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THE GOAL, THE CONCEPTS AND THE PATH TO SUCCESS

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The Goal

New Zealand has set the goal of reducing the environmental footprint of agriculture, particularly through reducing greenhouse gasses (Climate Change Response (Emissions Trading Reform) Amendment Act 2020 https://www.legislation.govt.nz/act/public/2020/0022/latest/whole.html) and contaminants to ground and surface water, especially nitrogen (Essential Freshwater Reforms 2020 https://environment.govt.nz/acts-and-regulations/freshwater-implementation-guidance/).
In Fit for a Better World, the Government's vision for the future launched in 2020 (Ministry for Primary Industries 2020), regenerative agriculture was proposed as a foundation for the design of a New Zealand approach to agricultural sustainability with an expectation "that regenerative farming systems will improve the profitability of farming while leaving behind a smaller environmental footprint".
In the 2022 update (Ministry for Primary Industries 2022), regenerative agriculture was suggested as a "potential opportunity for New Zealand to appeal to consumers, both domestically and internationally, who seek to understand the impact of their product purchases on the environment, animal welfare, and social wellbeing".
In addition, MPI stated that it is delivering, with business and industry bodies, climate-focused extension and advisory services "to grow and support whole-of-system farming change". This is because the food and fibre sector is a biological system, which means, according to the MPI update, that "changes need to be holistic".

Confusion

Confusingly, the document states on the very same page that "New Zealand is one of the most sustainable and low-emissions food and fibre producers in the world. To continue to maintain that position means staying on top of customer preferences, practice changes, and research and development…".
Latest research for sheep and beef (Mazetto et al. 2023) and dairy (Mazetto et al. 2022) puts New Zealand as amongst the lowest-emissions producers globally (of the countries measured). New Zealand farmers, unsubsidised in their production systems, have a track record of innovation, adaptation and adoption (Lissaman et al. 2013) which has allowed them to compete on the global platform. Multifactor productivity gains in agriculture have exceeded 2% since the Global Financial Crisis (https://www.stats.govt.nz/information-releases/productivity-statistics-1978-2021/) - almost double what has been achieved in the EU (OECD 2022; https://globalagriculturalproductivity.org/2022-gap-report/). Clearly, no New Zealand farmer is resting on any laurels.
More confusion appeared at the OECD Committee for Agriculture (COAG) held in Paris at the beginning of November last year, and co-chaired by Minister for Primary Industries, Hon Damien O'Connor. Ministers at the COAG meeting adopted the 'Declaration on Transformative Solutions for Sustainable Agriculture and Food Systems' https://www.oecd.org/agriculture/ministerial/documents/OECD%20Agriculture%20Ministerial%20DECLARATION%20EN.pdf. This means that New Zealand is sharing (headlines from the Government indicated 'leading'; https://www.beehive.govt.nz/release/new-zealand-leads-

new-global-sustainable-agriculture-declaration) in the vision for governments on the actions needed to transform agriculture and food systems with a view to i) ensuring food security and nutrition, ii) strengthening sustainability and iii) ensuring inclusive livelihoods.
By placing food security and nutrition first, the Declaration echoes the Paris Agreement of 2015, which stated that countries should do everything they can to reduce GHG emissions without reducing food production.
New Zealand farmers are trying to do what has been asked. This paper considers whether the task is possible and what might be a path forwards.

The Concepts

Manaaki Whenua Landcare Research has been leading the push towards regenerative agriculture as a solution (https://www.landcareresearch.co.nz/discover-our-research/land/soil-and-ecosystem-health/regenerative-agriculture-in-new-zealand/ accessed 26.01.2023) "not only for transformation on-farm but as a driver of transformation for the global food system, addressing issues as big as climate change, food security or even social and financial inequalities".
Further, regenerative agriculture is explained as *"a biodiversity-driven management system. It seeks to promote ecological synergies between components of the agroecosystem from the ground up, by:*

- *building soil health*
- *increasing plant and animal nutritive quality*
- *reducing stresses on stock animals*
- *reducing dependence on agricultural chemicals.*

Regenerative agriculture is farmer-led, highly adaptive and context-specific. Practitioners rely on peer-to-peer learning and intensive farmer observation to continuously adapt and optimise farming practices."
The implication appears to be that conventional farmers don't do these things (Sumberg & Giller 2022). This has created ongoing concern by conventional scientists (e.g., Edmeades 2018-2023; Rowarth et al. 2020, 2022a), but the juggernaut has continued, and government and farmer-funded reviews have been produced supporting the perceived opportunity in regenerative agriculture and identifying research needs (e.g., Alpha Foods 2020; Grelet et al., 2021).
Non-funded reviews of past work that can be used to predict what will happen with a change in management practice from conventional to holistic approaches have also been published (e.g., Edmeades 2018-2023; Rowarth et al. 2020a,b; Rowarth et al. 2022a,b) in an attempt (a) to assist focus research investment in areas where it might make a positive difference and (b) alert farmers and growers to the work that has already been done to enable them to become even more productive with reduced environmental impact.
By September 2022, government and industry investment in regenerative agriculture was estimated at $54.74 million (https://www.beehive.govt.nz/release/government-backs-largest-ever-pastoral-farming-study-regenerative-farming-practices) covering a multitude of trials (https://www.mpi.govt.nz/funding-rural-support/sustainable-food-fibre-futures/current-sff-futures-projects/sff-futures-projects-regenerative-farming-practices/).

Drystock

Research funded through the MPI SFFF fund on meat quality, addressing the second bullet point of 'nutritive quality', has been published (Anon 2021). Nine regenerative and nine conventional farms in the upper North Island of New Zealand were involved, and meat quality was analysed. There were no significant differences in quality factors between conventionally and regeneratively produced meat, including in the omega fatty acids in the

meat and the ratio between the omega 3 and 6 fatty acids. The increase in omega 3 and 6 fatty acids, and the ratio between them are often highlighted in organic versus grain fed meat and milk because they are considered to be beneficial to human health. The researchers commented that a difference might have been obtained if the pastures being grazed on the regenerative farms had had more species; only nine species were present (in comparison with eight on the conventional farms) whereas regenerative seed merchants recommend '40 or more'… for yield and resilience and variety for the animals.

However, research at Lincoln University (Black et al. 2017, 2021) has shown that a simple mixture of grass, legume and herb is optimal for dry matter production and for metabolizable energy. Black et al. (2017, 2021) have explained that studies suggesting increased species lead to increased production seldom include all possible monocultures and pairwise combinations of the constituent species used in the mixtures. This renders the results difficult to interpret with respect to diversity effects (the difference between the yield of a mixture and the weighted average yield of the monocultures).

Resilience (time until recovery after, e.g., drought) is often suggested as a reason for ensuring species diversity. The relationship in the Jena trial, although significant in the high fertiliser (200 kg N/ha) and 4 cuts a year plots, was very variable and not apparent in other treatments (two cuts a year and 100 kg N/ha) . Further, recovery after drought (termed resistance) was more dependent on management of grazing intensity than species richness (Vogel et al. 2012). Management for recovery included reduced grazing – which was actually mowing; this reduces the impact of preferential grazing in real life and calls into question the 'variety' aspects of hyper-diverse pasture. Yet another factor to consider in 'recovery' is the production before the drought. In the Jena experiments, the mean for the area was production of 8000 kg/ha and 4 cuts (Weisser et al. 2017). The drought recovery trial was cut 2x or 4x in a year and although the multi-species pasture gave 2x as much yield after drought as the conventional pasture, in the year overall, the conventionally managed (4 cuts) pasture gave approximately 25% more yield. The yield was given in g per m2, limiting its use for agriculture.

The impact on the environment is also important. In 2020 Lincoln University research determined the lifetime intake of feed for beef production in different NZ spring calving systems (Gibbs J. Pers. Comm. 2022). These varied in time to slaughter weight (300 kg carcass) from 18 months to 30 months. Using published data on metabolisable energy and nitrogen (N) inputs in the feed, the lifetime methane and N outputs (both GHG and urinary nN) was calculated for the different systems. An animal that took 18 months to reach a 300 kg carcass weight emitted half the methane and N compared to a slower-growing animal that took 30 months to reach the same target weight. Regenerative systems involving animals reaching weight at 30 months (and most in New Zealand will be 36 months) were comfortably the highest in both methane and N output – 100% plus increase per kg of slaughter weight in methane and N waste outputs.

The increase in GHG has been confirmed by more drystock research (Howarth et al. 2022) involving 16 paired (one conventional and one regenerative) farms, two pairs in Northland, three in Waikato, two in Taranaki and one in Canterbury. Annual accounts and Farmax modelling were used to make the analyses. In comparison with conventional farms, regenerative farms produced 125 kg/ha less meat and wool, a reduction from 326 kg/ha to 201 kg/ha (38%). As meat and wool were the main income streams, and costs of production were not decreased, Earnings Before Interest, Tax, Rent and Management Wage were also decreased – from $613/ha to $273/ha (55%). Farmax modelling indicated that GHG emissions intensity for conventional farms was 16.3 kg CO_2e/kg product in comparison with 20.2 kg CO_2e/kg product for regenerative farms. In this case the increase indicates each kg of

regenerative meat and wool was associated with 24% more GHG than conventionally raised meat and wool. Reduced income and increased GHG is not the outcome promoted.
The researchers were clear that regardless of farm type, "all farmers involved in the project sought to maintain a financially viable business, to maintain healthy soils, pastures, and livestock, and to improve the land". The relative importance of these factors did, however, differ between the two farm types.

Dairy
Results from paired dairy farms on the Canterbury Plains have shown a 22% reduction in milk with a 24% reduction in earnings before interest and tax (Align Farms 2022). In this comparison GHG per kg of milk was the same whether the milk was produced conventionally or regeneratively. Further, no differences have been reported for milk quality (N, omega fatty acids, linoleic acid, and macro and micronutrients). Because there was less milk per hectare under regenerative management, to achieve the same yield would require more land.
Together the results do not indicate that a regenerative farming approach leads to 'milk that is better for people and the planet'.
An increase in soil carbon is promoted as an advantage of regenerative approaches, the concept being 'regenerating the soil' with increased organic matter leading to increased soil organisms. New Zealand, however, does not have degenerated soils under pasture, and even under cropping generally contains more soil carbon than overseas counterparts. The increased organic matter is a result of overcoming the limit to photosynthesis post forestry with the application of phosphorus (Schipper et al. 2017), which enables legumes to grow, fix N and then grasses to flourish. Grazing management controls the balance between the species and the amount that is returned to the soil. Long pasture grazing, as advocated by regenerative proponents, results in deterioration in pasture quality (as shown by slower growing animals and increased GHG per unit of production) but an increase in organic matter, in theory.
In reality, first year results on the Align Farms indicated a reduction in soil organic matter (Align Farms 2022a), possibly reflecting cultivation to establish hyper-diverse pastures. The soil disturbance from sowing (or undersowing) species plus the effect of increased bare land, has been found to increase GHG emissions over all in comparison with conventional pasture (Schipper 2022 NZAGRC webinar). With time it is possible that an increase in organic matter would occur, but the increase will stabilize as soil organisms increase to take advantage of the increased food supply (Parsons et al. 2016). The majority of fresh inputs remain in the soil for less than 10 years (Stoner et al. 2021).
Reduced dependence on agricultural chemicals, particularly synthetic N, and a focus on biological N fixation is part of the regenerative approach (Grelet et al. 2021). Using Overseer modelling, Align farms reported halving N loss (from 65 to 33 kg/ha N) for the 2021-2022 year, associated with reducing N inputs from 162 kg/ha N to 33 kg/ha N (Align Farms 2022b). Some of this N loss could have been related to the establishment of hyper-diverse pastures, as found in the Jena trials (Weisser et al. 2017), which reported in addition a decrease in N loss with increased number of species, but an increase with legume presence.

More results
Meanwhile, research results from ongoing conventional research, plus farmer experience, and comparison with regenerative approaches, are building a picture that what is being proposed in regenerative agriculture does not, in grazing systems in New Zealand (and Australia), improve profitability and does not necessarily result in a decreased environmental footprint. When area of land required for a given yield is considered, environmental footprint is higher than conventional approaches.

The less than positive economics and animal welfare outcomes associated with grassland RA were highlighted in the media last year (Herron 2022 https://www.newsroom.co.nz/green-dream-pushes-farmers-into-red?utm_source=Friends+of+the+Newsroom&utm_campaign=07e0ce7251-Daily_Briefing+24.10.2022&utm_medium=email&utm_term=0_71de5c4b35-07e0ce7251-97837219). The problem for the Keens was the reduced amount of feed grown without application of mineral fertilisers, including N, and the ability of the stock to be managed to maintain pasture quality when hyper-diverse pastures were sown. Covid affecting processing capacity exacerbated the problem. Resilience and well-being were not enhanced and there was no premium for the animals that were produced.

Research funding

The negative in the current focus on regenerative agriculture in New Zealand is the opportunity cost in what might have been achieved with $55 million invested in pushing back the frontiers of understanding, not just confirming the predictions based on past research. Of course there will be people justifying the investment, but at heart they probably know that what they think they have achieved could also have been done as part of a progressive research project based on building on past and current knowledge of the proven science of pastoral agriculture rather than repeating it or trying to disprove it.

This points to the big problem – there is insufficient research funding in New Zealand to fund the work that is needed to enable farmers to produce animal protein with even less environmental impact than already achieved. Although more funding was announced in the last budget, inflation and a reduction in funding over the years has eroded critical mass and confidence. The result is that scientists try and put their desired work into a package that fits where the government is investing.

When Fit for a Better World was launched by the Ministry for Primary Industries in 2020, a desire was expressed to design a New Zealand based regenerative farming approach with increased profitability and decreased footprint. It has not yet been shown to do either. Lessons from organic production systems indicate that there is no reason to expect a change – there is no consistent credible research that supports the statements that production does increase after a period of adjustment (Kirchmann et al. 2016).

The question remains how agricultural scientists, researchers and rural professionals can swing their work back to where it can make a difference for the future – testing new ideas rather than confirming why the old ones haven't become mainstream, and working with farmers in their goals of constant improvement to ensure that they maintain their world-leading position in producing animal protein with least environmental impact. Critiquing is fundamental to making that improvement.

The Path to Success

Regenerative agriculture does have potential in some arable and horticultural operations where the approach could be integration with animals in some circumstances, and to include cover crops to minimise bare soil where appropriate. Again, the science to show the benefits of these practices has already been done. Note that rotational cropping is the norm in NZ already, and the type of tillage (conventional, strip till or no-till, for instance) used depends upon the ground to be cropped, the crop and season.

For drystock, Dr Gibbs has suggested that "If New Zealand genuinely wanted to rapidly and significantly reduce ruminant GHG and N outputs, a premium price on early slaughter age (<18 months) would reduce GHG outputs from beef by 25% if it resulted in half the current slaughter numbers achieving the premium requirements". He has calculated that this could be

done in a single year and that the same structural realities apply to lamb production. Regenerative systems cannot achieve what is required.
For New Zealand's sustainable agricultural future, research that allows drivers of change to be identified, and then integrated into farm systems, continues to be the likely path to success. The holistic pursuit of continuous improvement, touted as a distinguishing feature of regenerative agriculture, is not unique in New Zealand where soil, plant, animal and environmental research have combined with economics to put New Zealand at the forefront of sustainable food production. It is, however, the integration of specific disciplines that have made the difference (Rowarth et al. 2023), in combination with innovative farmers challenging the *status quo* (Lissaman et al. 2013).

Conclusions

Much of the enthusiasm around the regenerative approach is that it is better for the planet and people – that income will be at least maintained, and footprint will be lower. Increasingly the research is showing that there is no premium and that the reduction in environmental impact depends upon a reduction in animals, which leads to reduced income:

- If the premium expectations are based on the food product being "better", but no evidence exists for this – thus there is no basis for any desired premium.
- If the premium expectations are based on a lower GHG footprint per hectare (aside from a reduction in food output), is the premium real or simply a redistribution of profits amongst suppliers by processing companies?

If the consequence of a switch to a regenerative approach is simply less profit, less food and lower GHG/ha, the question must be asked if this is fiscally sustainable for either the farmer or the country?
Instead, and harking back to the Paris Agreement 2015, to do everything we can to reduce GHG without reducing food production, a return to enabling discipline experts to work together to enhance the New Zealand agriculture system through ever improved precision farming would seem to be a logical path to maintaining the pastoral agriculture leadership position. The path has also been shown to have a positive effect on water quality (e.g., McDowell et al. 2020). We have the track record to show it works and we are well positioned to achieve even better in the future.

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