An Analysis and Overview of Regenerative Agriculture

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Dr Charles N Merfield. MRSNZ

The BHU Future Farming Centre

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1. Introduction

Regenerative agriculture is a set of farming practices and a social movement that has been increasing in visibility and uptake by farmers & growers in New Zealand over the last five to ten years. However, its relative novelty and diversity of influences means that its origins and exactly what it is are unclear. This desk study aims to provide some background as to the origins and key components of regenerative agriculture, and its relationship to science and society. Due to the nature of the topic it is not a standard literature review, in part as there is very little literature directly studying regenerative agriculture. This report also considers the social side of regenerative agriculture, which, if done rigorously would be a substantial social science project, which is beyond the resources available for this desk study. A large part of the analysis of the social side of regenerative agriculture is based on the authors 30 plus years experience in organic agriculture, which shares many features, technical and social, with regenerative agriculture, and, the authors involvement in the New Zealand based regenerative agriculture group "Quorum Sense". The report is therefore inevitably subjective, but, it is hoped that it is also as objective and academically rigorous as is possible.

2. What's in a name? Defining regenerative agriculture

While the term 'regenerative agriculture' is increasingly widely used, it, is not the only term used to describe the collection of farming practices and philosophy that it encompasses. For example, Nicole Masters, the founder of "Integrity Soils"[1] a key proponent of, and regenerative agriculture (RA) educator in New Zealand, Australia and North America, states "Regenerative Agriculture is also known as Biological Agriculture, Holistic Ag, Ecological Agriculture, Natural Intelligence, Eco-Agriculture, Natural Farming, Humus/Carbon Farming…" (Masters, 2019). Other authors include a range of other farming practices and systems as being aligned / or compatible with RA, such as organic agriculture, agroforestry, permaculture, no-till, cover cropping, agroecology, and holistic grazing (LaSalle & Hepperly, 2008; Rodale Institute, 2014; Terra Genesis International, 2016; Toensmeier & Herren, 2016). One report even states "It's important to start with this: Regenerative Agriculture cannot be defined." (Soloviev & Landua, 2016, page 5). RA is therefore considered to be a still evolving concept at present, that lacks a formally agreed definition, a proposition that is further supported by the discussion below on the origins of RA as a concept, and its core practices and definitions.

This lack of single formally agreed definition of RA can be contrasted with other 'alternative agricultures' (alt-ags) particularly organic agriculture, which has a small number of very carefully enunciated definitions, e.g., by The International Federation of Organic Agricultural Movements (IFOAM) (IFOAM, 2019), the United States Dept. of Agriculture (Anon, 1995), and the European Union (Anon, 2007), and a formally agreed set of 'Principles' (IFOAM, 2005). This is considered a reflection of the fact that organic agriculture is approximately a century old with its first legal associations forming in the 1940s, so it has reached a stage of considerable maturity, while the current form of RA is only 10 to 20 years old with only country based associations, and no international equivalent to IFOAM. There are considered to be parallels with where RA is in terms of organising and formalising itself and creating its first associations, and where organic agriculture was in the 1940s.

2.1. Origin of the term 'regenerative agriculture'

The origin of the term and concept of 'Regenerative Agriculture' is not unambiguously known. Francis et al., (1986) states that "regenerative agriculture was proposed by Gabel (1979)" but it has

[1] integritysoils.co.nz

been impossible to verify the source due to its obscurity. The Francis et al., (1986) paper itself is therefore one of the earliest peer reviewed papers that explicitly refers to RA.

A number sources point to Robert (Bob) D. Rodale, as an originator of the term. Bob Rodale was the son of Jerome I. Rodale, who founded the Rodale Institute (rodaleinstitute.org) the leading organic agriculture research organisation in the USA (founded in 1947) and Rodale Publishing, in which Bob succeeded his father in both roles. The following quote is attributed to Bob Rodale, though again original source material has not been able to be obtained.

> "By marching forward under the banner of sustainability we are, in effect, continuing to hamper ourselves by not accepting a challenging enough goal. I am not against the word sustainable, rather I favor regenerative agriculture." Robert Rodale (Rodale, 1983; Wikipedia contributors, 2019b).

This quote is considered to still sum up the difference RA practitioners see between 'sustainable' and 'regenerative', i.e., the view, that sustainability is too low a bar, as it could be taken to mean sustaining practices that lead to negative outcomes (Simon Osborne, regenerative farmer, Leeston NZ, pers. comm. 2019), while linguistically regenerative involves an element of repair, reform, re-create, reconstituting, improve and made better. At the same time, it could be argued that the differences are somewhat semantic, and many people may consider there to be little difference between the current meaning of the terms 'sustainable' and 'regenerative' in relation to agriculture, as the concept of sustainability now contains elements of improvement, not just maintaining the status quo.

Rodale Publishing also formed the Regenerative Agriculture Association which published 'The new farm: magazine of the Regenerative Agriculture Association' from 1979 to 1995, along with a range of books (Anon, 2015, 2019). It appears the term fell out of use until the 2010s, when it was revived and linked to climate change with the publication of "Regenerative organic farming: A solution to global warming" first as a technical paper (LaSalle & Hepperly, 2008) and then as a white paper (Rodale Institute, 2014). Around 2008 the Rodale Institute undertook a considerable change of direction from being entirely focused on organic agriculture to having a strong focus on climate change and promoting farming practices, many of them organic practices, that could help mitigate and adapt to climate change (Jeff Moyer, Rodale Institute, 2008, pers. comm.). Rodale now actively promotes the concept of "Regenerative Organic Agriculture" and they are considered to be the originators of the term and its key proponent. However, not everyone in the organic movement considers 'regenerative organic' to be helpful with Sahota (2010, page 148) noting "New private standards like Regenerative Organic (introduced in March 2018[2]) continue to be launched adding to the certification complexity."

As discussed below, one of the current core objectives of RA is climate change mitigation through sequestering atmospheric CO_2 as soil organic matter (soil carbon). As climate change as an issue only started to reach public discourse in the 1990s, Rodale's original use of the term RA clearly predates the general awareness of climate change, so the current focus of RA on climate change clearly has to be a more recent insertion into RA.

Another early publication using the RA term is "Regenerating agriculture: policies and practice for sustainability and self-reliance" by (Pretty, 1995). Considering the very high standing of Pretty in agroecology (and all the sustainable / alt-ags) this book should also be considered a source of the RA term, particularly within the scientific literature as it is referenced in a number of papers e.g., (Sherwood & Uphoff, 2000; LaCanne & Lundgren, 2018). It is also noted that climate change is not listed among the chapter titles, as again, with a publication date in the mid 1990s the issue of climate change is only just reaching public awareness.

[2] https://regenorganic.org/

It therefore appears that, like many alt-ag names and terms, the use and meaning of RA has probably been coined several times by several people, and more importantly evolved over the approximately four decades it has been in use, particularly in terms of the current core focus on climate change mitigation. It is suggested that the concept of RA is likely to still be continuing to evolve. As a formally agreed definition of RA does not currently exist, even rather unhelpfully proposed as being indefinable (Soloviev & Landua, 2016, page 5) it is suggested that it is more helpful to look at the practices of RA to understand it.

2.1.1. Input vs. outcome focused

At this point a further contrast with organic agriculture is considered valuable in terms of understanding RA, as the two systems having almost opposite approaches in terms of defining / constraining what is permissible in the two systems. At a practical on-farm level (i.e., not philosophical level), organics takes an input restriction approach, which is defined by the 'standards' which are a set of rules ('laws') which define what is, and what is not, permissible in organic agriculture, often in considerable detail, e.g., of listing individual types of products, e.g., particular fertilisers, pest & disease control products, etc., that may, or may not, be used. It is therefore considered, at the farm level, that organic agriculture is an 'input focused' approach (even though it has wider more holistic aims). RA in contrast has no equivalent to the organic standards / rule book. Rather it has a set of semi-informally defined objective that it wishes to achieve, e.g., soil health, especially microbial health, building soil organic matter for soil heath and climate change mitigation and adaptation, etc. It then has a suit of on-farm practices, e.g., no-till, cover crops, minimising soluble fertiliser use, avoiding agrichemicals, integration of livestock, etc., that are used to try and achieve the various objectives. It is therefore considered an 'outcome focused' approach, in direct contrast to the input focused approach of organic agriculture.

It is therefore considered that the key to understanding RA is to understand the core objectives (desired outcomes) and the main farming practices used to achieve the objectives.

2.2. Regenerative agriculture's key objectives and practices

In keeping with the somewhat fluid nature of RA and lack of agreed definition, there is also no formally or universally agreed set of objectives and practices. There are a growing number of organisations dedicated to RA, e.g., most of which outline the key objectives and practices, often rolled into single concepts. Some main RA organisations / associations that have been identified are:

- Terra Genesis International (terra-genesis.com and regenerativeagriculturedefinition.com);
- The Regenerative Agriculture Alliance (regenagalliance.org);
- Regeneration International (regenerationinternational.org);
- Regenerative Agriculture Foundation (regenerativeagriculturefoundation.org);
- The Carbon Underground (thecarbonunderground.org and thecarbonunderground.org/our-initiative/definition);
- Regenerative Organic Alliance (ROA regenorganic.org) though the ROA is both organic and regenerative rather than just regenerative.

It is observed that currently RA and its associations appear to be mostly based and originating from North America, with Australia potentially being second in the level of activity. It seems that the dominant agricultural system in RA in both regions is extensive livestock and lower intensity arable / row-cropping systems, and particularly mixed farming systems with both arable crops and livestock. These are often situated in lower rainfall areas, represented by temperate grasslands, savannas, and shrubland biomes. It is suggested that the key objectives and farming practices of RA are shaped by the biophysical constraints of the biomes which RA has originated from, in a similar way to organic

agriculture has been shaped by the climate, soils and farming systems of Northern Europe (UK, Germany, Denmark, etc.) where it originated.

From the above sources and scientific publications a table has been created listing the key RA practices (Table 1, page 8).

From Table 1 it is clear there is a reasonable level of agreement among the different sources as to what practices constitute RA. The key ones are:

- Minimising or eliminating tillage (through no-till);
- Avoiding bare soil / keeping the soil covered at all times with living plants or residues;
- Increasing plant biodiversity (both pasture and crops);
- Integrating livestock and cropping (mixed /rotational farming).

Then there are further practises that are listed by a three or less sources:

- Maintaining living plants and their roots year round;
- Increasing soil fertility through biological means
- The use of compost

McGuire (2018) has also constructed a similar table which further contrasts RA with conservation agriculture.

Based on my participation in the New Zealand regenerative farming group "Quorum Sense" and their social media discussion platform, there is also a keen interest in reducing the amounts of soluble / mineral fertilisers and synthetic agrichemicals. Regarding fertilisers there is a strong belief that nitrogen fertilisers in particular are detrimental and the aim is to replace them as much as possible with biologically fixed N via legumes and free living diazotrophs. Some also express the view that they have been over fertilizing with phosphorus and other nutrients and are aiming to utilise existing soil P by increasing the biological activity of the soil, especially via mycorrhizal fungi. There is also considerable interest in the base-cation saturation ratio (BCSR) soil nutrient testing approach (Wikipedia contributors, 2019a), also called the Albrecht Kinsey system, even though mainstream soil scientists widely consider the approach to be unsubstantiated at best (Kopittke & Menzies, 2007).

Likewise for the agrichemicals: herbicides, fungicides and insecticides, there is a view among the Quorum Sense that they have negative effects, particularly on soil biology, and, therefore they should be avoided. As many of the farmers have been extensively using agrichemicals for many years, even decades, before their move to RA, they have good knowledge of the different types of chemicals and rate them as to how bad their negative effects are. Some are considered particularly harmful, e.g., neonicotinoids, and are completely avoided, while others are considered less harmful, and/or they are difficult to substitute, e.g., glyphosate, so are used sparingly. This view is not unique to this group, Gabe Brown (2018) in his first principle of soil health states "Synthetic fertilizers, herbicides, pesticides, and fungicides all have negative impacts on life in the soil as well."

Table 1. Key regenerative agriculture practices as defined by a range of sources

(Brown, 2018)	Limited disturbance. Limit mechanical, chemical, and physical disturbance of soil.	Armor. Keep soil covered at all times.	Diversity. Strive for diversity of both plant and animal species.	Living roots. Maintain a living root in soil as long as possible throughout the year	Integrated animals. Nature does not function without animals.		
(General Mills, 2019)	Minimise soil disturbance	Keep the soil covered	Maximise crop diversity	Maintain living roots year round	Integrate livestock		
(Regenerative Agriculture Initiative & The Carbon Underground, 2017)	No-till/minimum tillage.				Well-managed grazing practices stimulate improved plant growth, increased soil carbon deposits	Soil fertility is increased in regenerative systems biologically	Building biological ecosystem diversity begins with inoculation of soils with composts or compost extracts
(LaCanne & Lundgren, 2018)	Abandoning tillage (or actively rebuilding soil communities following a tillage event)	Eliminating spatiotemporal events of bare soil	Fostering plant diversity on the farm		Integrating livestock and cropping operations on the land		
(Rodale Institute, 2014)	Reducing or eliminating tillage / conservation tillage	Avoid bare soil / retention of crop residues	Enhanced crop rotations	Use cover crops between cash crops			Use compost
(Sherwood & Uphoff, 2000)	Soil structure / limited tillage	Soil cover	Diverse biology / Varying use and recuperative periods				

2.3. Regenerative agriculture's objectives

The same as the on-farm practices, the objectives of RA have also not systematically been agreed. Different sources have different perspectives. However, as for the practices, there are common themes.

Regenerative Agriculture Initiative & The Carbon Underground (2017) state "RA...reverse climate change by rebuilding soil organic matter and restoring degraded soil biodiversity – resulting in both carbon drawdown and improving the water cycle." Terra Genesis International (2016) states "RA...increases biodiversity, enriches soils, improves watersheds, and enhances ecosystem services." "...reverse global climate change...increased yields, resilience to climate instability, and higher health and vitality for farming communities." Rodale Institute (2014) states "Regenerative organic agriculture refers to working with nature to utilize photosynthesis and healthy soil microbiology to draw down greenhouse gases." and "Regenerative organic agriculture improves the resources it uses, rather than destroying or depleting them. It is a holistic systems approach to agriculture that encourages continual on-farm innovation for environmental, social, economic and spiritual wellbeing"

From the above examples, and the authors involvement in the RA farmer group Quorum Sense, a number of objectives can be identified.

Improving soil health is considered to be the core objective and issue of RA. Soil health is viewed quite holistically, e.g., it includes biodiversity, but, the main focus is on building soil carbon (soil organic matter) and improving soil biology. In many ways these are the same issues that launched the organic movement over a century ago and was the key focus of what is referred to as Organics V1.0, i.e., pre 1960s organic agriculture (Conford, 2001).

Within most of the alt-ags, not just RA, soil is often viewed as the core issue, as civilisation is entirely dependent on farming and farming is entirely dependent on the soil (Montgomery, 2007). Further, for many, if not most, of the global environmental issues (Steffen *et al.*, 2015) soil, i.e., the pedosphere, is a key component of the planetary systems which modulate the biosphere as a whole (Lovelock, 1979, 2006).

The next main objective is considered to be mitigating climate change through sequestering atmospheric CO_2 as soil organic matter, which is synergistically liked to the core objective of soil health - an example of a win-win scenario for climate change.

Adapting to climate change as an objective is strongly linked to the mitigation objective as the solution to both is rooted in building soil organic matter as that makes soil more resilient, and better able to deal with climate instability such as floods and drought.

Further building on the climate change adaptation there are objectives around improving ecosystem services (Costanza *et al.*, 1997; Costanza *et al.*, 2017).

There are also objectives around improving the health and vitality of farming communities, though as farming communities vary dramatically from subsistence farmers in the developing world through to the dispersed farming communities of the American Midwest, this, objective is clearly context dependent.

Therefore, the objectives stretch from the highly specific, e.g., building soil organic matter, to, the high level e.g., the vitality of farming communities and holistic e.g., improving ecosystem services.

2.4. How does regenerative agriculture differ from other alt-ags?

The practices listed in Table 1 and above are not considered particularly unique. The list of other alt-ags that RA crosses over with listed at the start of section 2 (e.g., organic agriculture, agroforestry,

no-till, cover cropping, agroecology, etc.) have many similarities. McGuire (2018) argues that the only difference between RA and Conservation Agriculture (CA) is that RA includes muti-species mixtures (generally at least >10 but as high as 50+ species) which CA does not but CA includes controlled traffic farming (CTF) (Tullberg *et al.*, 2007; Kingwell & Fuchsbichler, 2011). It is therefore unclear exactly what makes RA significantly different at a practical level from any of the well established sustainable farm systems approaches.

At the same time, as RA mostly consists of the well proven practices (e.g., residue retention) that underlie existing sustainable farm systems approaches, it should mean that there are few, radical and unproven techniques among RA practices. Indeed the title of McGuire (2018) "Regenerative Agriculture: Solid Principles, Extraordinary Claims" directly speaks to this position.

2.4.1. Regenerative agriculture - a biological and ecological approach

While RA has a lot of communalities with other alt-ags, it differs from some, with precision / digital agriculture (PA) considered to be a clear contrast. Precision ag is a technically focused farming approach with the aim of using high tech / information technology / digital systems to solve farming problems, both yield / profit issues and environmental issues. In comparison RA farming techniques, are not considered to be technical solutions, rather they are biological and ecological solutions (see Table 1 for examples).

There is considered to be something of a tension in agriculture between people who promote technical solutions and those that promote biological solutions for how best to address the multitude of planetary level issues (climate change, biodiversity loss, etc.) most of which agriculture is a part cause of, and suffers from, while also maintaining food production and many would argue also improving food quality. Clearly technical and biological approaches are not mutually incompatible, e.g., no-till, which is fundamentally about soil health requires technical solutions in the form of no-till seed drills. However, it is argued there is something of a divide among the alt-ags in that they tend to be either biologically or technically focused. RA is considered to clearly be a biologically based farming system.

2.5. A mindset vs. list of practices

While at base, RA can be viewed as 'just' a collection of practical farm techniques, most of which are not novel, it also appears that RA has become something larger. Some RA advocates are promoting that RA has moved into higher level system redesign and reconceptualisation of the farm. For example, Soloviev & Landua (2016) of Tera Genesis International, take a different approach in describing RA. It is their report that makes the statement "It’s important to start with this: Regenerative Agriculture cannot be defined." (Soloviev & Landua, 2016, page 5). In their report they do not list the kinds of farming practices listed in Table 1 rather they are focused on the farmer as an actor in their farm environment and they view RA as much about a change in mindset as changing practices, e.g., "The Levels of Regenerative Agriculture is a framework for self-assessment and collective aspiration" (Soloviev & Landua, 2016). The levels of RA are listed as:

1. Functional;
2. Integrative;
3. Systemic;
4. Evolutionary.

These are levels of progression of the understanding of the farm system by farmers / land managers as they better and more deeply understand RA as a holistic approach that involves not just the land, but, they themselves as land stewards. From my 30 years experience in organic farming, a common comment, is that converting to organic is as much about converting the farmers mind, as it is

converting the land, i.e., it is about re-conceiving and reconceptualising what a farm is and the farmers role in its stewardship. Soloviev & Landau's perspective of RA is therefore considered to be at a much deeper philosophical and even spiritual level, than the 'mere' farm practices listed in Table 1.

I suggest Soloviev & Landau's perspective places RA closer to organic agriculture in terms of considering itself as a philosophy, a holistic approach and a movement, compared with farming systems such as no-till and conservation agriculture, which while their proponents argue strongly for the merits of the system, they are 'just' agricultural techniques not a philosophy or higher level concept. From my involvement of the Quorum Sense and organic farming groups, many of the proponents consider their farming system and their personal philosophy / world view to be deeply entwined.

RA should therefore be viewed not just as a set of practices but rather a deep and fundamental re-evaluation of the farmers relationship with the farm, also how their farming impacts on the quality (healthfulness) of the food they produce and the effect that has on the health of their customers who consume that food, and finally on the wider biosphere and planetary systems. That RA has moved beyond being a set of agricultural practices into a higher level movement, has potentially important implications in terms of the transformation of agriculture that are discussed in the last section.

3. Regenerative agriculture and science

It is considered the relationship between RA and science to be quite complex and multifaceted.

3.1. Science cv. Values

As discussed above, at the highest levels RA is a philosophy, a movement and a value system, the same as organic agriculture. As such it lies outside the realm of science, in that values, i.e., matters of what is right and wrong, good and bad, cannot be answered by scientific experiments (Barrow, 1999), i.e., it is impossible to design an experiment to determine if yield maximisation or ecological resilience or social fairness, are the 'correct' approach to agriculture. As it is impossible to undertake an experiment to answer a values question, science as whole can only be mute on the issue (Barrow, 1999). However, it is believed that a significant proportion of those involved in agriculture, and wider society do not understand this distinction. For example Callaghan (2011) states “Putting aside the paradox of organic farming, unscientific to the core that it is, the rest is an absurd list.” The error made by Callaghan is one of scientism (Wikipedia contributors, 2019c) whereby things that have been created by science are considered 'good' and to oppose things created by science is unscientific. This is clearly exampled by nuclear weapons, which are clearly 'scientific' in that they involve sub-atomic physics which is some of the most profound and technical science ever achieved, but, opposing nuclear weapons is clearly not unscientific, rather it is a moral and ethical decision. Exactly the same applies to agriculture, for example opposing the use of pesticides due to concerns over their safety is not unscientific, as it is an ethical and moral decision as much as a scientific one.

Fundamentally RA (and organic agriculture) is a values system, and the only way to decide which value system is preferred is through debate / political processes, not science. At the highest level RA is beyond the reach of the scientific method.

3.2. Science and the origin of regenerative agriculture's values

While the scientific method is incapable of questioning RA's (and organic agricultures) philosophy and values, this is not to say that the information produced by science cannot be used to help decide which values RA (and individuals and society) wish to pursue. Indeed in many cases, new knowledge produced by science has been critical in individuals, and society changing their value systems.

RA's values are considered to be fundamentally driven by scientific information, for example, there is now a massive amount of evidence that intensive / industrial agriculture has lead to depletion of soil organic matter, biology, structure, and loss of soil from farmland, and that this has lead to larger scale issues, all the way up to planetary scale, such as climate change, biodiversity loss, excess nitrogen and phosphorous in the environment, etc., e.g., the nine planetary boundaries (Steffen *et al.*, 2015).

RA farmers have looked at the scientific evidence for the multiplicity of interconnected environmental and social issues facing humanity and decided that farming needs to take a different approach from that of industrial agriculture, by changing to a farming system that starts to repair the damage that has been done by intensive agriculture. They have therefore created their value system, at least in part, based on scientific information.

The kinds of scientific information RA farmers are using to both create their values and practical farming techniques is also considered to be very broad, from, high level information about issues such as climate change and biodiversity loss, all the way down to highly specific information, for example on the interactive functioning of mycorrhiza networks and how they operate a trading market for nitrogen in exchange for carbon (Bücking & Kafle, 2015).

However, fully analysing and identifying the values and core drivers of RA is a large sociological research project and far beyond this short report.

3.3. Science and regenerative agriculture's solutions

The relationship between science and the solutions proposed by RA is considered to be where standard scholarship norms start to break down.

Again, a comparison with organic agriculture is considered helpful, in terms of comparing the input rule based approach of organic agriculture with the outcome focused view of RA (see section 2.1.1 for previous discussion). For example, largely due to Rachael Carson's 'Silent Spring' (Carson, 1962), organic agriculture decided to completely prohibit the use of synthetic agrichemicals (xenobiocides) based on a precautionary principle approach (Montague, 1998; Conford, 2011; Akins *et al.*, 2019). In comparison, RA proponents take a more case-by-case approach to the agrichemicals. For example, as noted in section 2.2, neonicotinoids are considered particularly harmful and there are alternative options, so their use is totally avoided, but, other agrichemicals, e.g., glyphosate, are considered less harmful, and, in some situations the alternatives (e.g., tillage, or other herbicides) are considered more harmful so a lesser of two evils approach is taken, so glyphosate is used in that specific situation, with a longer term aim to find better alternatives.

In the above examples, organic agriculture's decision to prohibit the xenobiocides was based on a philosophical position (the precautionary principle) while RA farmers decision is based on a wide range of scientific evidence, e.g., the efficacy of the practice, the potential side effects (harms), and the alternatives, often on a case-by-case basis, as well as their value system. As the organic position is philosophical it cannot be contradicted by the scientific method as they are incompatible realms. In contrast, the RA farmers position is decided mostly within the scientific realm, and therefore is open to question by experiment / the scientific method.

3.3.1. Getting the science right or getting the right science?

However, many of these scientific issues, e.g., the safety and harm of agrichemicals, are complex and/or controversial due to a hierarchy of issues:

1. The science is still evolving - there are disagreements within the scientific literature;
2. Disagreements among different scientific 'tribes' (often based on different unspoken value systems);

3. There are commercial interests at stake;
4. The issue has reached the political sphere.

These complexities are not unique to RA or agriculture, but, are considered part and parcel of science and society. This means there is often a range of scientific data that can both support and not-support a particular stance, e.g., practice X will increase soil organic matter. The scientific gold standard is to consider the data in its totality, often with many caveats and nuances, but, it is considered there is a certain amount of selection of the data to support / validate RA position. For example, climate change, soil carbon and enteric methane is considered a particularly hot topic, as many RA proponents claim that they can sequester sufficient amounts of carbon in soil organic matter (soil carbon) to have a sufficient impact on atmospheric CO_2 levels that soil carbon sequestration should be considered a major component of climate change mitigation. There are a multitude of research papers showing that under the right conditions exceptional increases of soil organic matter can be achieved, even in just one year, e.g., (Machmuller *et al.*, 2015). However, when considered at the global system level based on the best knowledge of how much more carbon all soils globally can sequester, the often bold claims made by RA advocates start to unwind. For example the '4 per 1,000' / Four per Mille initiative[3], which shares a key objective with RA of substantial mitigation of climate change through sequestering atmospheric carbon in the soil, has received a number of sceptical, critical, analyses of whether the aim is biophysically achievable (Poulton *et al.*; Minasny *et al.*, 2017; Arrouays & Horn, 2019; Corbeels *et al.*, 2019; Soussana *et al.*, 2019). Another example is, the claim by RA advocates that the increase in soil carbon they achieve under pasture offsets the enteric methane produced by the ruminants (cows, sheep, goats, etc.,) grazing the pasture, has been rebuffed by the substantial, international collaborative report 'Grazed and Confused' (Garnett *et al.*, 2017) despite this, some RA proponents continue with their claim of soil C off setting methane, without providing an equally well argued scientific case to rebuff the conclusions of Grazed and Confused.

A final example of this is the multiple web articles by Andrew McGuire from Washington State University; College of Agricultural, Human, and Natural Resources Sciences; Center for Sustaining Agriculture and Natural Resources. In his articles he critiques a number of RA claims and considers that many of them are extraordinary and therefore need extraordinary evidence to back them up, which, in most cases, he considers the evidence to be underwhelming, e.g., (McGuire, 2018).

There is therefore considered to be something of dichotomy in RA, in that science is both 'used and abused' depending how well it matches to RA values and views. It should be noted that there is probably am amount of a practitioner vs. academic divide at work, as what counts as good evidence for a farmer (e.g., side by side on-farm comparisons) is not the same as what counts as good evidence for a scientist (fully randomised, and replicated, statistically analysed experiments) but, within western society the final judge / gold standard for deciding matters of fact is methodologically rigorous scientific experiments.

It is therefore suggested that RA is fundamentally science based (within its value system), both in terms of its analysis of the problems, and the proposed solutions, but, that it does not always use the best and/or current science, and, there is therefore an amount of data selection to support everything from on farm practices to the whole RA value system.

3.4. Regenerative agriculture in the scientific literature

On searching the scientific literature, both journal papers and academic books, for RA the number of hits was exceptionally low, e.g., searching for the term "regenerative & agriculture" in the Lincoln University Library general search facility generates < 10 hits. In comparison a web search provides a

[3] https://www.4p1000.org/

wide range of sources, including multiple websites (listed in the references and section 2.2), popular books e.g., (Brown, 2018), popular media articles and a plethora of online videos from simple short on-farm recordings of farming activities (e.g., making compost) to professionally made promotional / advocacy videos. In comparison, the very similar search term "resilient & agriculture" generates tens of thousands of hits, many of which are part of the larger term of 'climate resilient agriculture' e.g., (Lengnick, 2015; Swagemakers *et al.*, 2019). Substituting the words 'farming' and 'agriculture' in the above searches does not change the very large difference in the number of hits.

Regeneration International publish "Regenerative agriculture — annotated bibliography" (2019). The review lists 78 references, but, only two of those are peer reviewed publications (journal papers, conference proceedings, books) one is Francis et al., (1986) and the other Machmuller et al., (2015), plus two USDA publications, one of which is Albrecht, (1938) which clearly predates RA by a considerable time, and Albrecht's science and views are increasingly questioned by todays soil scientists (Kopittke & Menzies, 2007). Most of the references listed in the bibliography are online news media articles, a few books, and some reports by scientists who actively promote RA. The bibliography therefore reinforces the view that there is very little peer reviewed publications specifically on RA itself. It is concluded that there is therefore very little peer reviewed publications specifically about RA or comparing RA with other agricultural systems, e.g., as LaCanne & Lundgren (2018) undertook. So, while RA is using a wide range of scientific information, that information is about particular practices, e.g., cover crops, multi species mixtures, no-till, etc., rather than specifically about RA itself.

Virtually all the information on RA is therefore in the grey literature, i.e., newspapers, social media, websites, videos, etc. This clearly makes it easy for farmers to access, and is in forms they prefer, e.g., videos, but, it means that it is much less likely to be cited in academic literature. It therefore appears that the study of RA as a system is almost entirely absent from the scientific literature, and that there is a considerable divide between academics who are not engaging with RA (evidenced by the lack of peer publications) and farmers, who are engaging with RA with enthusiasm.

3.5. Scientific study of regenerative agriculture

However, it is suggested that there could be a considerable missed opportunity in scientists not investigating RA as LaCanne & Lundgren (2018) have done. This is because RA is integrating a range of farm practices, i.e., diverse plant species mixtures, minimising tillage / no-till, minimising bare soil and integrating livestock that are normally researched in isolation. Undertaking classical multi-factorial field trials of just one of these techniques, requires large and expensive long-term trials. Undertaking research at the whole system level, i.e., where several of these practices are integrated is orders of magnitude more difficult and expensive again. However, ecological theory predicts that synergistic effects through, symbiosis, i.e., commensalism, mutualism, and neutralism and other positive effects, means that the whole may well produce benefits greater than the sum of the parts. It is suggested that valuable new scientific knowledge could be gained by studying real-world RA farms, that would be impossible to discover using research farms, due to the complexity and duration of the experiments required.

3.5.1. Breaking down academic silos

Some researchers, e.g., McGuire (2018) have been critical of the claims made by RA proponents, for example yield increases from multi species mixtures (McGuire, 2016). While many of the critiques are valid and backed up by research evidence, they may also suffer from academic silos shortening researchers perspectives, particularly at a whole farm or whole biosphere level. For example, loss of biodiversity is one of the planetary boundaries at most risk (Steffen *et al.*, 2015) but McGuire (2016) does not consider the effect multi species mixtures may have on wider farm biodiversity, probably

because he is an agronomist not an ecologist. Another inter-silo perspective is that on mixed farms with both crops and livestock, is that livestock are often used to terminate the cover crops, i.e., eat them, and there is increasing evidence in the benefits of highly diverse forage on livestock e.g., (Provenza *et al.*, 2015), so while McGuire (2018) may be correct that the yield benefits of cover crop mixtures may be limited, there may be wider benefits for livestock. It is therefore suggested that when researchers are critiquing RA practices, they need to take a whole of farm and whole of biosphere view, rather than a narrower field of expertise view.

4. The social half of farming

Agriculture is perhaps unique among all industries, in how tightly the business, the farmer, their family and their social networks are intertwined. For example, most farmers, have their family home on their farm, and their social networks consist mostly of other farmers. The social and business sides of farming are therefore strongly entwined, and, many projects aiming for technological transformation in farming have failed, not because of the technology, but, for failing to account for the social side. This social side of farming is considered another key issue for RA farmers, as they see the need to ensure that their families and social networks are at least maintained, or better improved by changing to RA. They are also highly proactive in terms of using these farming social networks to inform other farmers about RA and help them change to RA. This can be from simple one-to-one conversations 'over the fence' all the way through fieldays and using information technologies such as social media, videos, websites etc. At the same time social norms, in terms of what is considered 'acceptable' ways of farming, e.g., spraying out fence lines, if the farm is neat and tidy, also exert considerable pressure on farmers not to try radical alternatives, such as RA, which break many social norms.

4.1. Linking farmers to their customers

These social issues also reach beyond the farmers networks, and extend to their customers / consumers \ the 'eaters' of the food they produce. Issues around food quality and links to health, such as those argued by Pollan (2006, 2008) are also important in RA and concepts such as 'nutrient density' and 'spray free' have been frequently discussed on the Quorum Sense network. Again, the similarities to Organic V1.0 are considered significant with the impact of soil health on the quality of food grown being a key issue for the founders of organic agriculture (Conford, 2001). There are also increasingly strong arguments made about the need for farmers & growers to connect with their customers and create value added products e.g., (Saunders *et al.*, 2013). RA farmers' focus on their customers and the quality of the food they produce are doing exactly that, so RA, like organic agriculture, is creating the kinds of value added, traceable, etc., foods that New Zealand needs to do more of.

4.2. Regenerative Agriculture as a social movement for change

As RA farmers are wishing to change their farming systems to address local to global issues, such as climate change, biodiversity loss, N & P pollution, food quality, etc., this means are actively trying to address the biggest social and environmental issues of our times. This is perhaps the most important aspect of RA that is being lost in detailed academic arguments about the pros and cons of particular farm practices (e.g., multi species mixtures by McGuire (2016)) i.e., that RA farmers are actively engaged in solving these massive global challenges. Considering that in New Zealand, and many other countries, the farming sector, or at least its political organisations, such as Federated Farmers[4], have argued that issues such as climate change do not exist, and then when such positions have become untenable, they have argued against agriculture's role in the issue and the need for change,

[4] www.fedfarm.org.nz

it should be welcomed by wider society that RA farmers are actively engaged in these issues, acknowledge that farming is responsible, and that they are changing their farming practices to try address the issues.

As noted at the start of this section, many projects aiming for technical change in farming have failed not due to the technology, but, because they failed to take into account the social dimension of farming. It is suggested that RA is a social movement as much as it is a technical approach to farming. If farming and farmers are to change how they practice agriculture to address the multitude of environmental and social issues humanity faces, taking a purely technical approach is highly likely to fail, the social side has to be addressed too. RA can therefore be viewed as a ready made, and made by farmers, sociotechnical solution. There could therefore be major advantages for wider society, and the political & technical components of government (e.g., MPI, MBIE) to actively engage with RA farmers and use RA as a way of dramatically increasing the engagement, from the bottom up, of the rest of the farming community, with the multiplicity of global challenges currently facing civilisation. A final comparison with organic agriculture highlights this potential, in that 100 years ago organics was in the same developmental stage as RA is today - a loose network of like minded farmers. A century on, organic agriculture is now a massive, global movement, working right at the heart of the politics of the future of food and farming while organic farmers are walking the talk in their fields and all the way to their customers dinner tables.

5. Conclusions

Regenerative agriculture (RA) is not straight forward to understand as it is not straight forward. There is general agreement among proponents as to what on farm techniques are core to RA or are not. The practices that appear to be universal are minimisation or elimination of tillage (soil disturbance); having a high diversity of plant species, both pasture and crops; avoiding bare soil; and integration of livestock and cropping (mixed farming), with the fundamental aim of improving soil health, particularly increasing / maximising soil organic matter (soil carbon) and soil biology (particularly microbiology). However, RA is also much bigger than a mere collection of farm practices, as it also is a social movement, a value system and a philosophy, with the objectives to dramatically change the industrial / intensive farming paradigm, to repair the damage done to planetary systems by mainstream agriculture, on the farm, at the planetary level and in the social spheres.

Its relationship with science is complex. Many of the concerns driving the value system, e.g., soil and planetary health, are based on scientific knowledge, and practitioners are keen to use scientific knowledge to achieve their aims, but, there is also considered to be some selecting of the science that best supports RA views. At the same time, as a farming system integrating a number of novel or re-discovered farming techniques (e.g., multi species pastures) it potentially offers a massive resource to science to study the outcomes of integrating these practices, with the knowledge created being of use not just to further improve RA systems but also agriculture as a whole.

Finally, considering the intransigence of the agricultural sectors over several decades, both in NZ and globally, to engage with wider society and politics, to address the multitude of global and environmental issues that face civilisation, that a group of farmers is actively acknowledging that agriculture is a core part of these problems, and, that they are changing their farm systems, to the best of their abilities and knowledge based on science and within economic constrains, to mitigate and adapt to these issues, should be exceptionally warmly welcomed. RA farmers can therefore be viewed as doing exactly what is required of the agricultural sector by wider society and should therefore be strongly supported.

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