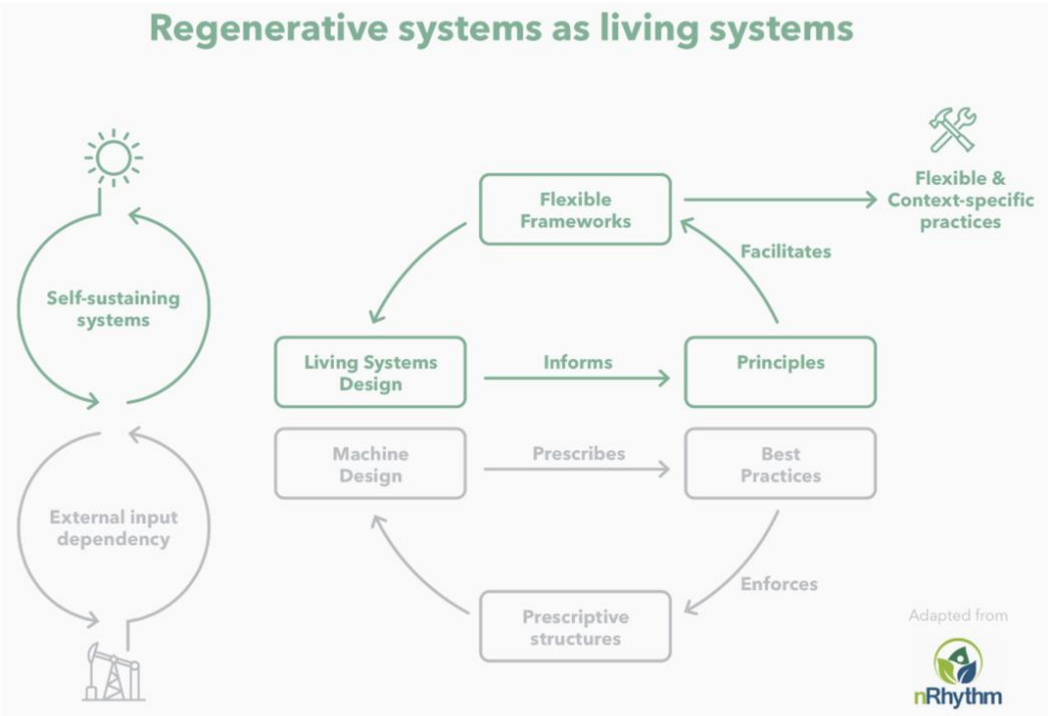


Figure 4. The differences between practices-focused (e.g. industrial systems) and principles-led systems (regenerative systems) (adapted from nRhythm, https://www.nrhythm.co - with permission).

Box 1. Lessons from humanitarian aid and international development

The shift from best practices to principles-centred design has been implemented in the last 10 years. We provide two global examples. The first is the Digital Development Principles, a set of nine principles endorsed by nearly every UN organisation, the World Bank, the Bill & Melinda Gates Foundation, many national governments, and scores of other international non-governmental organisations (INGOs). The digital principles help to guide investment in new areas of innovation, ensuring the area remains collaborative and duplicated failures are rare [4]. They also prioritise the inclusion of beneficiaries. The digital principles inform the movement of tens of billions of dollars each year.

The second example is the Digital Investment Principles, which direct funding for public health initiatives globally. Here again, major UN organisations, the WHO, INGOs and national development offices have endorsed the principles to help align investments. While a best-practices approach created fragmentation and opacity, these principles are driving huge gains in transparency and learning. By focusing on principles, we are not dodging the difficult task of definition: we are setting the stage for decades of successful collaboration.

Regenerative principles being applied in NZ [86]

We asked 21 leading RA practitioners (farmers and educators/consultants) in three sector-based focus groups, "What are the high-level principles that guide your farming practices and/or decisions?" and "What does it mean to have a regenerative mindset?" We focused discussions on activities taking place behind the farm gate.

There was strong alignment of principles between the pastoral, arable and viticulture sectors. Similarly, the RA practitioners' responses about a regenerative mindset were, for the most part, inseparable from the principles. We have therefore integrated all the responses into the 11 principles shown in Figure 5.

1.	**The farm is a living system**	Living systems are complex and constantly evolving – understanding how nature functions supports holistic decision-making.
2.	**Make context-specific decisions**	Context varies from place to place, person to person and season to season – adapt your system and practices to suit.
3.	**Question everything**	Be curious, question your beliefs and test different ideas.
4.	**Learn together**	Connect with like-minded peers to speed up the learning journey – include perspectives different from your own.
5.	**Failure is part of the journey**	Push beyond your comfort zone - small failures provide the best learning opportunities.
6.	**Open and flexible toolbox**	Try to use practices that help improve ecosystem function while keeping others up your sleeve for if or when you need them.
7.	**Plan for what you want; start with what you have**	Transitions take time – clear goals, monitoring and planning are key.
8.	**Maximise photosynthesis (year-round)**	Treat your farm like a solar panel – bigger green leaf area supports greater photosynthesis meaning more food for soil microbes and improved soil health.
9.	**Minimise disturbance**	Keep the soil covered and limit disturbance from chemical application, soluble fertiliser, machinery and livestock compaction.
10.	**Harness diversity**	Diversity benefits the whole ecosystem – microbes, insects, plants, birds, livestock and your community.
11.	**Manage livestock strategically/holistically**	Livestock are a powerful tool for building biological function and fertility in our soils, when managed well and adaptively.

Figure 5. Regenerative principles being applied in NZ. 11 principles were identified by a focus group of 21 leading RA practitioners (RA farmers and educators). *In: Lang et al. 2021* [86]

These principles reinforce the message in Figure 5 that regenerative systems need to be managed as living systems, complexity needs to be embraced, and an adaptive and context-specific approach to farm management and design adopted. The principles on the left of Figure 5 relate to social and psychological behaviours ('Mindset & attitude') whereas those on the right relate to the implementation of farm practices ('Instructional'). Not surprisingly, some of the instructional principles are similar to the current soil health framework (see: 6 Principles of Soil Health) taught by RA educators in the USA. Thus, while every farm is unique, there are universal social and ecological principles.

The more centrally aligned principles in Figure 5 show that RA is a journey, and that the transition takes time and will pose challenges. They reinforce the importance of the context of a given farm or farmer (including strengths and limiting factors), goal-based planning, and the exploration of new tools/practices while not abandoning the safe and familiar. Practitioners made the point that even following only a few of these principles can deliver positive outcomes, although the full potential comes from working with all of them.

This exercise and the resulting principles are just an initial contribution, and we expect they will evolve. Essential to this evolution will be the braiding of insights, visions and influences from mana whenua, including Māori agribusinesses.

1e A step towards understanding RA in NZ: to what extent are current farming systems generating regenerative outcomes?

If the claim that NZ farming systems are already regenerative were true, it would have significant implications for NZ's ability to capture international premium and niche markets. Clearly, the opportunity to position NZ as a world leader in regeneratively produced food and fibre is an opportunity we can't miss.

This question was also raised by our needs analysis focus groups (see section 2). In addition, most participants of our sector working groups indicated that they thought the statement "NZ is already regenerative" is not true, but they agreed with the statement "NZ becomes world leader in RA". Here we break the question down into the following sub-questions:

- Are currently measured **outcomes** indicative of the land being managed regeneratively?
- Are RA **practices** different from practices employed in mainstream farming systems?
- How in-line with regenerative **principles** are current mainstream farming management types?
- How do people deeply involved in our agricultural sectors perceive their performance?

We undertook a time-constrained scan of the peer-reviewed literature and websites for a high-level stock-take of the available information. We gathered all the information we could find in under 5 hours using Google Scholar, Web of Science and Google searches. We started with the premise that RA and mainstream management are entirely different. Table 2 summarises the current stock of information.

Table 2. Stock-take of information currently available in NZ about practices, principles and outcomes from RA and from mainstream farming systems. Knowledge gaps are indicated in bold.

		RA	Mainstream
Outcomes	**Observations: anecdotal (e.g. by farmers)**	At farm scale in all regions of NZ. **No observation at scale greater than the farm.**	At farm scale and greater scales (sub-catchment, catchment, region) in all regions of NZ.
	Observations: scientific studies	**Farm-scale NZ: pastoral RA farms – only one whole-of-systems study replicated across multiple pastoral farms**, still unpublished (Grelet, pers. comm.). Other studies on the way, focusing on one farm at a time (Smith & Scoffield, pers. comm.). Several published studies comparing organic or biodynamic with mainstream farms. Several studies focusing on outcomes generated by a subset of practices (deferred grazing, integrated pest management, various biological inputs, cover cropping, increased pasture diversity, livestock integration, and others; please refer below to the list of practices employed by RA practitioners in NZ). **Greater scale – no scientific data available for NZ.**	Wealth of published scientific data from existing NZ farms, catchments and regions; subject to considerable analysis
	Predictions: based on models	NZ: one preliminary unpublished, model-based simulation (Taitoko, pers. comm.). **More modelling studies needed for NZ to predict impact at farm scale and at greater scales**. Overseas: several published catchment- or regional-scale assessments e.g., [115, and many others; 135]).	Wealth of published predictions for NZ based on models such as Overseer. At farm and greater scale.
Practices		Published for individual sustainable alternative agricultures, which inform the evolution of RA (e.g. organic, no-till, integrated pest management). Catalogued here for the current RA concept in NZ.	Many published studies describing and cataloguing mainstream practices.
Principles		At farm scale: recorded in the present research. **At larger scale: none for NZ.**	Some research on what it means to be a 'good farmer' has been done, mostly investigating 'values' and how these underpin practices. Also several published guidelines for 'good farming practice principles' at farm scale e.g., [133] and at larger scale (e.g. to mitigate the negative impact of farming on freshwaters [113]).

Outcomes of agricultural activities in NZ

Since there are no published outcomes for RA systems in NZ we cannot compare them with mainstream farming systems. However, we can summarise some of the natural and human capital outcomes that can be directly or indirectly attributed to agricultural activities at the national scale, mainly from mainstream farming systems given the low percentage of RA farmers. The NZ agricultural sector is performing well and demonstrating leadership in some categories; in others it is creating environmental and social challenges. Such challenges need to be addressed if NZ is to claim to deliver 'regeneratively produced' food and fibre.

Table 3. Outcomes realised in NZ linked to agriculture.

What's working WELL			
Agriculture contributes substantial amount of national wealth		**Soil C stocks and agricultural GHGs**	**Commitment to the protection of NZ natural capital**
In the year ended March 2020, the gross domestic product (GDP) of this industry amounted to over 13.5 billion New Zealand dollars (NZD).	NZ ranks 7th producer of milk worldwide with 21.9 million metric tonnes produced in 2019 [159]	Very low emissions per kg of milk, meat & wool when compared with most other developed countries [92; 93]	Word-leading commitment to protecting NZ terrestrial capital: mountain and river declared legal entities
Primary industries (including mining and forestry) represent 7% of NZ GDP [160]	As of June 2019 there were approximately 26.7 million sheep, 6.35 million dairy cattle and 3.92 million beef cattle livestock in NZ [159]	New GHG-progressive scheme launched by Fonterra [45]	Increased protection measures for marine environment
Extending calculation to all economic activities linked to agriculture: Ag sector contributes approximately 12.4% of GDP and 78% of total exports [181]	In 2019 around 86,700 people were employed in the NZ agriculture industry, a slight increase from the previous year. The agriculture, forestry, and fishing industries had the second-highest number of enterprises operating in NZ, behind the rental, hiring, and real estate services industry [159]	Soil C generally high & maintained (some arable and dairy farms being the exceptions) – see soil carbon discussion in section 1g	Land-based ecosystem services in NZ are estimated to be worth 60 billion NZD per year, equivalent to 30% of GDP [39]
NZ's primary sector (including mining and forestry) reached 46.4 billion NZD out of a total of 58.3 billion NZD of goods exported to June 2019 [142]	NZ fresh fruit export value is estimated at 3.4 billion NZD, with kiwifruit the leading fresh fruit export [159]		
What's NOT working well			
Biodiversity outcomes[(*)]	**Soil**	**Water**	**Climate**
Almost 4,000 native species are currently threatened with or at risk of extinction [118]	192 million tonnes/year of soil is lost (equivalent of 400,000 dump trucks) and approximately 44% of soil loss comes from pasture [117]	95% of river nutrients are a result of diffuse loss from agriculture [136]. NZ continues to experience "worsening nitrogen pollution in rivers" [130] leading to harmful effects on biodiversity [129]	Nearly half of NZ's emissions come from agriculture [129] and NZ's gross GHG emissions per capita and per unit of GDP remain among the five highest in the OECD [129]
Almost three-quarters of native fish threatened with extinction [88]	One-third of soils in NZ have too-high phosphorus levels due to (over)supply of fertilisers [100]	Freshwater 2020 estimate 46% of lakes >1 ha are in poor or very poor ecological health [118]	Under climate warming, large areas of NZ are projected to have more droughts and more intense rain events [112] and climate warming will bring more pests and diseases that affect the agriculture and horticulture sectors [182]
NZ species extinction rates are among the highest in the world [129]	Nearly half of monitored NZ soils have too-low levels of macroporosity [100]	In Canterbury, Otago, Marlborough and Hawke's Bay, water demand is exceeding what is available and sustainable [129]	Average temperatures will increase by about 0.7–1°C by 2040 and by 0.7–3°C by 2090 [112], and by 2090 representative regions within NZ are forecast to receive 20–60 additional heatwave days per year according to climate forecasts [182]

[(*)]Agriculture is not the only driver of native biodiversity loss – The extent to which agriculture contributes directly or indirectly to biodiversity losses depends on the species / ecosystems and is a topic of active research.

Practices employed in RA systems

Here we list the main practices adopted by RA practitioners in NZ. Many practices employed in RA systems are also employed in mainstream systems and so they overlap. However, a number of practices (shown in **bold)** are found only in RA systems.

Table 4. Practices employed by RA practitioners in NZ. The list is not exhaustive and is continually evolving. Practices in bold are <u>not used</u> in mainstream systems.

Practice	Description	Purpose(s)
Diverse cover crops	Short-term non-cash crops sown between cash crops in arable systems, including species with different plant functional traits **(>8 species**). Seed growers may be limited to 4**–8** cover crop species to avoid cross-contamination risks.	• Maintain photosynthesis between cash crops to increase insect and microbe diversity and abundance. • Keep the soil protected from sun, wind and rain. • Mobilise and cycle nutrients for the following crop. • Improve soil health, especially soil structure. • Reduce pest and disease pressure in the following crop.
Diverse forage crops	Forage crops usually **with >8 species** that have different intended functions (i.e. animal nutrition, plant health and/or soil health). Commonly grazed in summer, autumn and winter.	• Similar role to traditional forage crops, providing feed when demand exceeds pasture supply. • Diverse diet where animal can self-select for different nutritional needs. • Provide habitat and food for beneficial insects and reduce pest pressure. • In-fill species suppress weeds. • Reduced fertiliser and chemical need. • Litter protects soil from hooves. • Some species regrow post-grazing. • Maintain/improve soil health.
Diverse perennial pastures	Diverse pastures are sown (**16 to 40+ species sown using direct drilling)** to assemble perennial plant communities with high functional diversity. Species composition and diversity change through time.	• Increase resilience to variable climate (including extremes). • Increase nutritional quality of forage. • More even growth rates year-round. • Maintain/improve soil health. • Reduce/eliminate leaching.
Bale grazing	Placing hay bales throughout paddocks that are strip grazed during winter. Hay is balanced with fresh pasture. **Intentional bale 'wastage' creates a fertiliser effect and improves soil health.**	• Feed supplement for cattle during slow-growth winter period, replacing need for forage crops. • Improve paddock performance due to nutrient, carbon and seed inputs. • Balanced protein, energy and fibre feed supply.
No-till and residue retention	Sowing of crops or pastures without cultivation. Retaining some or all crop residues on the soil surface as protection.	• Minimise soil disturbance. • Lower crop/pasture establishment costs. • Protect soil from wind, rain and sun. • Residue feeds worms and other soil microbes.

Integrated pest management	Managing arable land to promote beneficial insects, especially those that predate crop pests.	• Increase natural control of crop pests. • Reduce need for pesticides.
Minimising synthetic fertiliser inputs	Multiple different strategies, including shifting to foliar application, increasing nutrient cycling and nitrogen fixation, changing fertiliser sources.	• Decrease negative impact on soil biota. • Reduce risk of losses to waterways. • Increase efficiencies of uptake. • Reduce input costs while maintaining/improving profitability.
Minimising chemical inputs	Reducing/**eliminating** chemical inputs where practical, including seed dressings, weed sprays, fungicides, insecticides, drenches, dips, cleaning products, and/or **substituting with biological alternatives.**	• Minimise impact on beneficial insects, including neonicotinoids on bees. • Minimise impacts on soil and rumen microbiome. • Minimise potential harm to insects, fish, animals and people. • Improve ecosystem resilience to pest outbreaks.
'Buffering' synthetic and chemical inputs	**Using carbon-based products such as humate-derived substances to chelate fertiliser and chemicals.**	• Increase input efficiencies and reduce rates. • Support biological breakdown.
Inoculants, bio-stimulants and carbon-rich amendments	Inputs designed to enhance the function of soil, plant and animal microbiomes in either a targeted or general manner. Common products include **fish hydrolysate, seaweed derivatives, diluted seawater,** compost**, aqueous compost extracts, biochar**, isolated fungi/bacterial strains.	• Increase biological activity. • 'Turn on' quorum sensing genes. • Promote soil biodiversity. • Promote soil functional diversity. • Optimise mobilisation of nutrients from complex/bound forms to plant-available forms. • Physicochemical immobilisation of excess minerals including heavy metals.
Mineral balancing and trace elements	Ensure sufficient amounts of soil minerals are present for optimal soil and plant function. Ensure minerals are 'balanced' so as not to antagonise the ability of plants to take up what they need. **Some practitioners use the Albrecht–Kinsey soil audit methodology to diagnose balancing requirements.**	• Optimise elemental stoichiometry in soil. • Optimise soil flocculation. • Reduce/eliminate micronutrient deficiencies in plants and animals.
Timing interventions using the lunar calendar	**Some practitioners take into account lunar and other astral cycles to determine the timing of particular interventions on their systems, such as planting or harvest.**	• Optimise plant growth. • Optimise the quality of plant biomass at harvest.
Regenerative grazing management	**Adaptive multi-paddock grazing**, deferred grazing.	• Increased carbon fixation via photosynthesise as much as possible. • Promote carbon allocation below-ground via litter trampling or root exudate. • Increase nutritional value of forage for animals. • Provide shelter to livestock from wind and sun exposure.

Compatibility of practices employed in mainstream systems with RA principles

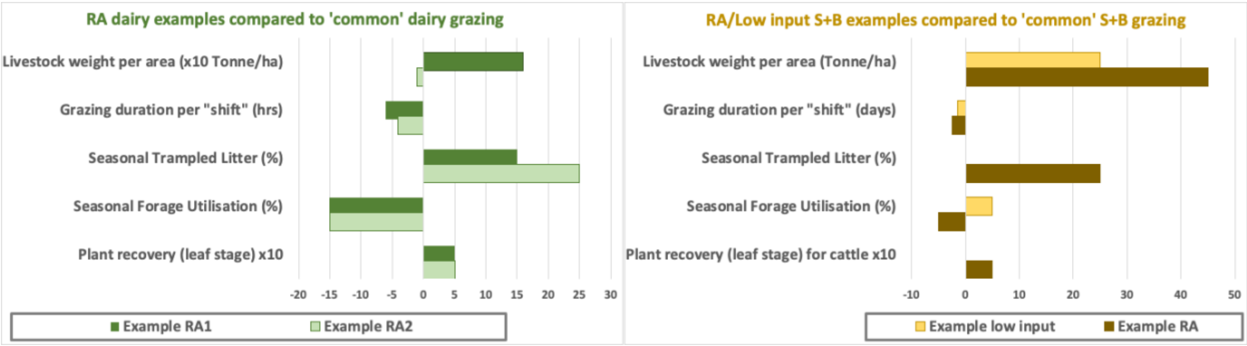
RA is most clearly described by principles rather than practices (Figure 5). To evaluate whether existing farming systems in NZ are managed regeneratively, we compared common mainstream practices with the principles introduced in Figure 5. There are both commonalities and differences (Table 5).

Table 5. Compatibility of common practices or management strategies employed in mainstream farming systems in NZ with instructional RA principles (as given in Figure 5: **#4 Maximise photosynthesis (year-round), #5 Minimise disturbance, #8 maximise photosynthesis year-round, #9 minimise disturbance, #10 harness diversity**).

Mainstream practice or management strategy	Compatibility with RA principles
Pastoral farming systems	
Rotational grazing systems promote perennial pasture growing year-round.	Compatibility with principles #8 and #9.
NZ perennial pastures include mixed grass & legume.	Compatibility with principle #10
Compared with much of the rest of the world, NZ rotational grazing systems are world-leading. NZ has some of the lowest greenhouse gas and water footprints per kg of meat, milk and wool globally [92]. NZ farmers also have a reputation for being highly innovative and fast adopters of new practices and technologies [10; 22; 172].	Compatibility with principles #4 and #5.
Set stocking, short rotations or regular severe (low residual) grazing suppresses grass growth and photosynthesis and can also create bare exposed soil between pasture plants.	Incompatibility with principle #8.
High rates of synthetic fertilisers common in more intensive systems are considered a disturbance to the diversity and function of the soil microbiome, as are herbicides used for weed control. Tillage for summer or winter forage cropping is a mechanical disturbance, and these tilled forages often receive selective herbicides and pesticides.	Incompatibility with principle #9.
Tilled summer crops and winter forage are usually monocultures and incur substantial soil losses. While grass + legume pastures are more diverse than monocultures, the diversity is very low relative to more common regenerative practices where 8 species from 3+ functional groups would be considered low to moderate diversity.	Incompatibility with principles #9 and #10.
Arable farming systems	
Adoption of no-till arable systems is increasing steadily [32; 73], while the number of tillage passes has been steadily decreasing over the last 10–15 years (minimise disturbance) [48].	Compatibility with principle #9.
NZ arable farmers also have some of the most diverse crop rotations in the world, with the Foundation for Arable Research (FAR) collecting levies across 45 categories and 80–100 different species (FAR, pers. comm.). Most arable farms have some degree of livestock integration across the rotation, although in some regions the traditional mixed cropping system with longer pastoral restorative phases has become less common (FAR, pers. comm.).	Compatibility with principle #10.
Winter fallow periods have largely disappeared, particularly in the South Island, due to an increase in autumn sowing for winter cover crops (e.g. oats, rape, ryecorn, grass, kale), and catch crops (e.g. oats, triticale) being grown post winter crop grazing events and prior to spring sowing. However, the paddocks are bare for short periods to allow turnaround time. (T Fraser, pers comm).	Partial compatibility/incompatibility with principle #8.
Most arable crops are grown as monocultures and weeds are controlled with selective herbicides, which reduces diversity. High rates of synthetic fertilisers are common, as are a wide variety of herbicides, insecticides and fungicides which reduce diversity and disturb the soil microbiome.	Incompatibility with principle #10.

Grazing management

Grazing management is a complex topic. NZ is a world leader in rotational grazing systems. To see how this differs from RA multi-paddock adaptive grazing, we gathered individual data on a few key metrics from farmers considered capable and successful managers (Figure 6).



	Dairy			Sheep & Beef		
Attribute (November to March only)	Common	RA1	RA2	Common	Low input	RA
Animal biomass Density (Tonne/ha)	90	250	80	5	30	50
Seasonal Forage Utilisation (%)	85	70	70	75	80	70
Grazing duration per "shift" (hrs)	12	6	8	72	36	12
Plant recovery (leaf stage) for cattle	3	3.5	3.5	3	N/A	3.5
Seasonal Trampled Litter (%)	5	20	30	5	5	30

Figure 6. The need to account for multiple nuances of grazing management when researching the impact of RA on the performance of pastoral farming operations. Here anecdotal data are shown for a selected number of grazing management attributes (restricted to cattle operations, and November to March) as reported by six individual farmers spanning a range of grazing management, from 'common' rotational grazing, via 'low-input' to RA (e.g. adaptive multi-paddock grazing). All dairy farms were in the Otago/Southland regions. Sheep & beef farms were spread out across North and South NZ. Absolute data are given in the table. To emphasise differences between 'common' rotational grazing and RA grazing management, the graphs display the data contained in the table, after calculating the relative differences between 'common' and RA/low input for both dairy (left panel) and sheep & beef (right panel) operations.

The differences highlighted in Figure 6 warrant explanation and exploration. In the pastoral focus group, RA practitioners explained why they focused their management on plant recovery, grazing density and trampled litter. Greater plant recovery captures more energy to feed livestock and soil microbes while encouraging deeper rooting. Higher grazing densities aim to (i) even out grazing and/or excess trampling to keep pastures vegetative, (ii) improve animal performance through frequent shifts and uniform nutrition, (iii) even out the distribution of manure and urine, reducing nitrate leaching and improving nutrient cycling between animal-plant-soil and (iv) moderate soil temperatures through trampled litter to increase water-use efficiency. They also stressed that grazing management must adapt to seasons, weather, stock classes and lifestyle preferences (which is why Figure 6 includes anecdotal data for November–March and cattle only).

Research on RA pastoral systems must explore in detail soil, plant and animal responses to management across the continuum of grazing systems. The large differences highlighted in Figure 6 emphasise that research into other aspects of pastoral systems (i.e. diverse pastures) must account for the nuances of grazing management. Any research that fails to do so will be of limited relevance.

Self-reflection: insight from the arable, dairy, sheep & beef, and viticulture sector working groups [55]

We asked the 60 participants in our sector working groups to reflect on what is working well in their systems and can remain the same, what is not working, issues to be resolved, and whether they consider NZ systems perform better than elsewhere [55]. Besides mentioning the advantages of our climate, participants from every sector expressed a belief that continuous improvement, learning, and innovation are inherent in the culture of NZ farming. They believe NZ is striving to be more sustainable and is attentive to animal welfare. The grass-based systems, diverse arable rotations and widespread use of precision farming practices and minimum tillage are considered strengths, as is the international reputation of NZ products.

Our participants also acknowledged where the systems are not working well and where there is a bigger gap between current and regenerative agriculture. Common to all sectors are concerns about water quality, intensive production-focused farming systems based on monocultures, and the proportion of our agricultural produce that is sold as commodity with no added value. Other concerns related to the lack of biodiversity in the systems, the high level of non-renewable resources used, profitability, and the lack of connection between consumers and producers.

Many participants consider that NZ systems perform as well as, if not better than, international counterparts, particularly in contrast to heavily industrialised systems. The advantages come not only from favourable climate and soils, but in the range of practices and quality and mindset of the farmers. However, some believe NZ systems are not superior to those overseas and cited systems driven by quantity not quality and high variability in farm performance within NZ.

1f NZ's unique context

Finally, a discussion of RA in NZ must be anchored in its particular biogeographical context and uniqueness. This is particularly relevant to overseas niche markets for regenerative products, which are affected not only by international definitions of RA, but by their own perception of what 'regenerative' means, which we also discuss at the end of this section.

Soil carbon [89]

NZ soils have a relatively high carbon (C) content. For example, the top 30 cm of NZ soils contains on average 90 tonnes per hectare, compared with 30 and 80 tonnes for Australia and England, respectively [42]. For comparison, we retrieved soil organic carbon (SOC) stocks data (0–30 cm) from the FAO's ecoregion/biome database https://ecoregions2017.appspot.com/ [42] for countries with similar geographical context to NZ. To do so, we only included countries with centroid latitudes ranging from 34° to 48° from both hemispheres (to avoid comparison with countries with large areas of peatlands) and countries with a total area larger than 10,000 km^2.

Figure 7 indicates that mean SOC stocks for NZ soils (averaged across the whole country) are at the higher end of the SOC range for countries at similar latitudes. These are national averages, and regional variations are significant (as indicated by the large standard deviations), but these data illustrate the inherent C richness of NZ soils.

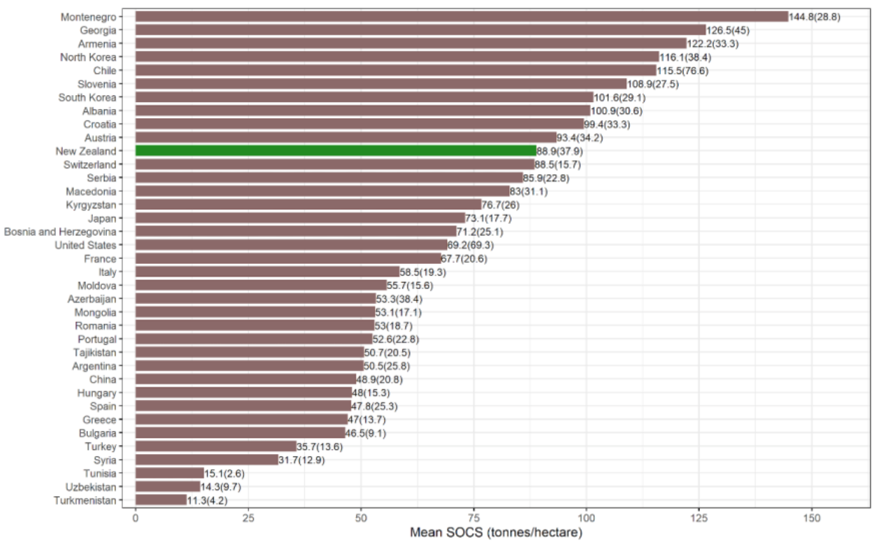


Figure 7. Mean SOC stocks (0–30 cm depth), by country [42]. Mean and standard deviation for each country are also indicated next to the relevant bar. Values for NZ are highlighted in green. *McNeill S & Mudge P. 2021. Unpublished (with permission).*

RA practitioners claim that their systems will decrease atmospheric CO_2 concentration by sequestering C in above-ground biomass and in soil, especially at depth [170]. Significant C accruals under adaptive multi-paddock grazing management are possible [83; 158]. If the top 0.3–0.4m of global agricultural soils could sequester 2 to 3 Gt of C per year globally, this would effectively offset 20–35% of global anthropogenic greenhouse gas emissions. This is a blanket calculation, which does not account for C stored at greater soil depth, and while some soils already have high C content and are less likely to accrue much more C, others may increase stocks by 10 per 1,000 or more.

The key question for RA in NZ is how and where can soil C further increase? Changes in NZ land use affect soil C stocks in the top 30 cm [108], although it is unclear if these changes reflect differential rates of loss or sequestration. However, there is limited published evidence indicating that specific management practices have a large impact on soil C stocks in NZ, even to 60 or 90 cm depth [149].

Soil C accumulation is not fully understood. As land management changes, soils may become sources or sinks of C, as a balance between inputs from plants on one hand and losses through decomposition of organic matter and leaching on the other. Recently attention has shifted from understanding the recalcitrance of soil organic matter to decomposition, to considering how to protect it from breakdown via physical, chemical or biological stabilisation [38]. Much of this stabilisation happens via adsorption onto mineral surfaces. Therefore, some believe that soils can become 'saturated' with carbon [154].

However, the concept of a C saturation threshold is disputed. Indeed, statistical analyses of NZ soil C data show that the top 0–15 cm of pastoral and cropping soils can store more C [107]. Modelling work has also shown that observed soil C (30 cm depth) is inconsistent with the amounts predicted by a saturation threshold for soil C [77], but matches a newly published model that links stabilised soil C directly to C input [78]. A recent study (using data from over 9,000 European soil samples, to 20 cm depth) found that stable mineral-associated organic matter saturates, but that the less stable particulate organic matter C may accumulate indefinitely, with C allocation between those two pools strongly influenced by nitrogen and the vegetation types (including forests) [26].

A number of recent investigations emphasise the overlooked roles of management-induced changes in soil depth e.g.,[156], which can result in soil C accruals via the build-up of topsoils, as anecdotally reported by RA practitioners, although quantification is technically challenging. There is also conflicting evidence on the impact of land use and management on the quantity of C stored below 30 cm (e.g. to 60 or 100 cm depth) [123; 184]. To address unknowns about C storage at depth, the National Soil Carbon Monitoring System for Agricultural Land in New Zealand is currently quantifying soil C stocks to 60 cm depth [123].

Evidence from both experimental and modelling studies is mounting for the so-called "soil microbial carbon pump" [184] or "liquid carbon" pathway [72]. Modelling and experimental studies show that accumulation of microbial necromass, initially fuelled by plant photosynthetates via rhizospheric processes, may be the primary driver of soil carbon accruals [114; 184]. Biodiversity stimulates this microbial carbon pump [81; 87; 184], which is highly relevant to RA.

In conclusion, how and where NZ soil C stocks may change and how stable any accrued C may be is being actively researched. Soil C increase might not be wanted in some sectors (e.g. some viticulture operations consider low soil C to be critical to 'terroir'). If soil C is to be included in the NZ emissions trading scheme, the magnitude of C accruals at depth is of interest. Some premium and niche markets for regenerative products emphasise climate change mitigation via agricultural carbon sequestration (see subsequent section on NZ's agricultural trade).

RA in NZ needs to expand its narrative around soil C to (i) soil C retention (including mitigating surface erosion and retaining soils), (ii) maintenance or increase of soil carbon functionality (e.g. impact on production, water capture and retention, biological activity and diversity, ecosystem resilience (ref)) and lastly (iii) potential acceleration of C sequestration in the top soils and subsoils by increasing plant diversity and regenerative grazing management e.g., [8; 13; 18; 116; 131; 144; 155; 157; 179; 183].

Native biodiversity [126]

Islands are more easily protected than continents from incursion of harmful species and contaminants. However, NZ also faces considerable challenges to protecting biodiversity as the primary production sectors (agriculture, horticulture and forestry) rely on exotic species [50]. The introduced grazers and browsers – sheep, cattle, domesticated deer and goats – are largely supported by introduced grasses and forbs.

The native flora evolved under the influence of bird browsing only. Introduced mammals, both those used for agriculture and feral species, can wreak considerable damage on natural ecosystems. The impact of birds and ruminant grazing is very different: ruminants have a much greater effect than birds, as teeth crush plant material more thoroughly and cut stems much closer to the ground. Hooved animals exert much greater foot pressure than birds, compressing the soil and compacting it to a much greater extent, especially in winter.

Native grasses have evolved to thrive in the face of bird grazing [7; 15], but unlike the often rhizomatous, sward-forming introduced grasses, they find it difficult to tolerate repeated sheep and cattle grazing [46]. Native herbs are often nutritious, and therefore often preferentially targeted by grazing mammals, and are also easily overwhelmed by sward-forming exotic grasses and fast-growing exotic herbs. Rabbits and hares often reach plague proportions in weakly managed landscapes and can decimate native herbs and lowing-growing shrubs alike. Without careful management, the native flora can gradually lose ground and then disappear entirely, creating large swathes without the native biodiversity that our native taonga species depend upon and support.

The native fauna, especially birds and reptiles, have been seriously depleted by invasive mammalian predators [67]. The largely endemic native fauna evolved without mammalian predation, and the introduction of these species (mustelids, rodents, possums, cats, etc.) has driven many species to, or close to, extinction. These native species would have played a diversity of critical, but now lost, roles in pre-human NZ ecosystems. The rapid expansion of livestock-based agroecosystems has therefore had a detrimental impact on our native species.

This point of difference between NZ and other countries is significant in the context of RA. Indeed, the prairies of North America and the savannahs of South Africa have inspired many of the modern grazing strategies implemented in RA, with practitioners seeking to mimic the original behaviour of native ruminants/herbivores to promote the return of native plant communities and original ecosystem functions, which they heavily influenced [148]. By contrast, the modern ecosystems of NZ, and especially horticultural and pastoral operations, are very different from those that were present historically. Therefore, an even bolder refocus of the RA biodiversity narrative is needed for NZ.

From a native biodiversity standpoint, even where remnants of the native vegetation remain (as wetlands, forest patches or grasslands, for example), their biotic composition and abundance have often been markedly altered from that of the past [106]. Many NZ ecosystems are novel [60] in that they now comprise new assemblages of species, both above ground and below ground, and therefore very different interactions and processes.

Farmlands and rural environments are the areas of NZ where native biodiversity is most threatened, and the allocation of management resources for these areas is scarce. A 2017 study assessing NZ residents' preferences for native biodiversity outcomes found that 90% of respondents (representatives of NZ key population demographics) are willing to pay something to improve native biodiversity outcomes above current levels [164].

With this in mind, the RA narratives in NZ needs to refocus on whether RA farming ecosystems can be further evolved to (i) protect existing native species, (ii) reverse declining trends to prevent native biodiversity extinction while (iii) increasing ecosystem total (all taxa) biodiversity to (iv) maintain or increase ecosystems multifunctionality [102]. While RA practitioners are actively seeking to promote (iii) and (iv), there is only limited integration of principles promoting (i) and (ii). Promotion of (i) and (ii) will require incorporating landscape-scale biodiversity processes and flows of species into farm design and management [104]. One can think of it as a "wildlife friendly approach to farming" [43]. This requires close observation and frequent adaptation – principles that are already an integral part of RA.

Hence, RA is a way to reconcile farming with conservation[128]. Adapted from [127], we propose five biodiversity principles to guide native biodiversity goals for RA farming systems in NZ:

- biodiversity-aware farm planning, integrated across the landscape and for the long-term
- understanding of current threats to biodiversity and anticipation of future threats
- continuous monitoring of biodiversity outcomes (e.g. native plants and birds, invertebrates including aquatic)
- adaptive biodiversity management based on monitoring outcomes
- enough humility and patience to learn from the land.

Soil erosion [35]

Soil erosion is estimated to cost NZ up to NZ$300 million per year, in part because of the steep landscape. The Land Use Capability classification splits the landscape into eight classes based on erodibility, wetness, soil properties and climate [99] with increasing limitations on the suitability of particular land uses as class numbers increase. Only the first four classes are suitable for all types of agriculture. Within classes 5–7, pastoral farming practices, such as winter grazing and single-species winter cropping, exacerbate the risks to surface erosion [16]. In classes 1-7, RA principles promote strategies, including the establishment of high-diversity fodder crops and perennial pastures, that increase soil aggregate stability and microbially-mediated changes in soil structure [121; 174], all of which have the potential to reverse soil surface erosion trends (see Table 2). However, on steep slopes (NZ hill country), these strategies will not solve erosion due to rain-triggered landslides, unless they also draw upon landscape arrangements that promote the growth and habitats of (native) trees.

Prior to settlement by Māori and then Europeans, NZ was largely covered in woody vegetation as fire was infrequent. Māori-lit fires had only a limited effect on soil erosion because forest was replaced by fern and scrub [138]. However, following the introduction of European pastoralism, forest, fernland and scrub were replaced by exotic, shallow-rooted grasses, which greatly exacerbated surface and mass erosion (slips) [14], especially in soft-rock hill country. This resulted in flooding and sedimentation in low-lying areas [49]. Climate predictions for NZ for more frequent and intense rain events (see Table 1) and soil erosion will worsen unless land management changes. One of RA's challenges will be to incorporate strategies such as agroforestry or silvopasture to mitigate slips and landslides. This will require context-specific (e.g. planting versus natural regeneration) and policy-aware strategies (e.g. accounting for constraints in the Emissions Trading Scheme).

In summary, the very existence of current mainstream agricultural sectors swims against the biological and geophysical evolutionary current of our islands. This raises the bar high for RA in NZ, and also provides an opportunity for NZ to own its RA narrative and differentiate itself from the rest of the world.

NZ's agricultural trade [147]

NZ's primary industries represent 7% of its GDP [119], which is more than three times the average for OECD countries. Agriculture itself contributes 12.4% of NZ traded GDP when the value-add of basic processing of agricultural products (excluding seafood) is included in the calculation (see section 1f). Clearly NZ's economy relies on its agriculture to a larger extent than many other developed countries. The marketing potential of agricultural products from RA farms can therefore have a substantial impact on the NZ economy.

On the domestic front, almost all New Zealanders (90%) are willing to pay to increase native biodiversity and would be willing to pay up to $7.39 annually for each 1% increase in freshwater quality, according to two studies including representative samples of NZ population (Tait et al 2016, 2017). So, if providing RA can actually deliver greater biodiversity and significantly increase freshwater outcomes, there might be a niche or premium market potential for RA produce within the domestic market.

Given the reliance of the NZ economy on exports, the main issue is whether there are large enough overseas markets for our regenerative products. This is difficult to assess because those markets are still evolving and insufficient market research has been done. The issue can be broken down into two main questions:

1. Can NZ regenerative products be competitive in overseas markets, whether as a commodity or niche/premium produce?
2. What premium or niche markets are there?

To provide insights into the first question, we present here new data on UK and Californian markets[163].

In November 2020 samples of 1,000 consumers in the UK and California were surveyed using online Likert scale questionnaires in order to find out how much they knew about RA and its benefits. Only 40% knew anything about RA (Figure 8).

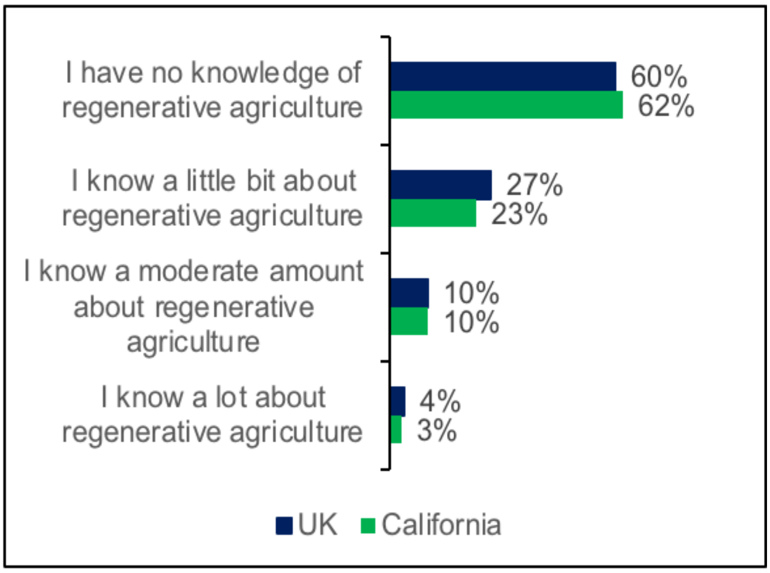


Figure 8. Knowledge of RA in a representative sample of UK (blue) and Californian (green) consumers; 1,000 participants answered the survey in each country. Adapted with permission from Tait *et al.* (2021) [163].

Respondents who knew at least a little bit about RA were then asked which factors they associated with RA. The strongest association for both UK and Californian respondents was care for the environment (Figure 9). Reduction of C emissions was in the top seven benefits, but only a quarter of respondents strongly associated RA with C capture. Animal welfare was much more strongly associated with RA in the UK than in California.

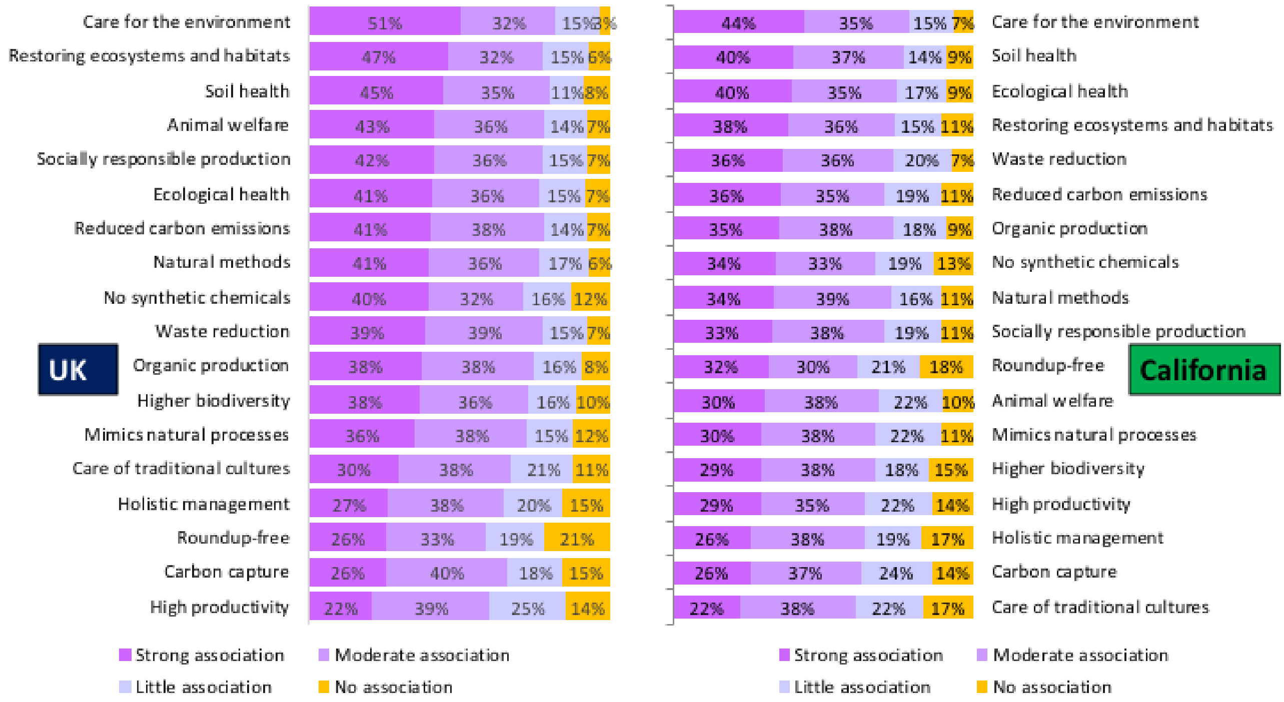


Figure 9. Factors associated with RA by UK and Californian consumers. Adapted with permission from Tait *et al.* (2021)[163].

Figure 10. Brand advert for regenerative produce emphasising the focus on reducing or eliminating carbon reductions. *Figure provided by the Merino New Zealand Company with permission to reproduce*.

The advertising strategies of brands and global marketing companies provide insights for question 2 (overseas premium or niche markets). Leading brands are promoting global issues. For instance, Allbirds have printed individual carbon footprints on all their products. They see RA as one of the biggest opportunities to reduce the impacts of their supply chain. While C is not the only metric that matters, they believe it simplifies the climate action message for both consumers and suppliers. Through the New Zealand Merino Company they are working with wool suppliers on a regenerative wool sourcing programme, ZQ^{RX}.

These types of commitments are becoming more common as brands align with consumers, making purchasing decisions in alignment with their personal values.

2 What do people want to know about RA in NZ and what research do they request?

2a Needs analysis across NZ's wider agri-food system

We ran 10 focus groups with four to five participants each, involving people from a range of professions across the NZ agri-food system as well as from media, finance, and science, and asked the participants what they wanted to know or what questions they had about RA [91]. Understanding of RA was generally low, but there was a strong desire for common language and greater understanding.

Discussions on the definition of RA were tense. Participants advocating for a clear definition were mostly scientists wanting to test or study anecdotal claims, or marketers viewing RA as a value-add opportunity. By contrast, many other participants supported a broader framework or continuum for RA that encompassed philosophy, principles, values and practices. This perspective was concerned that narrowly defining RA could limit its evolution through innovation and adaptation by farmers. Conversely, there was confusion about where the boundary of RA lies and, for example, whether synthetic inputs are 'permitted' and how to determine whether a farm is already regenerative or not.

Reasons for participants' interest in RA varied widely. Many participants had a strong market orientation and saw RA as a great opportunity (or necessary shift) to maintain or improve the value of our exported produce. Participants with a strong financial perspective were interested in the potential to de-risk borrowing and lending on a number of fronts, including exposure to regulatory change, commodity prices, climate change, etc. Farmers tended to be focused on the opportunity to better balance environmental, social and economic outcomes, including improving social license and sequestering soil C while keeping things simple and enjoyable.

Some of the participants curious about putting RA into practice were not satisfied with philosophy and design principles alone. There were views that NZ is a very different context to other countries and practices needed to be customised. The huge challenge of developing specific guidance for so many different contexts may partly explain why RA practitioners favour a principle-led framework and resist prescriptive definition. By contrast, the current complexity of information on RA is seen as a barrier to farmers who would otherwise be interested.

The extensive discussion on understanding and defining RA has led to three areas of suggested future focus:

- developing a 'Regenerative Agriculture Continuum' that helps farmers identify where they sit and explore options
- developing RA principles that outline the purpose, desired outcomes and instructional principles
- developing a schedule of practices for farmers presented in a conventional style and specific to different sectors and regions.

Most participants agreed on the need to gather evidence on RA outcomes, but the specifics varied greatly. RA-aligned farmers wanted validation of the benefits they had been observing, whereas non-RA farmers wanted more confidence that adopting different approaches would be environmentally and economically beneficial. Marketers wanted evidence to support in-market claims that could capture higher prices. Financiers wanted evidence so that they could adjust the risk profiles for lending to farmers adopting RA systems with unfamiliar attributes, such as low fertiliser inputs or diverse pastures and crops. Levy bodies wanted to especially know whether RA would help solve their sector's environmental challenges. Scientists wanted evidence for a wide range of reasons.

Overall, the reasons why participants were interested in RA varied greatly. Pull factors included being more environmental, more resilient, more values aligned, more profitable (including market premiums) and more fun. There were also push factors, such as regulation, societal pressure and problems with current systems. There was an extremely wide range of views as to what RA entails, which reinforces the need for this project. Almost everyone wanted to better understand RA in NZ, but the necessity for a clear definition was a source of disagreement.

2b Needs analysis by agricultural sector: insight into priority research topics for the arable, dairy, sheep & beef, and viticulture sectors

We asked the 60 participants in our sector working groups to rank particular research topics [55]. We designed quantitative surveys (using a Likert scale) based on the aspects of farming systems that participants rated as important for the system to be seen as being regenerative (see Figure 3, section 1c) and tailored these surveys to each sector. Participants could provide only one answer per question, choosing from four possible answers: 1 (not so important), 2 (quite important), 3, (very important) and 4 (extremely important).

The relative importance ranking for each topic was first analysed separately for each sector (data not shown). Rankings were then analysed across all four sectors. We coded each question against research areas that were common across all sectors, or against research areas that were sector specific. The relative distribution of ratings for each of these was then analysed across all respondents, without distinguishing their sector of origin, and these are shown in Figure 11. Sector-specific research areas are marked with an asterisk.

Based on the importance ratings given to each research area by participants in each sector (data not shown), we retrieved the top nine areas of research that received the most 'extremely important' ratings for each sector and assigned a ranking score to those (from 9 = highest ranking, to 1 = lowest ranking). We calculated the average ranking score obtained by each area of research and applied a weight correction to these scores to account for whether they were rated 'extremely important' by participants in a subset or in all four sectors.

Below is the list of research areas considered of extreme importance by participants after the weight correction was applied. The order did not change significantly by applying this correction (only topics 4/5 and 11/12 were in reverse order).

1 Impact of RA on freshwater outcomes

2 Impact of RA on food quality and safety

3 Relationship between RA and farmer empowerment and mindset

4 Long-term viability of whole systems and stewardship (impact of reducing inputs, long-term resilience to financial and climate change, next generation legacy, etc.) under RA

5 Impact of RA on animal welfare

6 On-farm total (all taxa) biodiversity under RA

7 Soil carbon (particularly in RA farming systems)

8 Impact of RA on farm and landscape resilience to extreme weather

9 Accountability in food systems

10 Impact of RA on NZ access to premium and niche markets

11 Role of RA in configuring farmscape for native biodiversity

12 Seed contaminations (arable) from multispecies crops and pastures

13 Relationship between farmer support and learning network

14 Profitability of RA farming systems

15 Role of RA for increasing enjoyment in farming.

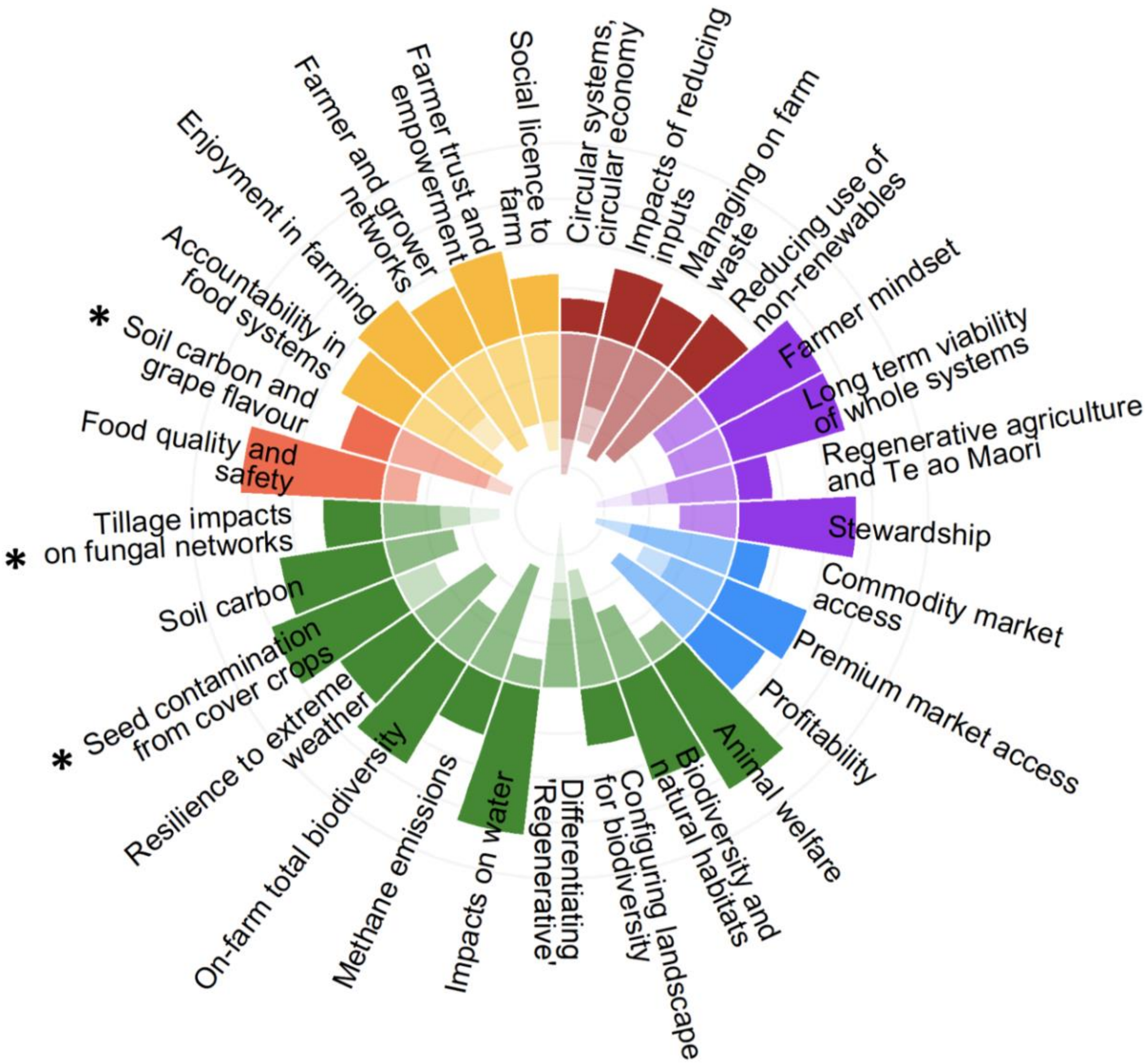


Figure 11. Importance ratings given to 29 research areas relevant to RA. There were 60 participants included in this study drawn from four agricultural sectors. Participants were asked to rank previously identified research needs using a Likert scale questionnaire. The figure shows the relative number of participants choosing 1 (not so important), 2 (quite important), 3 (very important) or 4 (extremely important) is indicated by the length of the bar segments and their respective shade of colour (from lighter shades to darker shades, in order of increased importance). All bars were arranged such that the relative number of participants choosing the highest rating (extremely important) is displayed on the outside of the white circle. Topics were grouped by broad topic categories: economy and access to markets (blue), environment (green), food quality (orange/light-red), social and farmer wellbeing (yellow), culture and values (purple), integrated circular systems (dark red). In Grelet GA, Robson-Williams M et al., 2021 [55].

2c Needs analysis for RA practitioners: what scientific research is called forth by RA practitioners in NZ?

Quorum Sense is a digital platform where practitioners of RA and their supporters can exchange information, express opinions, formulate ideas, and submit questions and answers in themed forums. Quorum Sense has 126 WhatsApp members (mostly restricted to RA practitioners operating at commercial scale), 700-plus newsletter members, and 3,000-plus Facebook members, depending on the platform of engagement. Quorum Sense has experienced 160% growth in 2020, averaging four posts per day (120 posts per month) in the closed Facebook group and dozens of messages per day in the WhatsApp group.

We invited members of the WhatsApp and Facebook groups to submit their top three impact research questions about RA, requesting that questions be tailored for scientists. Below is a summary of the 115 questions submitted by the approximately 60 Quorum Sense members who responded to our request. The questions are mapped against the themes presented in Figure 3.

Questions relating to soils dominate among most of the topics highlighted. A similarly high level of interest in soils characterised discussions within the sector working groups, which included no more than two RA practitioners per group.

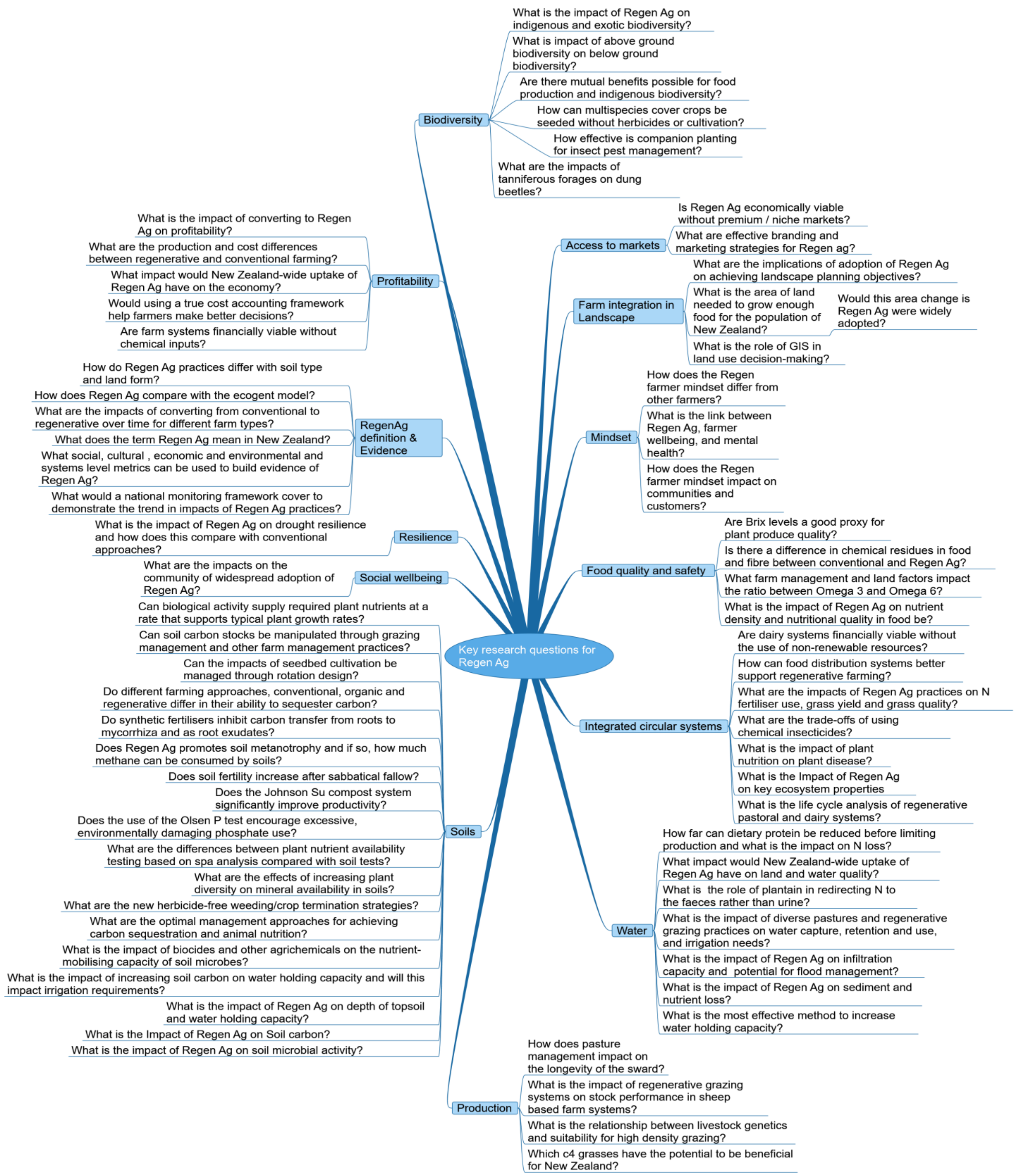


Figure 12. Research questions put forward by RA practitioners in NZ.

3 What are the knowledge gaps for RA in NZ and what scientific metrics are needed?

We assembled a consortium of 50-plus scientists and experts, drawn from multiple NZ research organisations, independent researchers and consultants. Multi-disciplinary teams were organised to cover most of the research topics identified by our multiple research needs analyses. Figure 13 presents a roadmap to areas of research explored by this consortium of experts, and how these relate to the research needs identified above in Section 2 [23; 25; 31; 33; 35; 52; 89; 90; 97; 126; 147; 150; 151].

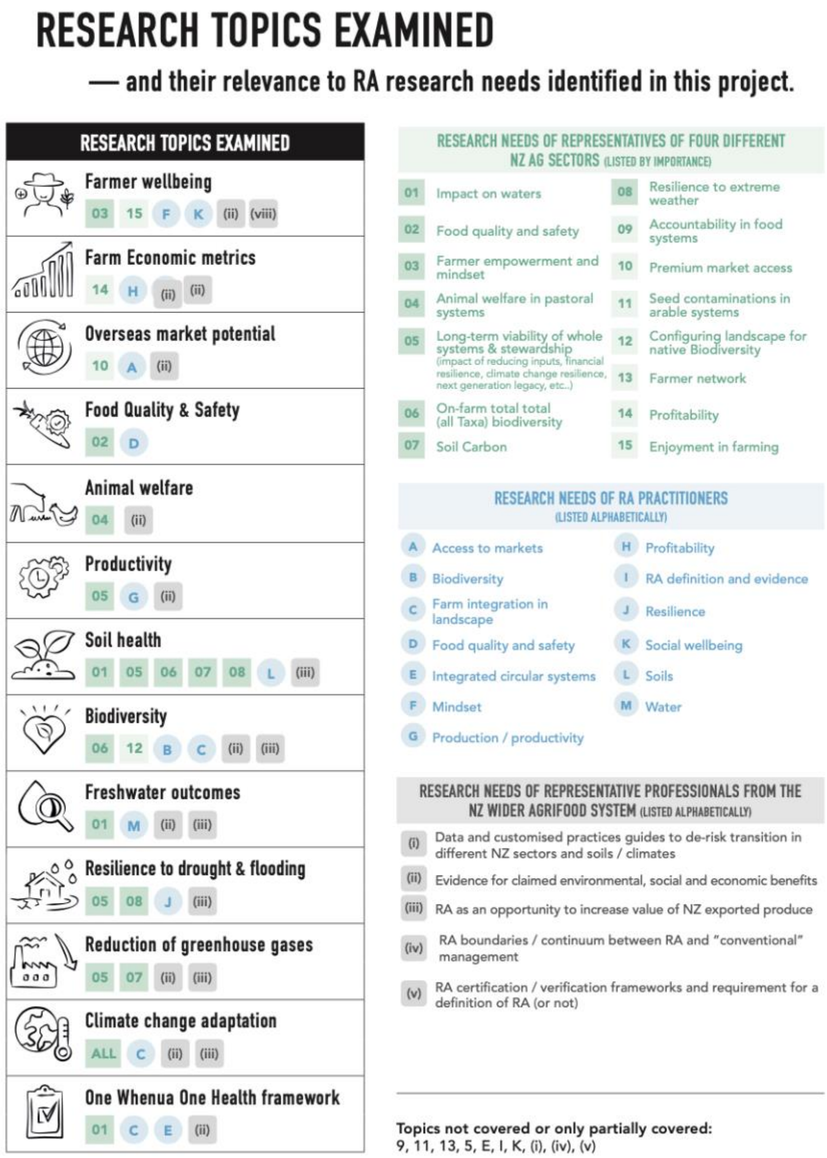


Figure 13. Research topics examined and their relevance to the research needs identified in this project.

Each team has summarised the claims made by RA practitioners for their particular topic of expertise and have identified the key knowledge gaps that will need to be filled for these claims to be tested. In addition, each team has also made some recommendations on relevant sets of indicators and experimental approaches/methods that can be deployed to test these claims [23; 25; 31; 33; 35; 52; 89; 90; 97; 126; 147; 150; 151].

Table 6 below lists the knowledge gaps identified by these teams of experts. Further information (Fact sheets and topic reports) can be found at https://ourlandandwater.nz/regenag and/or https://www.landcareresearch.co.nz/publications/regenag.

Table 6: Knowledge gaps for RA in NZ as identified by a consortium of >50 scientists and experts in each topic covered..
Further information can be found at: https://ourlandandwater.nz/regenag and/or https://www.landcareresearch.co.nz/publications/regenag.

<table>
<tr>
<td colspan="2">Farm economics [147]
▸ How well do RA farming systems perform financially when assessed using industry standard metrics (e.g. EFS = economic farm surplus)?
▸ How do RA farming system compare to other farming systems with regards to non-standard metrics such as:
• EFS per hours worked (owner/manager, employees) (to address concerns with time investment for AMP grazing)
• Long-term return on investment in natural capital (e.g. investment in soil health by planting diverse cover crops and multispecies mixes, expected to yield positive financial gains in subsequent years by reducing fertiliser costs, etc..)
• Investment in natural capital leading to savings on compliance costs.
• Carbon credits, EFS per Kg CO2 emitted or unit nitrate leached.
▸ What is the impact of “stacking” enterprises (i.e. multiple produce generated from same land unit area) on EFS?
▸ How might future changes in international markets affect NZ’s financial returns from agriculture?
▸ How do RA farming systems compare with others when true cost accounting/natural capital valuation? And how does this difference scale up to regional or industry scale assuming various level of RA uptake?</td>
<td>Overseas market potential [147]
▸ Which overseas markets have the potential to offer a regenerative premium?
▸ What are the views of the food/beverage/fibre and policy sectors within these markets?
▸ What are the consumer’s views of RA within these markets?
▸ What needs to be delivered/changed to meet market expectations?</td>
</tr>
<tr>
<td>Freshwater outcomes [25]
▸ What is the variability in the quantitative relationship between freshwater indicators with greenhouse gases (nitrous oxide and carbon dioxide), farm nutrient retention and regenerative farm practices?
▸ What are the impacts of RA farming practices across biophysical domains through time and at a sub- catchment scale?
▸ Errors of measurements for the methodologies employed to collect high resolution data, for telemetry and for data processing need to be evaluated, and their impact on the modelling of hydrological and biogeochemical processes assessed.</td>
<td>Soil health [151]
▸ What is the impact of RA on long-term nitrogen and phosphorus availability with reduced inputs?
▸ How does RA increase soil carbon concentration, if it does?
▸ Can RA improve the water cycle, and if so, how?
▸ Can RA improve mineral stoichiometry (balance)?
▸ What mechanisms or drivers lead to improved soil structure under RA?
▸ Can RA enhance biological activity in soils? How so? And what impact might this have on ecosystem functions?
▸ What are the impact of the bio-stimulants and bio-amendments used by RA practitioners?</td>
<td>Biodiversity [31; 126]
▸ Does RA increase both native and total biodiversity outcomes? What are the linkages between practices and biodiversity outcomes in different contexts (e.g. ecoregions)? Could RA have any unintended negative biodiversity outcomes?
▸ What landscape configuration of RA farming systems promote native biodiversity and ecosystem resilience?
▸ Can changes in indicators of biodiversity (e.g. native birds, insects, spiders) be used to predict the trajectory of NZ farming systems towards increased ecosystem health? What are the opportunities for upscaling NZ’s biodiversity monitoring capability, in collaboration with RA farmers/growers?</td>
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<tr>
<td>Adaptation to environmental change [90]
▸ Do RA farming system provide greater adaptation services compared to other farming systems in comparable biophysical context (climate, soil type, topography, business type, etc..)?
▸ What novel ecosystem services, if any, might evolve in the near future from RA farming systems in NZ?
▸ Can RA contribute to the understanding of both human-centric and eco-centric adaptation services in the context of NZ?</td>
<td>Resilience to drought and flood [35]
▸ Do practices under RA alter resilience to drought and flood compared to current management practices at field, farm and landscape scales?
▸ What mechanisms underpin differences in resilience between RA and current systems? If any?</td>
<td>GHG [89]
▸ Does RA increase the amount of carbon stored in NZ soils?
▸ Can RA substantially reduce nitrous oxide emissions for soils?
▸ Do ruminants managed under RA emit substantially less methane?
▸ Does RA increase the capacity of soils to consume methane?</td>
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<tr>
<td>Animal welfare [52]
▸ Animal welfare challenges with wintering Livestock: Can RA offers solutions? Or contribute to developing new solutions? Solutions have to be tailored to each NZ regions as constraints differ.
▸ Animal management that sustains purity of Freshwater: can RA offer solutions to maintaining ecological integrity of wetlands, riparian strips and freshwaters, and enhance animal welfare at the same time?
▸ Disease: Are animals in RA farms less affected by disease? Answering this question would also contribute to developing comprehensive national disease surveillance and treatment programmes to appropriately inform ‘healthy animal’ accreditation programme.
▸ Recovery from stressors post-calving/lambing: Are animals under RA recovering better/faster from reproductive events?
▸ Feeding value of multispecies pastures/crops: How does this match the nutrient requirements of the animal, and does the availability and accessibility of particular morphological components of the plants matches the ‘desires-needs of the grazer’.</td>
<td>Farmers’ wellbeing [23]
▸ What are the impacts of RA adoption on farmers’ wellbeing? Do these impact change based on the timing of adoption (as early innovator, early adopter, follower or laggard)?
▸ What are the impacts of RA adoption on the wellbeing of members of the farmer’s family?
▸ What motivates a farmer to adopt/transition to RA? What social wellbeing incentives drives transitioning to regenerative agriculture?
▸ Do RA practitioners differ from other farmers in their ‘mental models, worldviews, and cultural norms’?
▸ Does the adoption of RA impact on farmers’ mental models, worldviews, and cultural norms’?
▸ What is the role and the need for network effects among farmers in regenerative agriculture adoption?
▸ What are the social and wellbeing constraints on scaling up adoption of regenerative agriculture?
▸ Do farm families’ intergenerational transition processes change after adoption of regenerative agriculture?
▸ Does a farmer’s “social identity” or “sense of self” change after adoption of regenerative agriculture?</td>
<td>Food quality and safety [97]
There is scant data on the impact of RA on food quality. Specific food-related knowledge gaps can be pinpointed based on the potential (claimed) impacts of RA on ecosystem:
▸ Does RA increase protein contents?
▸ What is the impact of RA on other N-rich compounds?
▸ Does RA improve mineral concentration/“balance” in produce?
▸ What is the impact of RA on the ‘dilution effect’ (i.e. nutrient concentration versus yield)?
▸ How does RA impact on temperature-sensitive compounds? (e.g. vitamins)
▸ Do companion plants affect the nutritional qualities of crops/forage? Much research is still needed to confirm, quantify and understand the link between plant diversity and food quality.
▸ How does RA impact on food mineral content?
▸ Does RA cause unintended plant uptake of excess/harmful nutrients?</td>
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<tr>
<td>ONE WHENUA, ONE HEALTH framework [33]
▸ Current industry KPIs to assess farming systems reflect business, farm ecosystem and animal health and wellbeing. KPIs reflecting connectiveness between farms, public health and catchment’s wellbeing outcomes need to be developed to enable assessments of RA over the long-term and at larger scale (e.g. catchment).
▸ Baseline assessments of nature based services are lacking.
▸ How can regulatory design of land use change and agricultural policies respect and draw upon Māori worldview and knowledges systems of whenua-based interconnectivity?</td>
<td colspan="2">Productivity [150]
▸ What are the grazing principles in highly diverse pasture swards, e.g. how selective and competitive grazing affects pasture performance including feeding and nutritive values?
▸ How do young animals/low social order animals in mixed age/species livestock flocks/herds perform in terms of animal production?
▸ How is productivity of regenerative systems influenced by adverse events in comparison to conventional systems, including resilience and persistence?
▸ What are the impacts of farm management (diverse pastures/cover-crops/bio-stimulants) on product quality (meat/milk/wine) and quantity?
▸ Which tools require further development to estimate quantity and quality of diverse pastures?
▸ What is the potential for use of Brix measurements (e.g. determine the susceptibility of plants to insect pests)?
▸ Key knowledge gaps in our understanding of soil-plant-animal interactions in RA systems, in particular impacts of soil biological health on plant performance.
▸ Impact and trade-offs of different management on productivity and relationship with other farm indicators (e.g. farm profitability, food nutrient density and on-farm nutrient use efficiency, water use efficiency and greenhouse gas mitigation).</td>
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4 Research designs

4a Urgency, relevance, impact and legitimacy/credibility

The COVID-19 pandemic has exposed the fragility of food systems. […]. The nature and gravity of the challenges linking agriculture and food value chains to diets, health and planetary ecosystems can no longer be ignored — the case for fundamental transformation of food systems is now irrefutable. Achieving transformation will require a major shift in mindsets — especially regarding possible futures versus the status quo, and roles and responsibilities of public sector actors versus businesses in shaping dietary demand. Food systems contribute to economic prosperity, human health, and planetary health, and getting all three right matters. They are interlinked, exerting considerable influence on each other."

Webb, P., Benton, T.G., Beddington, J. et al. The urgency of food system transformation is now irrefutable. Nat Food 1, 584–585 (2020).

The future of the NZ food system is intimately linked to transformation of agriculture and food value chains at the global scale. Working with such system problems requires different approaches [37], where researchers intend to create change [120] and shift to being active contributors to a social process of tackling real-world problems [139]. Because researchers are themselves part of the affected system, the problems they investigate are not neutral objects of inquiry [141]. The values, individual context and worldviews of the individuals and institutions involved influence how such topics are researched, and how data and worldviews interact when testing a particular practice to assess its effect, validate its usefulness or change it. (Figure 14).

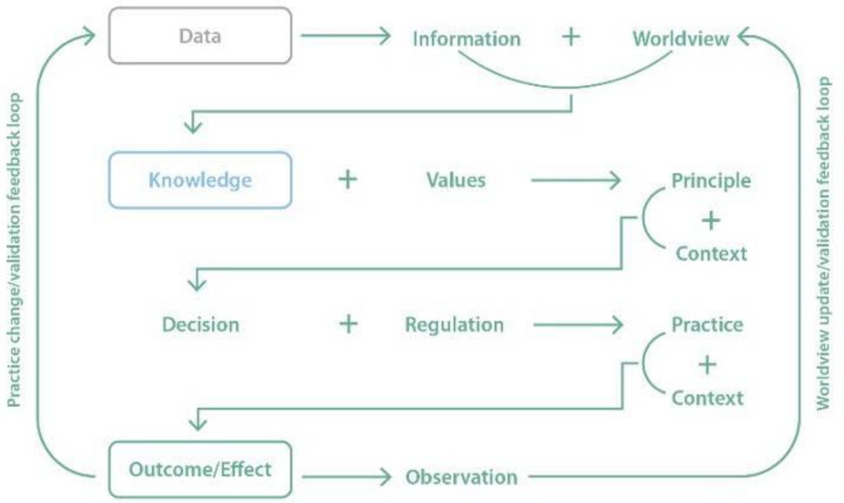

Figure 14. The link between data, information, knowledge/worldview and the testing of practices in order to assess its effect, validate its usefulness or change it.

These approaches, where researchers intentionally seek to create change, are the essence of transdisciplinary research, which underpins innovation strategies such as, for example, co-innovation and farm system research. Transdisciplinary research seeks to braid together multiple knowledge streams [84], including indigenous/local knowledge, western sciences, collaborative adaptive management, and relevant forms of citizen science, such as farmer science [80]. In this process, farmer experience, scientific understanding and, when appropriate, mātauranga Māori are linked. Transdisciplinary research also embeds integration and learning, relies on and promote adaptive processes and behaviours/mindset at individual and organizational level, and builds implementation pathways into the research itself [11; 17; 69; 120; 124; 139; 140; 175].

At the core of transdisciplinary research is the intent to consider multiple type of evidence as 'data' and to acknowledge the importance of context and values for the translation of data into knowledge, to then inform the testing of practice and its validation or change.

4b Lessons from overseas research in RA [55]

Transdisciplinary research has already been applied overseas to RA [82; 167]. These researchers have highlighted the tension between research experiments that meticulously control for certain variables and the desire to adapt in real time to the living systems that constitute one's farm and one's primary business. When this tension is resolved entirely in favour of the scientific preference, the results are suboptimal [20; 168; 169].

Experienced RA practitioners, such as US ranchers implementing adaptive multi-paddock grazing, may realise, mid-experiment, that a variable must change to allow for optimal outcomes. RA research must accommodate this sort of agile response or risk being irrelevant to the real world.

Scientists with decades of experience in RA research recommend to:

- Work with successful commercial farms managed under RA over multiple years and that are in a new 'equilibrium state' without a legacy of previous management [166].
- Collaborate with RA practitioners that have achieved superior economic returns via improved biophysical environments, because they can demonstrate the three-part components of operational sustainability: ecological, economic and social [36].
- Embed research collaboration with leading RA practitioners from conception to dissemination. This (i) addresses questions at commercial farm scale; (ii) uses a whole-system framework to integrate component science elements; (iii) incorporates proactive management under changing circumstances; (iv) identifies emergent properties and unintended consequences; and (v) provides research information to managers [167].
- Include a thorough selection process for the study location to discover which practices are or have been used and which inputs applied. This selection process is both critical and resource intensive (Teague, Lundgren, Grelet – pers. comm.).
- Combine approaches incrementally: (i) detailed field studies where no experimental treatment is applied other than the farm management, (ii) embedded small-scale experiments in the context of the targeted management options, (iii) simulation / modelling approaches [70; 71; 103; 132; 168; 177].

4c Different approaches to transdisciplinary research in the context of RA [53]

Relevant RA research designs fall into two broad categories:

- without deliberate intervention (i.e. no imposed research treatment – 'natural experiments').
- with deliberate intervention (i.e. research treatment imposed, including farm system research, on-farm plot trials and other experimental approaches (glasshouse, lab, etc.).

Within both categories, research designs can be optimised to accelerate feedback loops between science and food systems change.

Natural experiments – no deliberate intervention

In natural experiments, living systems are neither controlled nor manipulated by the research team other than via site selection [34]. This approach is common when complexity is an inherent part of the system, or when manipulations are unethical or unaffordable; for example, in community ecology [34], public health [28], or social policy assessment [27].

A natural experiment approach can be used to study, for example, the impact of RA on freshwater ecosystems, biodiversity, social and farmer wellbeing, marketability of RA produce, economic impact of RA on farm businesses and enquiries about emerging novel adaptations services (i.e. emerging ecosystem services enabling adaptation to future climate).

Natural experiments also include pairwise comparative approaches, where farms that have been managed under RA for multiple years are compared with adjacent farms, to assess the impact of RA on soil C stocks, GHG emissions, soil health, resilience to drought and flood, soil N and P stocks.

Long-term monitoring of commercial farms, including whole-of-system case studies, are a type of natural experiment, best suited to investigating transition dynamics (e.g. the transition from current agriculture to RA).

Research with deliberate intervention

Research approaches that include a deliberate manipulation of the system by the research team are used to establish cause and effect (e.g. when a study seeks to assess the effect of a particular practice and seeks to decipher the mechanisms underpinning the response). One such approach is farm system research which seeks not only to understand the behaviour of whole farming systems, but also to test, optimise or develop farming practices drawing on close partnership between scientists and producers. Below are examples of study methods employed in farm system research:

Modelling	Systems experiments	Economic research & evaluation
Partner farms	On-farm experimentation	Survey & scientific data analysis
Case studies	Adoptability assessment	Demonstration
System design	Impact evaluation studies	Co-designed pairwise comparisons (within farm)
Social research	Targeted component research	Co-designed pairwise comparisons (between neighbour farms)

Farm system research is transdisciplinary by nature. It is the approach of choice for producers willing to trial RA and seeking to quantify outcomes in collaboration with scientists. Farm system research is also particularly suitable to test the impact of RA on productivity.

Experimental approaches including plot trials, glasshouse experiments and lab experiments could also be co-developed by farmers/RA practitioners and scientists, to answer both cause-effect and mechanistic questions e.g. about soil health, the effects of bio-stimulants, the relationship between forage diversity and animal welfare.

Different approaches to data acquisition to accelerate feedback loops between science and food systems change

The June 2020 analysis of "The Future of Food & The Primary sector: The Journey to sustainability"[12] emphasised that a transformation of the NZ food system (as opposed to incremental changes) is *needed* to "fulfil [the] rapidly evolving market and societal demands". Of the eight fundamental changes identified in this analysis, four involved transformation related to the relationship between consumers and food produce: (i) finding ways to move exports up the food-value chain, (ii) stimulating changes towards healthier, more sustainable diets, (iii) responding to consumer preferences and market demand and (iv) accommodating issues relating to food sovereignty and healthy food access.

Interest in RA is rising nationally and overseas, and uptake among farmers is increasing. This rise in interest is driven by multiple RA narratives. RA is proposed as a solution to urgent systemic problems linked to agriculture and food systems such as climate change, biodiversity loss, declining water quality, the health of freshwater ecosystems, the wellbeing crisis in rural and farming communities [51; 57; 79; 105; 122; 143; 153; 162; 173] – and this list is not exhaustive. Other RA narratives include its role in the decentralisation of food systems and in restoring local food sovereignties [1; 61; 98; 145] and its perceived potential to secure additional overseas premium and niche markets [44; 94] which is significant for NZ, given the contribution of food and fibre exports to its GDP. It is reasonable to hypothesise that if at least some of RA claims were proven true, and consumer awareness about RA continued to increase both nationally and overseas, the buying behaviour of consumers might change and trigger a feedback loop between consumers, the media, marketers, scientists and producers – each of which has the potential to accelerate practice change at all levels of the food system and promote the four essential transformations highlighted by the June 2020 report [12].

We posit that direct data-based feedback loops between consumers, producers and scientists, where the collection, sharing and interpretation of data is not *primarily* mediated by scientists, but is on the contrary collaboratively mediated by producers, scientists and market representatives, would be more effective at enabling this direct feedback loop, and all four transformations. Such approach could also contribute to increasing NZ national capacity for monitoring changes in the environment, which was recently identified as a major failing of environmental research in NZ [137].

At the core of RA is a commitment to system transformation, improved environmental outcomes and the production of high value food and fibre produce (e.g. nutrient-density). We posit that RA research can draw upon this commitment and be designed to include the development of scalable environmental monitoring capacities within the farming community. These capacities include, for example, remote or proximal sensing technologies, and/or phone applications designed to enable data capture by the farmers/growers themselves. The development of these farmer-enabled capacities could support both an increase in national environmental monitoring capacity at high spatial and temporal resolution, and a data-driven feedback loop between producers and consumers. This feedback loop would serve four purposes:

1. Testing RA claims and validating/modifying current RA narratives – if co-designed with brands/marketers, can immediately trigger a shift of exports up the food-value chain by meeting consumers' expectations for outcome verifications.

2. Assessment of RA outcomes on-farm – if co-designed with producers, can result in immediate, highly efficient incentive for practice validation or change, as well as data for traceability, certification or outcome verification schemes.

Should RA claims be proven true:

3. Showcasing of RA aspirations (including aspirations of RA producers as well as aspirations from the wider community of support for RA) – as direct exposure to data about food quality and environmental outcomes emerge, consumers are better informed and might be stimulated to adopt healthier, more sustainable diets.

4. Enabling consumer behaviour changes driven by both consumer-pull and producer-pull approaches.

Finally, should RA claims be proven true, systems, structures and incentives that will enable or support RA will need to be identified (but this is beyond the scope of this paper and supporting documentation).

5 Recommendations for RA research

5a Research topics

- Stakeholders' research needs
  - Representatives of four NZ major ag sectors are asking for research on how RA impacts (1) Freshwater outcomes; (2) Food quality and safety; (3) Farmer empowerment and mindset; (4) Long-term viability of whole systems; (5) Animal welfare; (6) On-farm all taxa (total) biodiversity and (7) Soil carbon. They also asked researchers to assess how RA might increase (8) resilience; (9) accountability in our food systems and (10) access to premium/niche markets.
  - In addition to the above, representatives from the RA community highlight the need for scientific studies on how RA affects (11) soil health; (12) profitability and production; and (13) whole-of-system environment, social and economic outcomes at farm-scale.
  - Professionals in the wider agri-food system further want (14) data to de-risk investment and transition to RA; (15) 'conventional-style' practice guides for RA, customised for different sectors and NZ contexts; (16) an understanding of the 'RA continuum' and (17) clarity around the need for a definition/certification for RA (or the lack thereof).
- RA research would ideally focus on established RA commercial farms successfully managed under RA principles for multiple years, as well as transition case-studies.

5b Research designs/methods

- Use pairwise comparative approaches with sufficient level of replication for investigating biophysical attributes. Pairwise comparisons can be made between RA and neighbouring farms or between RA managed paddocks and controlled neighbouring paddocks in transition case-studies. They must be well replicated, designed to include strict pairing criteria, and tailored to the topic of enquiry.
- Use long-term time-series (preferentially 5+ years) across networks of unpaired sites including both RA farms and farms that deploy conventional/best practice management. These time-series must build on adequate baselining and include sufficient numbers of farms to detect any management-driven change versus inherent site-to-site variability. Such designs are particularly suitable when (i) pairing is unfeasible and (ii) to investigate biophysical attributes that operate at scales larger than the farm (e.g. some aspects of freshwater and biodiversity outcomes including land – water and practice – biodiversity interactions).
- To investigate socio-economic attributes, including motivation for RA uptake, use surveys or similar large-scale methods with large representative samples of population or businesses, and smaller, carefully selected, representative samples of individuals or businesses when using other qualitative methods such as interviews.
- Use farm system research approaches and deploy the 'Observe-Learn-Test' scientific principle to investigate the impact of individual RA practices on farm performance, when those are being applied as part of a whole-of-system shift to regenerative farm management, and for deciphering interactions between multiple practices that are either implemented simultaneously or sequentially. Research projects that will focus on the impact of individual RA practices without accounting for other system change will provide limited insights about the overall impacts of RA management.

- Use farm system research approaches to assess the impact of RA on productivity and on the circular integration of resources within the farm to support its long-term viability.
- Life cycle analyses will be essential to assess farm nutrients, carbon and GHG footprints (not covered here).
- Economic assessments offer limited insight if they do not account for increase or decrease in natural capital. Natural capital valuation and/or true cost accounting are therefore strongly recommended for assessing the full economic impact of RA.
- Datasets should include benchmarked metrics of significance to a combination of producers (RA and others) and scientists, as well as consumers.
- Use modelling approaches – e.g. scenario analysis, multilayer network modelling and machine learning where relevant – to integrate results obtained from measurements taken at multiple scales and on multiple outcomes, and to describe/predict whole-of-system present and future state.
- Pathways to building evidence could ideally combine (i) fast, affordable, scalable observations at high spatial and temporal resolution (e.g. using sensing technology), (ii) on-the-ground-precise scientific observations, (iii) farmers' observations (e.g. app-based farmer-driven data capture) and (iv) modelling/machine learning outputs. The integration of all four pathways is particularly suited to investigating freshwater and biodiversity outcomes and has the potential to enable direct feedback among farmers/growers, scientists, and consumers and to contribute to a national effort in environmental monitoring.

5c Research that supports system change

- Adopt transdisciplinary research approaches where farmers, educators, scientists, representative of regulatory bodies as well as representative of the supply and value chains (e.g. brands, retailers lor other marketing companies with influence on consumers) are involved.
- Collaborate with RA practitioners who have demonstrated improvement in environmental and economic outcomes and are held in high regards by their community of practice (thereby indirectly demonstrating successful social outcomes).
- Collectively maximise synergy and complementarity of topics and methods, adopting some common metrics to allow comparability of results, including metrics benchmarked and relatable to producers (farmers and growers), especially to those already adopting RA. Different research projects will be needed for different key knowledge gaps and to provide complementary outputs. Promote processes that enable data acquisition, interpretation and dissemination that is jointly undertaken by farmers/growers, scientists and representatives of the market.
- Focus research efforts on areas or communities where the most gains might be had from RA (e.g. where environmental constraints, such as drought, are the most extreme, where surface erosion is the most severe, where local socio-political contexts already promote rapid change in land management).
- Promote research project leadership that is adaptive, agile, committed to outcomes, and motivated to operate for the common good of NZ, and operate from the Māori principle of Whakamana – Manaaki (i.e. to maintain and uplift the mana of all parties in the ecosystem). That might mean sharing both power and resources.

5d Concluding recommendations

There is an pressing need and demand to test the claims made by RA proponents using robust scientific methodology. Bearing in mind (1) the cost of research and the limited funds available, (2) the increased uptake of RA practices amongst the NZ farming community, regardless of whether these practices have or not been tested by NZ scientific institutions and (3) the call for an urgent transformation of the NZ food system, all whilst honoring and promoting food sovereignty and iwi-led tikanga approaches to land management, we recommend that RA research be designed to:

1. Prioritise mātauranga Māori-led research approaches where and when relevant.
2. Test and explain RA claims (or invalidate them to prevent unintended negative consequences).
3. Inform/support change to NZ agriculture and food system by:
    a. Informing/supporting farmers through transition to RA or adaptation of RA to NZ, starting with RA practices that have scientific validity (e.g. increased ground cover, increased biodiversity, reduced use of pesticides, and many others);
    b. Using research findings to inform RA narratives specific to NZ;
    c. Accelerating data-based feedback between scientists, consumers and farmers/growers;
    d. Building capacity and skills – especially with regards to national environmental monitoring and holistic approaches to scientific enquiries.

The success and impact of RA research on the NZ agri-food system can be accelerated by it being undertaken in an adaptive, transparent and agile manner in genuine partnership with iwi, successful RA practitioners, the wider farming communities, industry and decision-makers, scientists, and representatives of market/brands to promote rapid uptake of research findings by both consumers and producers.

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7 Appendix 1: Te Reo Māori glossary

Te Reo	English
Hua parakore	A produce / product of pure state, uncontaminated, having no impurities
Kai māra	Gardens, gardening, cultivation Kai māra – is the agent who gardens, cultivates
Manaakitanga	Practice or action of hospitality, generosity, care, support Manaaki is to host, care for, support
Kaitiaki	Kaitiaki is the agent or custodian who holds specific knowledge and skills for the care and benefit of a resource
Kaitiakitanga	Guardianship through whakapapa and rangatiratanga, environmental responsibility
Kaupapa Māori	Māori led research using Māori values, principles, and methods
Kawa	Cultural protocol or custom at local level, ceremony
Mana	Prestige, authority, control, energy
Mātauranga	Māori knowledge, system of knowledge
Rangatira	Chiefly status, revered, leader
Tangata	People, human beings
Tangata whenua	People of a place, location, belonging to the land
Te ao Māori	The Māori world, world view, Māori beliefs
Te ao mārama	Enlightenment, understanding
Te waka kai ora	A national Māori collective of organic practitioners and experts
Tikanga	Correct procedure, cultural practice, custom, values
Tohunga	Specialist, expert
Whakapapa	Genealogy, ancestral lineage, layers
Whakamana	The action of giving prestige, respect, and authority
Whenua	Land, placenta, landscape