Regenerative Agriculture:

How might New Zealand benefit?

Kellogg Rural Leadership Programme

Course 49 2023

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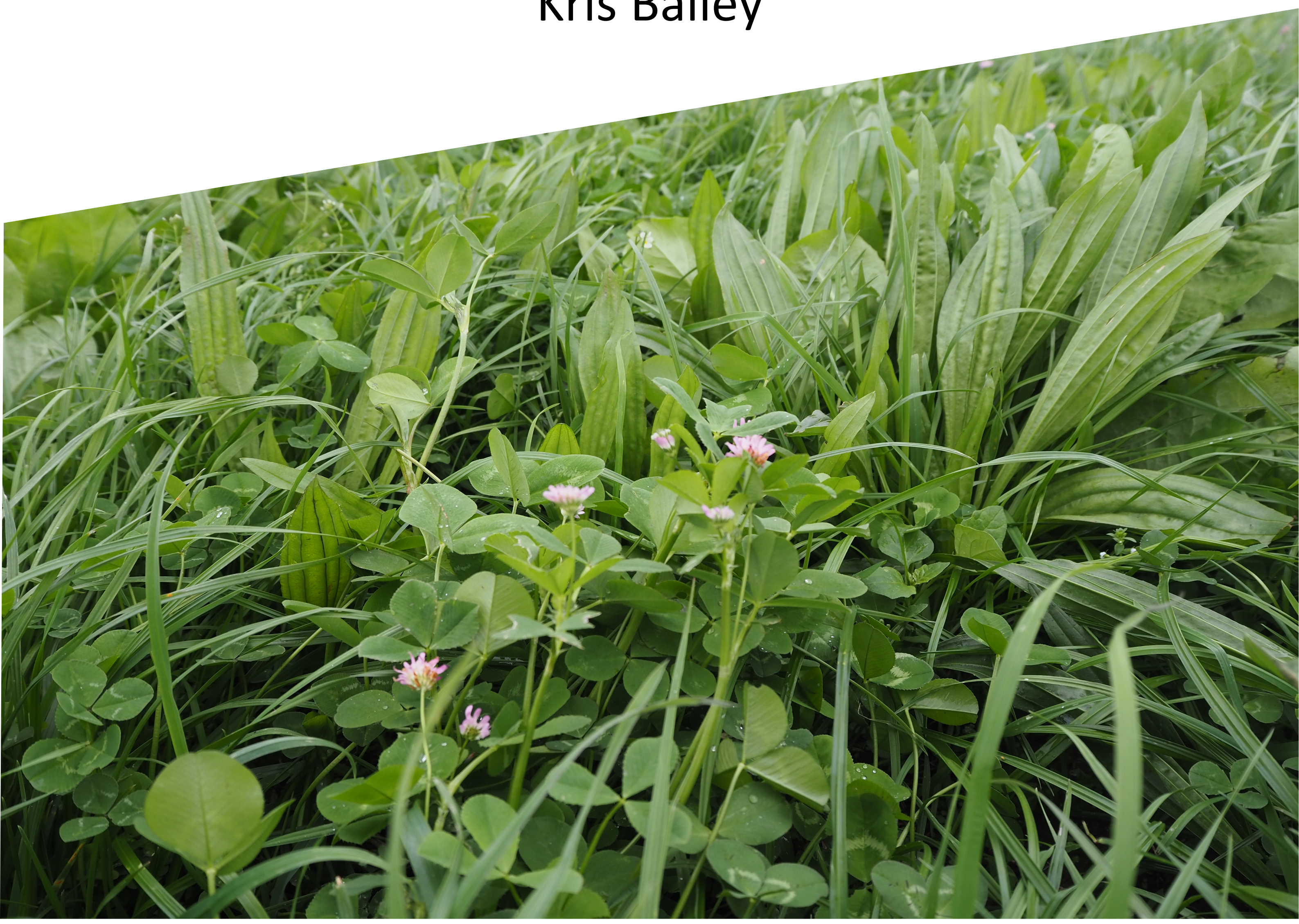

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Executive Summary

New Zealand agriculture is grappling with change as it seeks to find a new balance between feeding the world's growing population while maintaining profitability and reducing negative environmental impacts. There is a lot of doubt whether regenerative agriculture (RA) can provide a better way to address this global challenge and there is concern that it may increase emissions intensity, lower farm profitability, and struggle to feed the growing population.

RA is regarded by some as the solution to the global food crisis. Positive environmental outcomes can, in some cases, be achieved with the use of RA. High rates of carbon sequestration have been proven, albeit in depleted USA soils rather than in NZ.

RA is not well defined and there is a lack of scientific evidence backing some of its claims. Results from the system have proven to be unpredictable and highly variable. Some successful farm practices such as minimum tillage, avoiding bare ground, and using mixed pasture species are attributed to RA when in fact they were used well before the RA concept emerged. These are already considered best management practices in a NZ conventional system.

There is evidence that greenhouse gas emissions and N leaching can be reduced on a per-hectare basis using RA. However, this appears to be achieved mainly through reducing inputs, resulting in lower production and farm profitability. When analysed per unit of production, these environmental gains were much less apparent.

The benefits of altering soil microbiology are frequently discussed among RA communities. The claimed benefits have not been thoroughly tested and will require more research.

Some farmers using RA concepts say they are achieving similar levels of production with fewer inputs. RA systems must be tested over many years to see if any initial benefits can be maintained. For example, if high levels of soil fertility existed before changing to RA, these can be 'mined' for several years before production levels then crash.

This report suggests that, while there are positive aspects of RA, it is unlikely to match the productivity and profitability that can be achieved with conventional agriculture. If this is the case, RA may be able to reduce environmental impacts, but it will fail to help grow the food supply to meet the needs of the world population increase or to maintain NZ export income.

If, as appears likely, that agricultural outputs such as meat and milk produced using RA methods have higher emissions intensity, there is a real risk for the farmers involved. Offshore customers for NZ agricultural products look very favourably at NZ's low emissions intensity and demonstrate little interest in NZ's internal debate about sector-by-sector total emissions. Higher emission intensity products may be discounted in value. Further, NZ farmers will soon have to start paying more for their emissions. Improved efficiency and lower emissions intensity will be the key to viably adapting to this change.

NZ farmers and growers should note how RA has been used in marketing to obtain a "green premium". The industry can learn from RA about leveraging these advantages.

Recommendations

1. Treat investment into regenerative agriculture with caution due to the lack of scientific evidence, and variation in its outcomes and likely reduction in farm profitability. This applies to farmers, growers, and processors.
2. Research the untested claims of regenerative agriculture. Particularly soil microbiology and the effect it has on plant growth. Such research is difficult to carry out at farmer level and will likely require input from CRIs.

3. Introduce practices such as minimum tillage, avoiding bare ground, and mixing low numbers of pasture species, to those farms that are not doing so already.
4. Develop marketing strategies for NZ food and fibre which leverage the consumer positivity associated with 'greener' farm practices. This will likely require input from both processors and industry-good organisations.

Acknowledgements

Thanks to the New Zealand Rural Leadership Trust and the support of the team responsible for the Kellogg programme: Chris Parsons, Scott Champion, Patrick Aldwell, Lisa Rogers, and Annie Chant. Thank you for your commitment, dedication and help in growing future leaders.

Thanks to the three case study farmers, and several industry experts who gave their time to contribute to this project. Thank you all for being so forthcoming with information, and for being a pleasure to deal with.

Thank you to my employer Ravensdown for the commitment towards my career development.

Finally, thank you to the rest of cohort 49. You have all made my experience memorable through your contributions and discussions throughout the course.

1.0 Introduction

For decades the priority of NZ farmers has been on producing as much food and fibre as possible, bringing in export revenue and driving the economy. Now the priorities are changing. The sector is committed to playing its part in keeping climate change within the parameters of the Paris Agreement, with the goal of being carbon neutral by 2050. Achieving this goal while feeding a growing global population presents an enormous challenge.

This reality has triggered the uptake of regenerative agriculture (RA), a production system of US origin which promises to feed the world while being the solution to climate change, biodiversity loss, declining water quality, and the farmer wellbeing crisis.

New Zealand is in the early-evaluation phase of RA, and the topic is polarising among farmers, scientists, and the community. This is mostly due to a trade-off between science and values. NZ agriculture was built on a solid foundation of science, and many believe that a science-based approach is the only way forward. Whereas RA is a philosophy, a movement, and a value system, with much of it lying outside the realm of science, in the sense that values cannot be answered by scientific experiments, i.e., it is impossible to create an experiment to determine if yield maximisation or ecological resilience or social wellbeing, are the ‘correct’ approach to agriculture.

RA is generally not well understood by consumers, however, those who learn about it are often in favour of the idea, and willing to pay a premium for product which is produced sustainably (B&L NZ & NZ Winegrowers, 2021).

In the middle sits the processors, who are driving toward sustainability and are looking at systems such as RA to lower their carbon footprint. Companies such as Nestle, McCain, and Tesco have recently announced goals of lowering their carbon footprint through the use of RA on their supplier farms.

Both consumer and processor demand for sustainable produce is growing, creating an opportunity for NZ Agriculture.

2.0 Aims and Objectives

The aim of this project is to:

1. Define regenerative agriculture in a New Zealand context.
2. Evaluate the success of regenerative agriculture systems in NZ compared to conventional systems.
3. Develop recommendations for the industry on how aspects of regenerative agriculture can be utilised to reduce the environmental footprint of farming while maintaining profitability.

2.1 Research question

With those objectives in mind, the research question for this report is:

How might New Zealand benefit from regenerative agriculture?

3.0 Methodology

This report looks at existing literature and three case studies to determine how New Zealand might benefit from regenerative agriculture. The project begins with a literature review to provide clarity on:

- The definition and origin of RA, and how the concept has evolved.
- The underlying principles of RA, and why it was developed.
- The claimed benefits of an RA system, and how they compare to existing farming systems.
- Any potential unintended consequences of an RA system.

The RA system was developed in the United States; therefore, a portion of this literature review includes offshore research. This research was then analysed alongside NZ-based data.

Semi-structured interviews were conducted with three case study farmers across the dairy and sheep & beef industries who, while differing in the degree of their 'buy-in' to the RA system, have adopted RA principles. This provides some quantitative data on RA systems in NZ. The perceived advantages, disadvantages, and challenges of the RA system are reported on.

Thematic analysis was used to form key themes and ideas from the interview transcripts, following methods described by Braun & Clarke (2006). Discussion and analysis were then carried out by comparing and contrasting results from each of the case studies and reviewing the themes alongside the appropriate literature. Conclusions and recommendations were drawn from this analysis.

The Delphi method was used to increase the qualitative strength of the report recommendations. Four industry experts were selected to participate. They were carefully selected based on their deep understanding of New Zealand farming systems and familiarity with regenerative agriculture. Panellists were each sent a copy of the initial report recommendations and asked to rank them in terms of importance and provide any additional feedback.

3.1 Case study farms

Case study interviews were conducted for three New Zealand farms. Align Farms Clareview property is frequently referred to throughout the report. This is a 265 ha dairy farm located on the banks of the Ashburton River. At the beginning of the 2021/22 season Clareview farm was split in half, with one side of the farm running a regenerative system, and the other half conventional. Key RA practices used include; planting diverse pastures; grazing at higher pasture cover; reducing synthetic inputs; minimum till; and stimulating soil microbiology. They are taking a science-based approach, ensuring they are accurately comparing the two systems by collecting data on; pasture growth; pasture quality; milk production; farm profitability; GHG emissions; N loss; animal health; soil microbiology; well-being and more.

The remaining two farms are a lot less scientific in their approach to RA. Both have experimented with RA practices including diverse pastures, RA grazing, reduced synthetic inputs, minimum till, and alternative fertilisers. Their approach to RA being less scientific, the results are qualitative rather than quantitative.

Two dairy farms and one sheep/beef farm were studied. They are labelled throughout the report as Align Farms, Dairy Farm 2, and S&B Farm 1.

3.2 Limitations

The biggest limitation of this report is the small size of the case study population. Three farmers were interviewed, covering both the dairy and S&B industries. While the analysis on these farms is fairly in-depth, drawing industry-wide conclusions from this small sample is difficult.

Also, many years of data need to be collected before meaningful conclusions can be drawn. For example, RA farms may reduce fertiliser input, but it may take some years of depleting pre-existing nutrient levels before a notable change in grass yields becomes apparent. S&B Farm 1 were able to provide results from a decade of RA practices, while the other two case studies only provided data from two seasons.

4.0 Literature Review

4.1 Defining regenerative agriculture

RA originates in the USA, with the first written reference in 1983 by Robert D. Rodale. The concept was developed as a means of restoring organic matter to soils which had been repeatedly cultivated and cropped. The consequences of repeated large-scale mono-cropping can be dire, with the USA dustbowl of the 1930s a reminder of just how important soil structure is to our agricultural systems.

A common theme throughout the literature, as noted by Grelet et al. (2021); Merfield, (2019); and Rowarth et al. (2020) is the lack of clarity about what RA actually is. There is a set of principles which guide the thinking around RA. These differ slightly throughout the literature, with the most common being:

1. Build and sequester soil carbon
2. Minimise soil disturbance
3. Maintain ground cover
4. Minimise agrochemical and synthetic fertiliser use
5. Foster plant diversity
6. Integrate livestock

Based on Giller et al. (2021); Merfield (2019); and McGuire (2018).

There is no clear-cut distinction between conventional and regenerative farming systems, but rather a continuum of practices with significant overlap between the two (Grelet, et al., 2021).

One of the earliest known definitions of RA comes from Rodale (1983), founder of the Rodale Institute. A USA-based non-profit dedicated to growing the regenerative organic agriculture movement. In 1983 he defined RA as:

"One that, at increasing levels of productivity, increases our land and soil biological production base. It has a high level of built-in economic and biological stability. It has minimal to no impact on the environment beyond the farm or field boundaries. It produces foodstuffs free from biocides. It provides for the productive contribution of increasingly large numbers of people during a transition to minimal reliance on non-renewable resources".

A key statement in this definition is the words *"at increasing levels of productivity"*. There are many other more modern descriptions of RA available which fail to address the topic of productivity altogether. Most modern definitions are focused on the perceived outcomes of RA; increased biodiversity, enriched soils, climate change reversal, restoring soil organic matter and carbon sequestration (Rowarth, et al., 2020). Listing these outcomes provides clarity on why RA may be worth pursuing, however, it does not help in defining the topic itself.

Definitions of RA gain an extra layer of complexity when they start describing the farmer mindset. Proponents often view RA as much about a change in mindset as changing practices, considering it as a philosophy, a holistic approach and a movement (Merfield, 2019).

Grelet et al. (2021) describe it as *"a mindset that questions the status quo, and instead of becoming defeatist sees opportunities for different ways of living, working and farming"*. They also mention the *"holistic pursuit of continuous improvement, not only on environmental but also on social, economic, and cultural outcomes"*.

RA has similarities with the definition of organic agriculture: *"a production management system which promotes and enhances agroecosystem health, including biodiversity, biological cycles, and soil biological activity"* (FAO & WHO, 1999).

The difference is organic systems take an input restriction approach at farm level, which is defined by a clear set of standards. In contrast, RA has no equivalent to the organic rule book. It takes a more philosophical approach, with a set of variable outcomes that it wishes to achieve. It then has a fluid list of on-farm practices that are used to try and achieve said outcomes. RA is therefore considered an 'outcome-focused' approach, in direct contrast to the 'input-focused' approach of organic agriculture (Merfield, 2019).

4.2 Popularity gain

There is no doubt that RA is gaining popularity on several fronts. Consumers are becoming increasingly aware of how their food is produced, with many willing to pay more for environmentally sustainable foods (B&L NZ & NZ Winegrowers, 2021). It is becoming more mainstream among farmers, and references in the media have seen a 20-fold increase between the years 2017 to 2022 (Giller et al. 2021).

RA has attracted attention because both farmers and many consumers are looking for new ways to address the challenge of sustainably producing food while feeding a lot more people. The global population is expanding, expected to reach 9.7 billion people by 2050 (Ruiz et al. 2020). A food system must be developed which can feed the population with minimal impact on the environment and climate. RA is being promoted as a way to produce food sustainably, without compromising production or profitability, while building soil carbon with minimal environmental impact.

4.3 Regenerative agriculture practices

In line with the fluid nature of RA and lack of agreed definition, there are also no universally agreed set of practices. Several authors from both USA and NZ provide lists of practices associated with different variants of RA, the most recurring practices are summarised in Table 1:

Table 1: Common practices associated with RA. Adapted from: (Grelet et al. 2021), (Merfield, 2019), (McGuire, 2018), (Giller et al. 2021).

Practice	Description
Reduced tillage	Direct drilling of crops and pastures into existing stubble or drilling with minimal cultivation.
Multi-species pastures and crops	Planting long-term pastures and short-term crops using a blend of at least 8 plant species and sometimes >40.
Reduced agrochemical use	Reducing chemical use where possible. Includes: seed treatment, herbicides, fungicides, insecticides, drenches and dips. Biological alternatives are used where possible.
Reduced synthetic fertiliser use	Multiple different strategies, including mineral balancing, shifting to foliar application, increasing nutrient cycling and nitrogen fixation, and changing fertiliser sources.
Integrating livestock	Often through rotational grazing, regenerative grazing and deferred grazing.
Cover cropping (avoiding bare soil)	Short-term crops are sown when the soil would otherwise be left bare.
Integrated pest management	Managing crops in a way that promotes beneficial insects, especially those that predate crop pests.
Inoculants, bio-stimulants and carbon-rich amendments	Inputs designed to enhance the function of soil, plant and animal microbiomes. Often includes fish hydrolysate, seaweed derivatives, diluted seawater, compost, aqueous compost extracts, biochar, and isolated fungi/bacterial strains.

Many RA antagonists in NZ will argue that these practices are tailored to USA arable farms and that farmers are already employing many of them under conventional agriculture in NZ. The literature would agree with this view:

- Grelet et al. (2021) give a detailed comparison of RA versus conventional practices in NZ showing that more than half of the common conventional farming practices were compatible with RA principles. Key incompatible practices included: set stocking; grazing to short residuals; high rates of synthetic fertiliser and chemical use; monoculture cropping; full tillage; and fallow periods.
- Moot (2021) comments that NZ farmers are using many RA practices already, including crop rotations, cover crops, rotational grazing, minimum tillage, compaction minimisation, soil organic matter for nutrient cycling, and minimising soil erosion.
- Giller et al. (2021) drew a similar conclusion, suggesting that crop rotations, cover crops, and livestock integration, are generally considered to be ‘good agricultural practice’ and remain integral to conventional farming.

4.4 Claimed benefits of regenerative agriculture

In broad terms RA is said to be a possible 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 (Grelet, et al., 2021).

The claimed benefits range from the highly specific, for example, the increased nutritional quality of forage, through to the high level, for example, improving the vitality of farming communities. Table 2 summarises the most commonly stated benefits of RA from the literature.

Table 2: Claimed benefits of RA. Sourced from: (Grelet, et al., 2021), (Merfield, 2019), (Rowarth, et al., 2020).

Improved soil health including: - Higher soil carbon level - Better soil structure - Improved soil biodiversity	Reversal of climate change including: - Decreased atmospheric CO_2 concentration - Greater ability to sequester carbon
Reduced nutrient leaching	Increase resilience to variable climate (including extremes)
Restoration of landscapes	More even pasture/crop growth rates year-round
Improved ecosystem multifunctionality	Increased pasture/crop yields
Improved water cycle	Increased nutritional quality of forage
Improved well-being of farmers	Increased natural control of crop pests
Improved health and vitality for farming communities	Shelter provided to livestock from wind and sun exposure

4.5 Regenerative agriculture vs the science

There is a considerable lack of scientific evidence backing the claims of RA. The industry is now facing an unusual situation where decades of research and development may be ignored in the pursuit of RA. This poses significant risk to our industry and our country.

To date, there are no published findings on RA systems in New Zealand. Consequently, it is not possible to make a direct comparison of results between RA and conventional methods. This section looks at some of the claimed benefits of RA and analyses them in a scientific context based on existing research.

4.5.1 Carbon sequestration

One of the main claimed benefits of RA is the ability to decrease atmospheric CO_2 concentration by sequestering C in both above-ground biomass and in the soil, especially at depth. Significant C accruals under adaptive multi-paddock grazing management are possible:

- Stanley et al. (2018) report average accruals of 3.59 Mg C ha−1 yr−1.
- White Oak Pastures (2019) report an average of 2.29 Mg C ha−1 yr−1.

When extrapolated by Grelet et al. (2021), these figures suggest that C sequestration at these levels has the potential to offset 20–35% of global human greenhouse gas emissions. When studied on a global scale, based on the best understanding of how much more C soils globally can sequester, the bold claims made by RA proponents are not supported by evidence.

Notably, most of the data sets (including the two above) come from somewhat degraded soils in the USA. Moot (2021) argues that the gains seen overseas will not translate to NZ because our soils are younger and are already comparatively carbon-saturated (Figure 1).

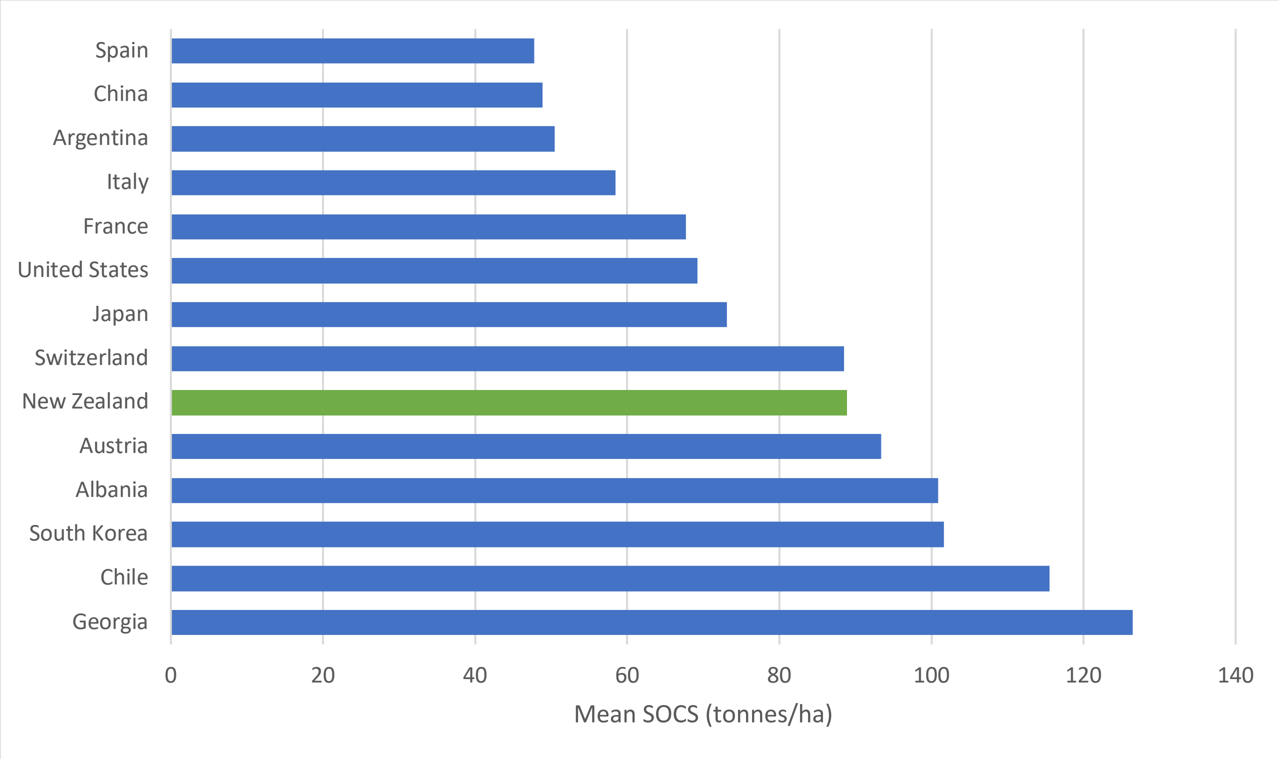

Figure 1: Mean SOC stocks (0–30 cm depth), by country. Value for NZ is highlighted in green. (Grelet, et al., 2021).

The amount of C that soil is capable of storing is highly variable. A continuously cultivated, degraded clay soil, heavily depleted of soil C, is capable of storing much more C than degraded sandy soil. A fertile soil may already be close to what is called its C 'saturation potential', meaning soil C can only be increased marginally using regenerative practices (Giller, et al., 2021).

White Oak Pastures (2019) note in their research that the rate of carbon sequestration may slow as the soil becomes carbon saturated. They began from a point of very low organic carbon content in the soil, with high C saturation potential. They expect that the rate of C sequestration may slow considerably in the coming decade or two.

RA proponents claim that the carbon sequestered under regenerative grazing practice offsets the intestinal methane produced by the ruminant animals grazing the pasture. Garnett et al. (2017) have rejected this claim, concluding that at an aggregate level, the emissions generated by animals grazing pasture still outweigh the C sequestered.

Requirement for other nutrients

Nutrients other than carbon are needed to build soil organic matter and sequester carbon. One tonne of C in organic matter is associated with approximately 80-100 kg N, 20 kg P, 14 kg S and lesser quantities of other nutrients (Kirkby, et al., 2011). If C is added to soil in which there is no surplus N, P or S, there will be no increase in soil organic matter and the carbon will be lost to the atmosphere as CO_2 (Giller, et al., 2021).

The reduction of fertiliser input in the RA system is problematic, considering the requirement for other nutrients to successfully sequester C. Large increases in soil C are frequently claimed, without acknowledgement of the source of the extra nutrients required (Rowarth, et al., 2020).

Although considerable amounts of C sequestration have been proven with the use of RA, it is important to look at these figures in the context of C sequestration potential, and allowances need to be made for the non-carbon nutrients required to build soil organic matter.

4.5.2 Diverse pastures

One of the practices associated with RA is the planting of diverse pastures and crops, often with 40 or more species sown. The benefits of this are claimed to be: increased resilience to variable climate; increased nutritional quality of forage; more even growth rates year-round; improved soil health; and reduced nutrient leaching (Grelet, et al., 2021).

However, existing research suggests that the more species that are combined into a pasture sward, the more difficult it becomes to graze at the optimal time; that is, striking the perfect balance between pasture quality and dry matter production. For example, ryegrass plants reach optimal yield and quality at the 2.5-3 leaf stage. After this, the older leaves undergo senescence, and the sward loses quality (Fulkerson & Donaghy, 2001). When multiple species are mixed, optimal grazing management will inevitably be compromised for some species.

Research by Black et al. (2017) examined different combinations of pasture species at Lincoln University under irrigated sheep management. Their model showed that the optimal seed mixture contained just three species: 25% ryegrass, 28% plantain and 47% red clover (a total of 22.0 kg seed per hectare).

RA principles suggest that allowing the pasture to grow longer pre-grazing and leaving higher residuals than New Zealand research currently recommends results in more leaf litter being incorporated into the soil, thus increasing soil organic matter content. This less frequent defoliation means that erect species such as grasses can grow taller and consequently shade out more prostrate species such as clovers. This interspecies competition can result in weed ingress which decreases pasture quality (Rowarth, et al., 2020).

4.6 Possible unintended consequences

4.6.1 Food security

The global population has increased very rapidly since 1960. To increase feed supply for these people, land was deforested in the 1930s to 1950s and converted to productive arable land. After 1960, the rates of conversion slowed, and focus was put on intensifying existing arable land. Labelled ‘The Green Revolution’, Figure 2 shows how irrigation and synthetic nitrogen fertiliser were used to produce more grain from the same area of land.

A plateau has been reached over the last couple of years as farmers are beginning to reduce N fertiliser (Figure 2). According to Moot (2021), to feed the growing population one of two things must happen:

1. Production is increased from the existing area of agricultural land.
2. Agricultural land area is increased (more deforestation).

It is also important to consider that as more land is deforested for food production, less productive land will inherently be brought under cultivation, requiring disproportionate land use conversion over time (Giller, et al., 2021).

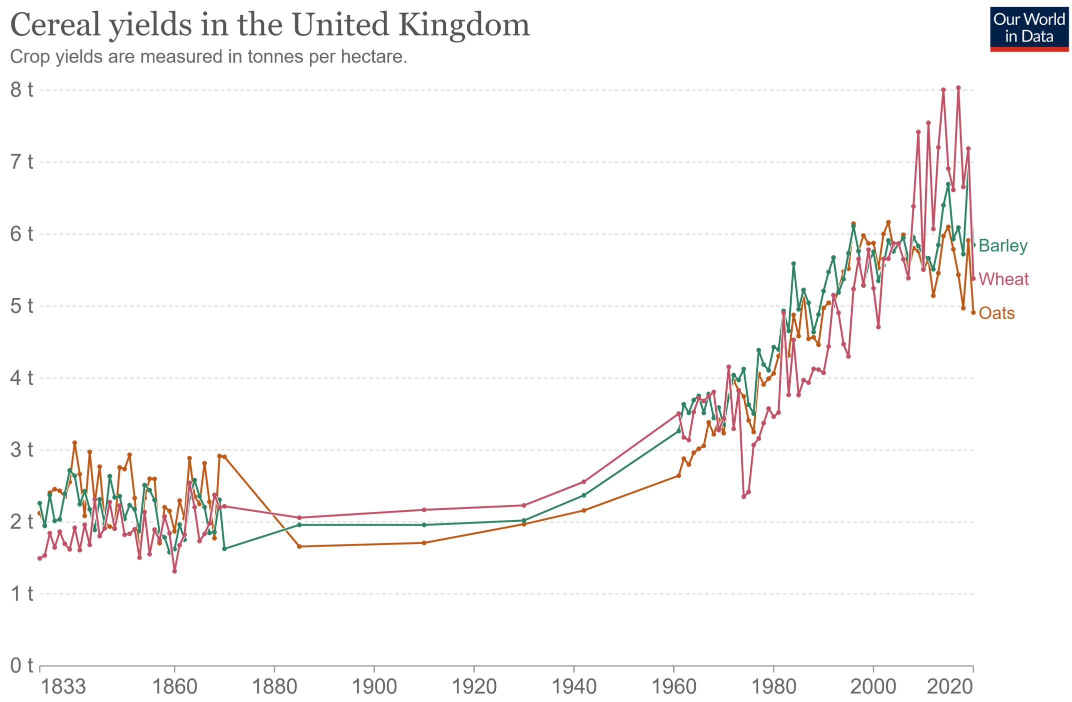

Figure 2: Historic cereal yields in the United Kingdom (Ritchie, et al., 2022).

Critics argue that RA is not capable of maintaining, let alone increasing, the same level of production as a conventional farming system. For example, White Oak Pastures in the USA claim to be one of few farms which are now carbon positive (i.e., sequestering more carbon than they are emitting). This is a result of their move to an RA system. However, when analysed by Carter & Mehta (2023) they found that the regenerative multi-species pasture rotation used on the farm requires 2.5 times more land to produce the same amount of meat as conventional production.

Food security does not feature in regenerative agricultural literature but with the planet expecting to have 9.7 billion people by 2050, this cannot be ignored. If global agriculture settles for decreased yields associated with RA, then it is likely that either; more land will be deforested; or there will be an increase in undernourished people.

4.6.2 Methane emissions

Moot (2021) argues that one of the most effective ways to reduce greenhouse gas emissions (particularly methane) is to grow animals at their full genetic potential. If animals are fed well, they will grow faster and therefore spend less time on the farm before being sent for slaughter. A shorter lifespan means that less energy is wasted on maintaining regular body functions in the animal, and more can be put towards growth and development. A shorter lifespan also reduces the time in which the risk of nutrient leaching is highest. Although, more animals could be carried as a result of a shorter life span in which case N leaching may be unchanged.

By adopting regenerative grazing management, farmers can expect to see decreases in pasture quality and pasture yield, thereby not growing animals at their genetic potential. The consequence is increases in both GHG output and N losses per unit of production (Rowarth, et al., 2020).

4.6.3 Increased agrichemical use

Minimum till is customary among RA practitioners, as well as many conventional farmers. The practice involves drilling new pastures or crops into the stubble from the previous crop, without disturbing the soil by way of cultivation. Reducing disturbance to the soil minimises soil organic matter loss in between crops.

One of the disadvantages of a minimum till system highlighted by Stewart (2023), is the absence of any physical weed control. If weeds are not controlled by cultivation, they are often sprayed with a non-selective herbicide instead. The most common herbicide for this task is glyphosate, and a no-till system can increase overall glyphosate use by up to four times.

This was also noted in a case study by the Ministry for Primary Industries (2022) about a farm which used to cultivate the soil for weed control but now spray with glyphosate (mixed with fish and fulvic acid to reduce the rate) and direct drill.

5.0 Analysis

Primary data was obtained during semi-structured interviews with the three case study farmers. Thematic analysis was carried out following the processes described in Braun & Clarke, (2006).

All interviews were recorded, and software was used to create full interview transcripts. The transcripts were checked against the original data, then systematically reviewed and coded, enabling repeating patterns to be identified. A mind map was then developed to outline the representation of interview insights into high-level themes (Figure 3).

Figure 3: Mind map showing the distillation of interview responses into themes using thematic analysis processes outlined in Braun & Clarke, (2006).

From here, themes were defined and further refined into those listed in Table 3. Many of the themes listed in Table 3 are intertwined. For example, fertiliser use is listed as a theme on its own, but it impacts heavily on environmental benefits, diverse pastures, soil, and production and financial.

Data were then compared, contrasted, reviewed against appropriate literature, and critically analysed within each theme, with findings discussed in section 6.0.

Table 3: Final themes developed using processes outlined in Braun & Clarke, (2006).

Diverse pastures	Wellbeing
Fertiliser use	Production and financial
Soil	Environmental benefits
Animal health	Challenges
Social and community	Opportunities

6.0 Findings and Discussion

6.1 Diverse pastures

All case study farms were experimenting with diverse pastures, with varying degree of buy-in. Align Farms planted half of their property in diverse pastures, while the other two farmers planted just 3-4 paddocks. Diverse pasture mixes contained between 15 and 25 different species and were used as either perennial pasture (> 5 years), or as an annual cover crop to provide summer or winter feed.

6.1.1 Pasture yield

In the 2021/22 season pasture growth on the Align Farms regenerative side slightly exceeded growth on the conventional side (17.0 t DM/ha vs 16.6 t DM/ha). Interim data from the current season is showing the regenerative pastures producing more than 2 t DM/ha higher than conventional.

The conventional paddocks received 161kg N/ha, and the RA paddocks an average of just 5.5kg N/ha.

Conversely, the other two case study participants measured diverse pasture yields to be significantly less than conventional. The worst of these was a diverse paddock at S&B Farm 1, where back calculation shows that only 2.2 t DM/ha was harvested over 12 months. Neighbouring paddocks on the farm were comfortably producing 12-15 t DM/ha/year under a conventional system.

There are many factors at play which have influenced the success or failure of RA pastures in this case. The first is baseline soil fertility and fertiliser input. Align Farms is a high-performing dairy farm with Olsen P levels ranging from 15-30. As mentioned in section 6.2.1, they still apply maintenance fertiliser to their RA pastures every year to maintain these levels. S&B farm 1 however, had been running a low-input system for over a decade, and Olsen P level for the RA pastures was measured at just 8. Data from the Winchmore long-term field experiments suggest that the lower Olsen P level could account for losses in pasture production of up to 6 t DM/ha/year (McDowell & Condron, 2012).

The second factor contributing to the discrepancy is grazing management. S&B Farm 1 adopted the rule of thirds discussed in section 6.1.3, the result being only 33% of pasture grown was eaten by the animal. The measurement provided by S&B Farm 1 was pasture 'harvested', not total grown. Total pasture grown was more likely in the range of 6-7 t DM/ha. Align farms were grazing to lower residual and harvesting more dry matter (discussed in section 6.1.3).

The third factor is species selection in diverse pastures. Align Farms take a very targeted approach, only selecting a limited number of roughly 15 species, and ensuring that they are suitable companions in terms of growth habit and perennially. S&B Farm 1 planted mixes of 25 species, containing some annual species (e.g., kale), and some perennial species (e.g., ryegrass). This led to sub-optimal grazing, with a high weed burden as mentioned by Rowarth et al. (2020) in section 4.5.2.

Fourth, and finally is the method of pasture measurement. Instruments such as the plate meter and tow-behind reader are often calibrated to leafy ryegrass & white clover pastures. The addition of more ligneous vegetation (e.g. chicory seedhead) could lead to overestimation.

Despite the higher-yielding pasture at Align Farms, the RA side produced 22% less total milk solids production in 2021/22 when compared to conventional. This season the RA side is tracking 16% behind conventional. This suggests two things:

1. Less feed is being utilised on the RA side (i.e., more trampled back to the soil).
2. Reduce pasture quality on the RA side.

All three case study participants commented that diverse pastures were notably less consistent and predictable compared to conventional pastures. The unpredictability is likely a result of running a lower input system. For example, if a conventional paddock has low soil fertility, higher production can be achieved with capital fertiliser input. In an RA system such fertiliser use is discouraged, and production is thereby limited. The same principle can be applied to agrichemical use in weed or pest-infected pastures. Low-input farmers have less weed and pest control and therefore results are less predictable.

The conclusion is that diverse pastures can achieve high yields. However, pasture utilisation, feed quality, and repeatability need to be considered. The drop in milk solids production at Align Farms RA block is of concern in this regard.

6.1.2 Pasture quality

Data from Align Farms shows that on average regenerative pastures are of lower metabolisable energy (ME) value than conventional pastures. Summer months show the biggest loss in quality on the RA side, with some measurements 0.8 MJME/kg DM lower (Table 4).

Table 4: Pasture quality ME measurements taken from Align Farms regenerative vs conventional pastures.

Sample date	Conventional (MJME/kg DM)	Regenerative (MJME/kg DM)	Difference %
September 2021	13.1	12.4	5.3%
October 2021	12.3	12.1	1.6%
November 2021	11.9	11.6	2.5%
January 2022	11.8	11.0	6.8%
May 2022	12.0	12.3	-2.5%
November 2022	12.1	12.0	0.8%
December 2022	11.4	10.6	7.0%
January 2023	11.3	10.9	3.5%
Average	12.0	11.6	3.3%

In the other two case studies, farmers commented that long grazing rounds used on RA pastures during spring led to decreased pasture quality and an infestation of weeds. RA pastures were pushed out to a 35-day grazing round when conventional would have been closer to 20 days. As discussed in section 4.5.2, this less frequent defoliation means that some species will undergo greater senescence, leading to a build-up of dead matter, and consequently lower pasture quality. Erect species will also shade out more prostrate species such as clovers resulting in weed ingress.

Pasture quality is a function of grazing management. As explained in section 4.5.2, the report by Fulkerson & Donaghy (2001) would predict a drop in pasture quality when combining many species with differing maturity dates in a pasture sward.

6.1.3 Grazing management

After seeking advice on grazing management of diverse pastures, all three of the case study farms were encouraged to implement a holistic grazing plan. Holistic grazing involves large herd sizes with maximum density in minimum time, emphasis on plant recovery periods, and lengthy post-grazing residuals (Savoury Institute, 2015).

One of the grazing methods recommended to all three farmers was the rule of thirds, where 1/3 of the sward is eaten, 1/3 trampled into the soil, and 1/3 left behind. After trying this method, none of the farmers agreed with the idea due to the following reasons:

- Only 1/3 of the sward is utilised, therefore farmers were unable to harvest enough dry matter to maintain a suitable level of production.
- It's an intensive system that requires a lot of human management, and expertise.
- Quality of pasture was reduced, particularly during summer months.
- Sub-optimal grazing due to the differing maturity time of species.

Each of the farms has subsequently developed their own grazing system for diverse pastures. Align Farms for example have set a new target of 3500 kg DM/ha pre-graze cover down to 2000 kg DM/ha post-graze cover. This hybrid system runs higher pasture cover than a conventional model might, however, it harvests too much dry matter to be considered truly regenerative.

The high pasture covers used in a regenerative grazing system are one of the possible reasons why RA pastures can achieve high yields with lower fertiliser input. The amount of photosynthesis which a plant can undergo is strongly influenced by the amount of green leaf which the plant has available (labelled leaf area index, or LAI). In a ryegrass pasture, for example, the growth rate is slow in the first few days following defoliation, when LAI is low. Once the plant has produced new leaves, LAI is increased and so is the overall growth rate of the plant. Looking at Align Farms for an example, post-graze residual on the conventional side is around 1500 kg DM/ha, compared to 2000 kg DM/ha on the RA side. The extra biomass left behind after grazing will inherently lift LAI and pasture growth rates. However, it will have a negative consequence on pasture quality as reflected in the section 6.1.2 data.

6.2 Fertiliser use

There are many different strategies for fertiliser use within a RA system. Most of which share the common objective of lower fertiliser inputs. Strategies implemented by the case study farmers for this report include; reduction in maintenance fertiliser; reduced synthetic N fertiliser use; and increased use of alternative fertilisers.

6.2.1 Maintenance fertiliser

In a conventional farming system, regular soil testing is undertaken to measure fertility, particularly levels of available phosphorus (measured using the Olsen P test). Farmers and fertiliser company reps will use this information to calculate the level of fertiliser required to maintain fertility or increase it if required. If maintenance fertiliser is not applied, then soil fertility will be mined.

S&B Farm 1 has taken a regenerative approach to fertiliser for over a decade now. They have based their fertiliser decisions around the idea that having soil microbiology in perfect balance reduces the need for fertiliser, particularly phosphorus (P). Soil comprises a large amount of non-immediately plant-available P, and RA proponents claim that by fostering healthy microbiology they can more rapidly convert it to plant-available P, thus reducing or eliminating the need for fertiliser (see section 6.3.1 for more detail).

The result from S&B Farm 1 contradicts this theory. S&B Farm 1 began its regenerative journey with Olsen P levels of 20-30, which is considered very fertile for sheep and beef country. After a decade in the regenerative system, they had mined their Olsen P levels down to as low as 3 in the worst affected paddocks.

During this time, the advice they were receiving was that P levels were high and that there was no need to apply synthetic P fertiliser. Soil testing was completed using the Mehlich test, which is an acid-based test measuring total P, rather than just the component which is plant-available.

While soil fertility was declining, their fertiliser bill was not. It was estimated that under the regenerative programme, their fertiliser spend was 30% higher than that of a conventional system. Their fertiliser use was formulated around copious amounts of lime, seaweed juice, molasses, and K-Plus.

The results of this example of mined fertility were:

- Extreme losses in production. Pastures which should be capable of getting 8-9 grazing's per year were only getting 3-4.
- The farm became more exposed to the effects of droughts because they were seldom in a period of feed surplus.
- Establishment of new pastures and crops was poor, and often had to be re-drilled two or three times.
- There was large variation within crop paddocks. E.g., kale paddock with some areas chest height, some below the knees.
- Requirement for more supplement feed to fill the feed deficit (higher operating costs).
- The farm required a substantial capital fertiliser application plan to get back to a suitable fertility level, which has come at a great cost.
- Farmer well-being was a lot worse.

An evaluation of the Winchmore trial data from McDowell & Condron (2012) would suggest that an Olsen P drop from 20 down to 3 could reduce pasture production by up to 70%. Pasture production was not measured on the farm, however, the farmer agreed that 70% of losses were in line with what they were seeing anecdotally.

Align Farms take a conventional approach to maintenance fertiliser application. They soil test every paddock on the farm annually, using conventional testing. Maintenance fertilisers, particularly phosphorus and potassium are applied as required to both conventional and regenerative pastures. They are not seeing any long-term decrease in fertility.

6.2.2 Reduction in synthetic N

Widespread practice across all case study farms was the reduction or absence of synthetic N fertiliser in their regenerative pastures. Instead of using urea, common alternatives included fish fertiliser, seaweed fertiliser, fulvic acid and others.

Align Farms are applying an average of 161 kg N/ha to their conventional side, and just 5.5 kg N/ha to their regenerative side using the products listed above. Despite the reduction in N, regenerative pastures are still achieving high yields. This is likely due to: higher pasture covers capable of undergoing more photosynthesis (explained in section 6.1.3); higher legume content fixing atmospheric N; enhanced soil microbiology mineralising N. Although the latter is yet to be verified by any research.

This approach appears to be working for Align Farms. However, others have reported a substantial loss in production in RA systems with low synthetic N use. The discrepancy is likely confounded by baseline fertility, grazing management, and species selection as discussed in section 6.1.1. The variable results between farms again highlight the inconsistency and lack of control which is associated with the RA system.

6.2.3 Alternative fertiliser regimes

Another frequent practice among RA farmers is the use of alternative fertiliser methods, such as Albrecht Kinsey (A-K). This method suggests that fertilisers should not simply focus on feeding plants, but rather use the relationship between the physical structure of soil and its exchange capacity and base saturation percentage for optimum plant growth.

Dairy Farm 2 has been experimenting with the A-K method for the last 4-5 years and concluded that production was no different to that of a conventional system.

A paper by Bryant et al. (2019) reinforces this result. They compared the A-K method to conventional in a large-scale dairy situation, concluding after 4 years that there was no difference in milk yield or pasture growth associated with fertiliser policy. Pastures contained 6% more clover on the A-K farm than on the conventional farm. This was attributed to the higher N fertiliser inputs into the conventional system (151 v 115 kg N/ha). No reason was given to explain why the fertiliser N inputs were different between the two treatments.

The authors state that a noticeable difference between the two methods was the improved reproductive performance and fewer health issues at calving for A-K. However, the data shows no significant difference in the empty rate or proportion of downer cows between the two treatments. The A-K method was considerably more expensive.

6.3 Soil

6.3.1 Soil microbiology

Fostering healthy soil microbiology is one of the principles which underpin the RA system. Fungi, bacteria, protozoa and nematodes are abundant in soil, and claims are frequently made in the RA community that ensuring these are present, functioning, and in the correct balance can provide many benefits. These include disease suppression, improved soil structure, and reduction in the use of pesticides, fertiliser, and water (Soil Foodweb, 2023).

Both of the dairy farms were taking measurements of fungi-to-bacteria ratios (F:B) in their RA paddocks. They are targeting a F:B ratio of between 0.75:1 to 1:1 to create a thriving environment for pasture growth. Testing at Align Farms has shown that some paddocks are fungi-dominant, some are bacteria-dominant, and some are well-balanced. All paddocks however showed that most bacteria and fungi in the soil are inactive. Some measurements were as low as 10% of the bacteria active, and 0% of the fungi. These results were consistent with Dairy Farm 2 also.

Some of the measures put in place to activate the fungi/bacteria or improve the ratio are:

- Reducing or avoiding tillage.
- Avoiding agrichemical application.
- Selecting plant species based on the biological state of the soil.
- Allowing weeds to grow.
- Preparing a special brew of compost tea to spread over the pasture to stimulate soil biology.

Improvement in the number of active fungi and bacteria was noted, however, they are still well below desired levels.

Little is known about the effect of altering F:B ratios in pastoral land. A recent Canadian study by Khatri-Chhetri et al. (2022) found that F:B ratio was higher in conventionally grazed (set stocked) grasslands than in a rotational RA grazing system and declined with stocking density. This result conflicts with a previous study that suggests the F:B ratio was higher under rotational grazing than set stocked pastures (Teauge, et al., 2011).

Discrepancies between the two studies may be due to differences in grazing system, vegetation type, climate or methodology. Regardless of the cause, this highlights the fact that soil microbiology is not well understood in an RA grazing context, particularly in New Zealand. Considerable research is required in this space before the benefits listed above can be substantiated.

6.3.2 Soil structure

Soil structure is a key component of plant growth and survival due to its influence on water storage and transport, oxygen supply, and biological processes such as carbon and nitrogen mineralisation, nitrification and denitrification.

In all three of the case studies, farmers had practices in place with the aim of building, maintaining, or minimising damage to soil structure; for example, minimum tillage and maintaining ground cover. It can take decades to see improvement in soil structure, therefore evidence from the case study farms is not yet apparent.

Literature confirms that repeated cultivation is detrimental to soil structure and that the yield from a no-tillage system is often the same if not better than from a cultivated seedbed (Lane & Willoughby, 2013).

Minimum till and maintaining ground cover are both practices which the case study farmers are using to maintain soil structure without compromising profitability.

6.4 Animal health

Several animal health metrics were being monitored at Align Farms including; submission rates; conception rates; blood samples for trace minerals; body condition score; coat condition; mastitis and lameness incidences. Of these, the only results of any significance were higher instances of mastitis on the RA side and higher instances of lameness on the conventional side. The data only spans 5 months, and this is not a long enough period to draw any conclusions.

Anecdotal comments were made about animals appearing healthier on RA pastures, particularly with shiner coats. This is not reflected in any data. Animal health effects noted on the other farms were; lower requirements for supplementation of Mg and Ca; and fewer instances of facial eczema. It is unclear if any differences are statistically significant.

6.5 Social and community

Part of the RA philosophy is to be more connected and involved with the local community. This idea has led to some interesting initiatives for the farmers who contributed toward this project. One farm set up an environmental panel to oversee the farm. They invited members of the community to come together and advise them on how to run the farm more sustainably. This idea attracted several people with varying backgrounds and helped bridge the disconnect between farmers and consumers. One of the challenges with this approach was taking the idealistic advice and finding practical ways to implement it on farm ensuring that it is repeatable and doesn’t compromise profitability.

Another initiative was setting up a small market garden by Align Farms, where each of the staff are given a weekly veggie box containing seasonal vegetables from the garden. This was developed to provide staff with a greater level of food security and nutrition and to provide them with as much home-grown food as possible. Earlier this year they started selling the boxes commercially to members of the community.

Farmers’ social licence to operate has been under pressure in recent years, particularly following events such as the Dirty Dairying campaign launched in 2002, the inhumane slaughter of bobby calves, and cows grazing knee-deep in Southland mud. While by no means a representation of the industry as a whole, these events serve as a reminder of just how easily trust can be eroded with the community.

A report by Clark-Hall (2018) recommended that to improve farmers' social licence, farmers should "*create targeted engagement strategies from the ground up. Give the ownership back to the stakeholders/communities and industry*". The strategies mentioned above appear to be doing just that, and can only be viewed as a positive step toward maintaining trust with the community.

6.6 Wellbeing

Farmer wellbeing is a particularly frequent theme associated with RA as noted by Grelet et al. (2021). This demonstrates RA's tendency to ask broad questions about wider systems rather than having a narrow focus on inputs and outputs.

The RA system aligns farmers closer with nature and teaches them to work with nature rather than constantly fighting against it. There is also better awareness among the RA community about looking after the body and mind.

All case study farmers believed that RA can positively influence the well-being of themselves and their staff. However, two of them also commented that the added complexity of the system, and losses in production, can very easily have the opposite effect.

6.7 Production and financial results

Comprehensive financial results were only available for one of the case study farms, this being Align Farms.

In the 2021/22 season (Table 5) the RA side carried 78 fewer cows, a 14% lower stocking rate than the conventional side. Milk solids (MS) production per cow was 8.6% higher on the conventional side, and MS/ha 22% higher. Farm working expenses (FWE) per hectare were 20% lower on the RA side, primarily due to reduced supplement feed and fertiliser costs. EBITDA/ha was 23.9% higher on the conventional side.

Interim results from the 2022/23 season are showing much less of a gap between RA and conventional (Table 6). The stocking rate remained similar, however, MS/cow was back just 2% on the RA side and MS/ha back 16%. FWE remained similar across the two seasons, and EBITDA was 9.5% higher on the conventional side compared to RA.

Both production and overall profitability have been behind on the RA side for two consecutive years, but it is worth noting that the gap is closing between the two. Align farms are confident that within the next couple of years, they can have the RA side matching or exceeding the profitability of conventional.

Their staff have decades of experience with conventional dairy farming systems, and only a couple years in the RA space. With more experience, they plan to increase per-cow production on the RA side, and they anticipate that rising input costs will work in favour of the RA programme in future.

Table 5: Align Farms Clareview 2021-22 production and financial results:

Actuals 2021-22

Align Farms Ltd- Clareview

FY22 Profit & Loss | *Actuals for the period ending 31 May 2022*

Actuals to 31 May 2022- Accrual basis (12)

		Conventional	Regenerative	Combined
Effective Aera		148	148	296
Stocking Rate		3.74	3.21	3.47
Cow Numbers		553	475	1,028
Milksolids		236,894	185,673	422,567
Milksolids Per Cow		428	391	411
Milksolids Per Ha		1,601	1,255	1,428
Payout Kg/MS		$ 9.30	$ 9.30	$ 9.30
Stock Sales p/KgMS		$ 0.23	$ 0.23	$ 0.23
Gross Income per KgMS		$ 9.53	$ 9.53	$ 9.53
Total Revenue		$ 2,256,439	$ 1,768,547	$ 4,024,987
Total Farm Working Expenses (F.W.E)	Per KgMS	$ 5.44	$ 5.56	$ 5.50
	Per cow	$ 2.332	$ 2.174	$ 2.259
	Per Ha	$ 8.713	$ 6.978	$ 7.846
Dairy Operating (Surplus/Deficit) (EBITDA)	Per KgMS	$ 4.08	$ 3.96	$ 4.03
	Per cow	$ 1.748	$ 1.549	$ 1.656
	Per Ha	$ 6.533	$ 4.971	$ 5.752

Table 6: Align Farms Clareview 2022-23 production and financial interim results:

22-23 Actuals to 31 Oct 22 (5+7)

Align Farms Ltd- Clareview

FY23 Profit & Loss | *Actuals for the period ending 31 May 2023*

Actuals to 31 Oct 2022- Accrual basis (5+7)

	Conventional	Regenerative	Combined
Effective Aera	148	148	296
Stocking Rate	3.84	3.28	3.56
Cow Numbers	568	486	1,054
Milksolids	249,920	208,880	458,800
Milksolids Per Cow	440	430	435
Milksolids Per Ha	1,689	1,411	1,550
Payout Kg/MS	$ 9.25	$ 9.25	$ 9.25
Stock Sales p/KgMS	$ 0.29	$ 0.29	$ 0.29
Gross Income per KgMS	$ 9.54	$ 9.54	$ 9.54
Total Revenue	$ 2,383,258	$ 1,991,897	$ 4,375,155

Total Farm Working Expenses (F.W.E)	Per KgMS	$ 5.56	$ 5.23	$ 5.41
	Per cow	$ 2,447	$ 2,248	$ 2,355
	Per Ha	$ 9,391	$ 7,383	$ 8,387
Dairy Operating (Surplus/Deficit) (EBITDA)	Per KgMS	$ 3.98	$ 4.30	$ 4.13
	Per cow	$ 1,749	$ 1,850	$ 1,796
	Per Ha	$ 6,713	$ 6,075	$ 6,394

S&B Farm 1 didn't provide any financial data. However, they commented *"We were in a really bad financial position where we were doing [RA], and it didn't help in any way. We were spending more money than we would have using conventional fertiliser, and we were getting poorer results."*

This highlights that switching an entire farming operation to RA practices comes with significant financial risk, and therefore investment into RA should be analysed and treated with caution.

6.8 Environmental results

Align Farms modelled environmental data (Table 7 and Table 8) shows the RA system has a lower environmental footprint than conventional in every metric. On a per hectare basis, total greenhouse gas emissions (GHG) are 21-26% lower in the RA system, methane emissions are 17-20% lower, CO_2 is 23-42% lower, and nitrate loss 31-49% lower than conventional.

These figures represent total per-hectare values and don't account for the lower production on the RA side. With the production factored in, GHG/kg MS is only 6% lower on the RA side compared to conventional. CO_2 is 7-26% lower, N loss 18-35% lower, and methane emissions are between 0.8% lower to 2% higher on the RA side.

Table 7: Align Farms 2021/22 environmental results:

	Conventional	Regenerative	Difference
Total GHG/ha (t CO2-eq/ha/yr)	2329.9	1716.4	-26%
Methane (t CO2-eq/ha/yr)	1540.8	1233	-20%
Nitrous Oxide (t CO2-eq/ha/yr)	455.2	288.8	-37%
Carbon Dioxide (t CO2-eq-ha/yr)	333.9	194.5	-42%
Kg MS/t GHG (t CO2-eq/ha/yr)	101.7	108.2	6%
N Loss (kg N/ha)	65	33	-49%
N Surplus (kg N/ha) -	244	129	47%
Nitrogen Conversion Efficiency (%)	29	39	34%

Table 8: Align Farms 2022/23 forecast environmental results:

	Conventional	Regenerative	Difference
Total GHG/ha (t CO2-eq/ha/yr)	2340	1841	-21%
Methane (t CO2-eq/ha/yr)	1550	1284	-17%
Nitrous Oxide (t CO2-eq/ha/yr)	433	280	-35%
Carbon Dioxide (t CO2-eq-ha/yr)	357	276	-23%
Kg MS/t GHG (t CO2-eq/ha/yr)	106.8	113	6%
N Loss (kg N/ha)	48	33	-31%
N Surplus (kg N/ha)	229	152	34%
Nitrogen Conversion Efficiency (%)	32	40	25%

This data suggests that there is a strong positive relationship between MS production and per-hectare GHG emissions. The RA system shows only a marginal improvement in GHG emissions over conventional on a per unit of production basis. It does however provide substantially less N loss.

6.9 Challenges

A common challenge among the case study farms was the added complexity of grazing diverse pastures in a regenerative way. To do this well requires an experienced fully invested manager. It also requires much more time and effort than a conventional system and is harder to convey messages to other staff on the farm.

Of particular note was the added stress of running both RA and conventional systems concurrently on the same property. This creates a considerably higher workload for staff and often led to elevated stress levels.

There are very few RA resources available to farmers in NZ. The lack of experience and confidence has left them often *"flying blind because the methods are a lot less prescriptive, and there is not a lot of support available"*.

Being early adopters of RA, the farmers struggle to benchmark themselves against neighbouring properties and only have a small community with whom they can compare notes with.

An unintended consequence for all case study farms was the lack of consistency and repeatability with the RA system. As discussed in section 6.1.1, this is likely a result of running a lower input system whereby farmers have less control and therefore results are less predictable.

7.0 Opportunities

7.1 Winning the green premium

The financial results discussed in section 6.7 don't favour RA. Yet, those results could be turned around if meat and milk produced by regenerative means were sold at a premium, mirroring the organic industry.

B&L NZ & NZ Winegrowers (2021) carried out a study to understand the current state and future market potential of RA in products within the USA, Germany, and the UK. This research revealed a bright future for consumer interest in RA by concluding that:

- Although just 39% of respondents had heard of RA, there was resounding open-mindedness, interest to learn more and a generally positive disposition to the term and the principles behind it.
- Consumers can learn about RA in a short space of time, and after doing so, it generally will increase their likelihood to buy RA products.
- RA has strong potential to address consumer preferences around taste, health, environment and social impact while commanding a market premium. People across all three countries may pay 20% more on average for sustainably produced food.

It is worth noting that since this study was conducted inflation rates have risen markedly, and many consumers globally are now facing a cost-of-living crisis. Such circumstances are likely to steer consumer spending towards cheaper products, with potentially greater environmental impact.

Many of the benefits of RA that were presented to consumers in this study were theoretical. To build and maintain trust with consumers, one must be cautious of overpromising the benefits that RA has on the environment, taste, and nutrition until more thorough research is conducted. New Zealand must conduct research to better understand the benefits of RA on its unique ecosystems before bold claims can be made to consumers.

For a product premium to be attained, then either the product must be discernibly different (e.g., different amino acid properties) and/or the farm system producing the product must be different and able to be validated by audit as such. A report by Howarth et al. (2021) tested meat from both RA and conventional systems, concluding there was no significant difference between farm types in the levels of fatty acids considered to be beneficial to human health.

Validating RA-produced product also presents a challenge. It is difficult to audit a system which cannot easily be defined and has no clear set of rules or outcomes. Third-party certification may help overcome some consumers' fear and scepticism about greenwashing. Such schemes already exist. For example, The Savoury Institutes Ecological Outcome Verification (EOV) certification, which tracks five key outcomes defining land regeneration: 1) ground cover, 2) water infiltration, 3) biodiversity, 4) primary productivity, and 5) soil carbon and health. The unique thing about EOV is that it is purely outcome-focused and pays little attention to inputs or practices.

Another challenge is supply chain management. Meat and milk processors would need to be set up to process both regenerative and conventional products at the same time. This would take significant infrastructure investment.

The fact that many conventional NZ farmers are carrying out practices which are considered regenerative may well work in their favour. Rotational grazing, multi-species pastures, cover crops, and minimum tillage are common practice among conventional NZ farms already. Perhaps there is an opportunity to share this story with consumers and position NZ-produced food above countries that are not following suit.

It is evident that provided their financial situation allows it, consumers are willing to pay a premium for sustainably produced food. However, there are several challenges to overcome before NZ farmers are likely to pocket the green premium from their RA practices.

8.0 Conclusions

The analysis suggests that RA is unlikely to exceed the meat or milk yield and overall profitability which can be achieved with conventional agriculture. The global population is continuing to rise and is expected to reach 9.7 billion people by 2050. The world needs a global food system which can feed this many people from the same area of agricultural land but with less impact on the environment. RA seems unlikely to achieve both outcomes.

There are aspects of RA which may have a positive effect on the environment without negatively affecting output and farm profitability. For example, practices such as minimum tillage, avoiding bare ground and mixing pasture species (provided no more than 3 species in the sward). In a USA-based cropping system, these practices may seem revolutionary, but in a New Zealand context, most of these are already considered best management practice in a conventional system.

Further conclusions from this study are:

- There is a lack of scientific evidence to support some of the claims of RA. Altering soil microbiology is one area which has not been thoroughly tested and is not well understood.
- Results from a regenerative system are unpredictable and highly variable. With a lower input system, farmers are more vulnerable to natural events.
- Positive environmental outcomes can be achieved with the use of RA. High rates of carbon sequestration have been proven, albeit in depleted USA soils. Greenhouse gas emissions and N leaching can be greatly reduced on a per-hectare basis; however, this is less significant when calculated per unit of product.
- Diverse pastures grazed in a low-input RA system cannot match the yield or feed quality of a conventional system. It is possible that a 'hybrid' system which employs a mix of both RA and conventional practices can produce pasture yields which exceed conventional, with considerably less nitrogen input. Lower pasture quality and utilisation mean this does not translate to greater milk yield or profitability.
- Some RA practices may have a positive effect on the environment without affecting farm profitability. E.g., minimum tillage, avoiding bare ground, and mixing pasture species (provided no more than 3 species in the sward). These are generally considered to be good management practice in a conventional system already.
- Fertiliser use is essential for maintaining soil fertility, pasture production, and farm profitability in the long run.
- There are no conclusive animal health benefits from an RA system.
- Community involvement associated with RA is a positive step toward maintaining trust with the community.
- There may be an opportunity for NZ farmers to obtain a premium for more sustainably produced food. However, there are many challenges to overcome before this can happen.

To answer the research question *"How might New Zealand benefit from regenerative agriculture?"* the response is as follows.

Farmers who are not in tune with today's best management practices may gain a lot by implementing some existing conventional practices that are included as part of the RA narrative. However, for those at the forefront of conventional farming, the benefit could be in leveraging the marketing potential of RA to win a green premium.

The industry needs to use science to validate what farming practices are used. Technology such as precision agriculture and gene editing could be used to increase production and lower environmental impact at the same time. This is where the focus could be.

This leaves one big question: How do we continue to feed the growing population without degrading our climate and environment? Nobody wants our species to march towards its extinction because it's not 'economical' to do otherwise. There is a lot of doubt that RA can provide a better way to address this big global challenge and real concern that it may exacerbate the problems.

9.0 Recommendations

The recommendations from this report are:

1. Treat investment into regenerative agriculture with caution due to the lack of scientific evidence, and variation in its outcomes and likely reduction in farm profitability. This applies to farmers, growers, and processors.
2. Research the untested claims of regenerative agriculture. Particularly soil microbiology and the effect it has on plant growth. Such research is difficult to carry out at farmer level and will likely require input from CRIs.
3. Introduce practices such as minimum tillage, avoiding bare ground, and mixing low numbers of pasture species, to those farms that are not doing so already.
4. Develop marketing strategies for NZ food and fibre which leverage the consumer positivity associated with 'greener' farm practices. This will likely require input from both processors and industry-good organisations.

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Appendix 1: interview questions

Defining regen ag

- How do you define RA?
- What RA practices are you currently employing?
- What led you down this path? I.e. what were the drivers for change?
- Where do you to seek advice and information around RA?

Pros/cons

- Are you measuring the results from your RA work?
- If yes, what variables are being measured?
- Why were these variables chosen?
- What results have you seen to date under the RA programme compared to conventional?
- What has been the effect on soil properties, pasture growth and pasture quality?
- What do you think are the disadvantages to the RA system?
- What unintended consequences have there been as a result of the RA system?

So what?

- How is RA adding value to your farming business?
- How can the value be quantified?
- What do you think the future of regen farming in NZ looks like at farm level?
- What do you think the future of regen farming in NZ looks like at industry level?
- What effect do you think RA could have on our food/fibre exports?
- What do you think is stopping more people from employing RA practices?