Manaaki Whenua
Landcare Research

An introduction and guide to the 'alternative agricultures': an enquiry into values

Prepared for:
Our Land and Water National Science Challenge & the NEXT Foundation

September 2021

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

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Extracted from: Grelet GA, Lang S 2021. ‘Think piece’ on Regenerative Agriculture in Aotearoa New Zealand: project overview and statement of purpose. Manaaki Whenua – Landcare Research Contract Report LC3954 for Our Land and Water National Science Challenge & The NEXT Foundation.

Find the full project overview, white paper and topic reports at
ourlandandwater.nz/regenag and www.landcareresearch.co.nz/publications/regenag

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

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

Foreword from the project leads

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

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

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

How was the work stream of this think piece organised?

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

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

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

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

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

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Contract Report: LC3954-1

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The BHU Future Farming Centre

Please cite as follows: Merfield C. 2021. An introduction and guide to the 'alternative agricultures': an enquiry into values. Manaaki Whenua – Landcare Research Contract Report LC3954-1 for Our Land and Water National Science Challenge & The NEXT Foundation.

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1 Introduction to this report

1.1 Acknowledgements

I thank and acknowledge the many valuable, informative and helpful comments from both the named reviewers and other anonymous reviewers which have considerably strengthened this report and also ensured that its purpose and aims are as clear as possible.

1.2 Disclaimer

Readers should note that this report is strongly influenced by the British ancestry of the author, his historical and cultural perspectives and the authors three decades of lived experience of, and direct involvement in, the alternative agricultures, particularly organic agriculture, including practical farming, relationships with many farmers & growers, memberships of advocacy organisations, as well as associations within the academic community. There are many other valid perspectives that could be been used to discuss the content of this report, drawing from different cultures and worldviews, including those of the many indigenous peoples living throughout the world and having developed their own ways of relating to the land and to food, or the various perspectives offered by mainstream African, central and Eastern European or Asian cultures – all of which have contributed to shaping and evolving our food systems to this day.

The report's aim is to give an introduction and be a guide to the alternative agricultures (alt-ags) for people who have some general knowledge of agriculture but are somewhat bewildered by the many different alt-ags, what they are about, why there are so many, and the problems with mainstream agriculture they are trying to address. It does this to provide context in all forms, e.g., historical, philosophical, practical, for the emergence of Regenerative Agriculture, which to a considerable extent stands on the shoulders of the other alt-ags. The current form of Regenerative Agriculture has principally emerged from North America and mainly from the USA, and therefore mostly draws on influences from those and other English speaking areas. This again produces a significant British and American bias into this report, which is **not** meant as a disparagement or underestimation of other cultures and countries agricultural evolution and achievements.

The report is definitely not a critical or deep analysis, nor a systemic review. It also does not aim to pass judgment or define the farming systems. As such it only aims to be an informed reflection on the topic, backed up, when relevant, with references to academic and grey literature, with the aim of providing a simple overview of the alt-ags.

For readers interested in exploring the topic in more depth there are many other far more in-depth, critical and analytical texts available. Example of such guides written in English include USDA National Agricultural library[3] and Thirsk (2000) "Alternative Agriculture: from the black Death to the present day". Other guides exist in other languages and will be influenced by different historical and cultural perspectives. However, for many indigenous agricultures, such as Māori, written literature of any kind is sparse and presents both a significant future opportunity and necessary responsibility to address.

1.3 Introduction

There are a growing number of farming systems that promote themselves as being an 'alternative' to the mainstream farming paradigm of 'intensive agriculture'. They are described as alternative in that they offer alternatives ways of conceptualising and undertaking farming compared with mainstream agriculture. They range from the narrow focus of no-till, which aims to eliminate tillage but has no other focus, to approaches such as agroecology, organic agriculture and regenerative agriculture, which seek to change many aspects of the production system and are whole system approaches, both at the farm level, and also at the global level of how agriculture is embedded in the planetary spheres and processes[4].

This guide is structured to offer a basic description of the different systems with a little history, where relevant, to give readers a basic explanation of the more common and historically important alt-ags. For each alt-ag, links to additional resources, mostly key books and website are also provided, should the reader wish to find out more. Others guides to alt-ags can be found, that emphasise different aspects of their similarity and differences from the ones highlighted in this present report.

Because this report seeks to provide an overview of 'alternative' agricultures, modern/intensive agriculture needs to be put in its historical context to explain why it dramatically differs from earlier forms of farming, and also what the alt-ags are opposing. The report also presents a discussion of the role of ethical values in agriculture, as it is posited that the differences between industrial and intensive agriculture and the alternative agricultures are fundamentally differences in values (e.g., anthropocentric vs. biocentric value systems).

There are, therefore, three main sections to this report. First, the role of values (i.e., normative ethics) in agriculture is discussed. Normative ethics is the branch of philosophical ethics that investigates the questions that arise regarding how, in a moral sense, one ought to act.

Second, a brief history of agriculture is outlined to put industrial and intensive agricultures in historical perspective and to highlight the key scientific and technological developments that created industrial and then intensive agriculture.

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[3] www.nal.usda.gov/afsic/sustainable-agriculture-definitions-and-terms-related-terms

[4] en.wikipedia.org/wiki/Earth_system_science

Third, and the main part of the report, partly uses a historical perspective to explain the alternative agricultures, because their histories and how they have evolved are often a key part of what they are today, particularly for those with long histories going back over a century. The different systems are also presented roughly in order of importance, based loosely on how much land is farmed under each system, while trying to fit similar and related systems next to each other to achieve some coherence in what is at times a somewhat arbitrary aggregation.

1.4 Two notes on terminology

Three terms are used to describe modern agriculture in this report: mainstream, industrial, and intensive. The three terms are used somewhat interchangeably, depending on context, but 'industrial agriculture' and 'intensive agriculture' also have particular meanings as described later in a section on the history of agriculture.

In British, New Zealand, and Australian language usage, agriculture and horticulture are considered separate entities, and farmer/farming is distinguished from grower/growing: agriculture and farming deal with livestock and arable crops, while horticulture and growing relate to vegetable production and other forms of cropping. In comparison, in North American usage, agriculture includes horticulture, and farmer/farming also implies grower/growing. Additionally in N. America low density livestock production over large areas is referred to as 'ranching'. For the sake of brevity and readability, for the rest of this report the American forms 'farming' and 'farmer' are used to describe all others, i.e. agriculture includes horticulture and all forms of livestock production and 'farmer' implies 'grower' and 'rancher'.

2 The roles of values in agriculture and their relation to science

In the 29 September 2011 edition of the *New Zealand Herald*, Sir Paul Callaghan wrote, "Putting aside the paradox of organic farming, unscientific to the core that it is, the rest is an absurd list" (Callaghan 2011). Sir Paul is not the first – nor the last – person to claim that organic agriculture is unscientific. Often this belief is based on the logic that intensive agriculture is based on science, therefore other agricultures that reject some or all of the techniques of intensive agriculture are unscientific. However, this is an example of 'scientism', where the scientific method is being used in excess of its true reach e.g., the promotion of science as the best or only objective means by which society should determine **normative values**.

'Values' and 'value systems' are used here in their ethical and philosophical sense: a value system is a set of consistent values used for the purpose of ethical or ideological integrity, with the aim of determining what actions are best to do or what way is the best to live i.e., how one ought to act in a moral fashion. Values, in this sense, are part of normative ethics, the branch of philosophy that studies ethical behaviour and what is considered 'normal' by different human social groups. A (crude) parallel can be drawn with moral norms and the aims and objectives of a business, such as 'to be the No 1 car rental company'. Both moral norms and aims and objectives guide how a human social group or business *should* or *ought* to behave. For example, for Māori the equivalent of a values system is tikanga.

Despite the immense power of the scientific method (i.e., conducting experiments), there are a few aspects of the natural world where science is fundamentally incompatible with the question being asked, and therefore completely incapable of asking, let alone answering, the question. Questions of values are one such aspect.

2.1 The relationship between values and science

For a subject to be within the remit of science it has to be theoretically possible to conduct a methodologically valid experiment to answer the question/hypothesis posed (Barrow 1999). The theoretical qualifier is required, because a wide range of experiments can be conceived but not implemented because, for example, they may be unethical (e.g., they require intolerable harm to humans or animals), or may be physically impossible at this point in our technological development (e.g., a particle accelerator the size of the solar system). Within this conception there are very few things that fall outside the remit of science: questions of values and ethics are one area (Barrow 1999).

It is simply impossible to design an experiment to answer a moral question. For example, there is no experiment that can tell you if murder or slavery is right or wrong. The answer to moral questions can only be determined by debate and discussion within a society. Different societies may answer the question differently, even contrarily, and the answer may change over time within a society e.g., the answer to the question if slavery is right or wrong has completely reversed in much of the world over the last three centuries.

Therefore, fundamentally there is no absolute answer to a values question, only a mutually agreed answer for any given society at any given time.

To further illustrate the relationship between science and values, there are many experiments on humans and animals that are methodologically correct from an experimental standpoint, but ethically unconscionable. The decision that an experiment is unethical is not determined by previous experiment, but by society as a whole, and an ethics committee specifically. This highlights the fact that ethics is a higher-level authority than science, so if something is scientifically valid but ethically invalid, the ethical decision trumps the scientific decision. This why unethical experiments are stopped by ethics committees, and no amount of argument about the methodological soundness of the experiment can sway the result.

This relationship between values and science is considered to be at the heart of the relationship between mainstream agriculture and the alt-ags, and also in countering the scientism that lies at the heart of much of the criticism of the alternative agricultures.

2.2 An enquiry into agricultural values[5]

That agriculture is inherently political, because it is underpinned by values and ethics, is poorly understood. According to Wendell Berry,

> *'Eating is an agricultural act'* (Berry 1990)

According to Michael Pollan,

> *'Eating is a political act* (Pollan 2006, 2008)

from which it follows that food production is a political and ethical act.

> *The production, transformation and distribution of food and agricultural products are generally accepted as routine aspects of daily life around the world. Therefore, such activities have rarely been addressed within the realm of ethics. But food and agriculture, and the economic benefits that derive from participation in the food and agriculture system, are means to ends that are inherently ethical in nature.* (FAO 2001[6])

What we should eat, how we should obtain our food (e.g., grow it, purchase it, barter for it), and how we should farm to produce that food are not questions the scientific method can answer, because they are questions of values, ethics, morals, and also therefore politics. What science can and does provide is a probability of what the outcomes of our choices will be; such as if our food choices will make us healthy or sick, the social and

[5] Acknowledgements to Robert M. Pirsig.

[6] www.fao.org/3/x9601e/x9601e03.htm

economic impacts of where we obtain our food (e.g., supermarket vs. community-supported agriculture), and if our farming systems will destroy or are compatible with the planetary systems that support us. Therefore, while science cannot answer a values question, it can – and very much does – provide us with increasingly accurate and refined understanding of the world, on which value decisions can be made.

For example, science is increasingly showing us that many animals, which in the past have been considered to have no feelings, have an internal mental experiences quite similar to humans, and that they feel fear, stress, pain, anxiety and other emotions. Based on this scientific information, increasing numbers of people have made an ethical decision that experimenting on animals and/or eating them is immoral. Science provides the knowledge: people make the value judgement.

Likewise, science informs our decisions about how we should do farming, and also provides the knowledge to achieve the farming system we wish to achieve. For example, science tells us that the world population is growing at an exponential rate. To feed that growing population it is decided to increase food production. Science then provides methods to grow more food, such as the use of nitrogen fertilisers and agrichemical pesticides. The counter-example is that science tells us that agriculture is destroying the planetary systems on which life, including our own, utterly depends. It is decided that agriculture needs to work within planetary system boundaries. To do so, science tells us that we need to reduce the use of nitrogen fertilisers and pesticides.

These two examples show that that if you focus on different areas of knowledge produced by science (e.g., a growing population vs. planetary boundaries), and look to science for solutions, science can give contrary answers due to the different questions being asked. There is no fault in the science: in both examples the science is correct. The contrary answers are due to focusing on different areas of scientific knowledge and asking different questions, arising from contrasting value systems. These examples are not new. They are facets of the ongoing debate of anthropocentrism vs. biocentrism and ecocentrism (Pyra 2009). Anthropocentrism is the moral belief that human beings are the most important entity in the universe and interprets or regards the world in terms of human values and experiences. Biocentrism is an ethical point of view that extends inherent value to all living things, based on an understanding of how the earth works, particularly as it relates to the biosphere. Ecocentrism extends the inherent value of biocentrism to the whole of nature including humans, it therefore closely related to biocentrism but at the biggest scales (Pyra 2009).

The error, therefore, at the heart of the scientism that intensive agriculture is scientific whereas organic farming and the other alt-ags are unscientific is due to mistaking what *is* with what should or *ought to* be.

2.3 The 'is–ought problem'

Confusing what is and what should / ought to be is known in philosophy as the `is–ought problem', or Hume's guillotine, named after the philosopher and historian David Hume who first articulated it. This states that it is not possible to make claims about what *ought* to be based on statements about what *is*.

Within agriculture this is exemplified by the idea that because we *can* increase yields, then we *ought to*. Increasing yield is the core objective of intensive agriculture, and this is widely viewed as a scientific objective, because yield increases have primarily been achieved through science (e.g., nitrogen fertilisers and agrichemical pesticides). However, the belief that yield *should* be increased is clearly not a scientific objective: it is a value judgement, because you cannot design an experiment to show that you *should* increase yield. You can very clearly however, design experiments that show *how* to increase yield. Indeed, most agricultural science of the last 70 years has been dedicated to doing exactly this, but, as per Hume's guillotine, just because increasing yield *is* possible does not mean that we *ought* to increase it.

2.4 Intensive agriculture is not 'scientific'

This, then, is considered to be the fundamental logical and philosophical error at the very heart of intensive agriculture: that it is viewed as being 'scientific' when it is clearly a value system. Intensive/mainstream agriculture is therefore no more, and no less, scientific than any other agricultural system, because at heart the decision as to how one *should* farm and also how one *should* eat is fundamentally a values, ethical, moral and political decision, not a 'scientific' decision.

Therefore the arguments as to which is the 'best' or 'right' or 'correct' way to farm cannot be decided by experiment or science. As discussed above, information and knowledge produced by science can and do inform the debate about 'how to do' agriculture, but even then, depending on the different value systems (e.g., anthropocentric: wanting to feed more people vs. ecocentric: staying within planetary boundaries) using the same available scientific knowledge will give different weights to different parts of that knowledge, and therefore produce different views on 'how to do' agriculture.

The relationship between science and agriculture is therefore entirely mediated by values. Values determine how people interpret scientific knowledge and values determine how to do agriculture. It is therefore 'values all the way down'.

Therefore, the charge that organic or any other farming system is scientific or unscientific is, to quote Wolfgang Pauli, "not even wrong", because the charge utterly confounds two incompatible domains of human knowledge: ethics and the scientific method. In other words, it is a 'category error' (Ryle 1949, 2020). An analogy to illustrate the error is that nuclear weapons are clearly scientific as their conception and creation require the most profound science of our age (i.e., quantum mechanics). However, the decision to use, not use, or not even build and possess nuclear weapons is clearly not a scientific decision: it is an ethical and political decision. No one decries the non-use of nuclear weapons as being unscientific. Indeed, the statement is patently absurd. Therefore the claim that the non-use or prohibition of some forms of scientific technology (e.g., agrichemicals, genetically engineered organisms) by various alternative agricultures is unscientific is likewise patently absurd.

2.5 Examples of agricultural value systems

Most farming systems have not explicitly stated their value systems, though some have aims or objectives. For example, no-till's primary and clearly stated aim is protecting soil (Baker and Saxton 2007), particularly from wind and water erosion, which means its core ethical value is 'soil protection'. As explained above, the value system of intensive agriculture is maximising yield, and perhaps maximising profit, depending on the value system of the individual farmer (though it should be noted the two aims do not always coincide). These values are pretty much the totality of the values of intensive agriculture in that they have been pursued with little regard to anything else, at least at a political level, since the 1950s. At the farm level of agriculture, maximising yield or profit is always tempered by the biophysical constraints of the farm, the soil, the weather, the temporal nature of farming, etc.

In contrast, two farming systems that have clearly stated their value system are permaculture and organic agriculture. These value systems are presented here as examples of what explicit agricultural value systems look like, and also to show diametrically opposing creations.

Permaculture has three explicitly stated 'foundational ethical principles':

- care of the Earth: provision for all life systems to continue and multiply
- care of people: provision for people to access those resources necessary for their existence
- return of surplus: to those two goals – if there is extra of something, use it either to help people or to help the Earth, but never waste it (Mollison 1988; Holmgren 2002; Fiebrig et al. 2020).

Permaculture's ethics were defined and refined by its founders, Bill Mollison and David Holmgren, who are in effect their sole arbiter. In comparison, organic agriculture undertook a democratic consultative approach to define the 'Principles of Organic Agriculture'. Previously the International Federation of Organic Agriculture Movements (IFOAM) had the 'Principle Aims of Organic Production and Processing', which were amended so many times they became confused and unclear and needed to be replaced (Luttikholt 2007). A taskforce was then established by the IFOAM board, which undertook an expansive grassroots consultative process to develop the draft principles. These were then extensively debated by the IFOAM General Assembly (equivalent to a parliament or legislature) when it met in September 2005 in Adelaide, Australia, and debated the final text for an entire day (Luttikholt 2007). The approach was both highly democratic (i.e., started by the elected board, implemented by the General Assembly) and highly inclusive due to the effective consultation process. As a result there has been no consideration of amending them since, they are set in stone, just like the Ten Commandments. The four principles are:

> **Principle of health**: organic agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible.

> **Principle of ecology**: organic agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them.
>
> **Principle of fairness**: organic agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities.
>
> **Principle of care**: organic agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment. (IFOAM 2005)

These principles have been actively used to guide organic agriculture since they were laid down, so they are not just lofty ideals but real-world ethics.

2.6 A new agricultural (ethics) revolution

It has been suggested that the current upsurge in the number and amount of alternative agricultural systems is a symptom that the value systems underpinning mainstream agriculture are being increasingly questioned and challenged, and that societies are undergoing a shift, a paradigm change, even a revolution in the values they wish to see underpin the systems that produce their food and fibre, and that manage a large proportion of their landmass (their farms). For example, José Graziano da Silva, Director-General of the Food and Agriculture Organisation (FAO) of the United Nations (UN) said in 2015, "The model of agricultural production that predominates today is not suitable for the new food security challenges of the 21st century". He also noted that

> *Since food production is not a sufficient condition for food security, it means that the way we are producing is no longer acceptable. What we are still mostly seeing is a model of production that cannot prevent the degradation of soils and the loss of biodiversity – both of which are essential goods, especially for future generations. This model must be reviewed. We need a paradigm shift. Food systems need to be more sustainable, inclusive and resilient.*[7]

It is not just the Director-General of the FAO who is calling for a paradigm shift/revolution in agriculture. There are now a substantial number of high-level reports (e.g., from UN organisations) as well as academic and general discourse calling for change (e.g., Millennium Ecosystem Assessment 2005; FAO 2007; McIntyre et al. 2009; De Schutter 2010, 2014; TEEB 2010; UNEP 2012; IPBES 2019). There is an increasing view globally – among farmers, scientists, citizens and politicians – that intensive agriculture has been found wanting and that an alternative is required. The current alternative agricultures are therefore more the new mainstream agricultures in waiting than alternative, as in just a different way of doing things. Their aim is to be the future of agriculture.

[7] www.fao.org/news/story/en/item/278192/icode/

2.7 The use, or non-use, of science in agriculture

There is one final component in the analysis of the relationship between agriculture, values and science. As discussed above, scientific knowledge informs the ethical values of the alt-ags, and scientific knowledge and experiments are used to determine how to achieve those ethical values. Such farming systems could be described as 'science based' or 'science informed'. Most of the alternative agricultures are 'science based', but there are a few that don't follow this Enlightenment model, and instead their value systems are driven by factors other than scientific knowledge. Examples of these are the Amish in the USA, biodynamics that originates in Austria / Germany and Māori agriculture in New Zealand as an example of indiginous agriculture.

The Amish are a group of traditionalist Christian church fellowships of Swiss-German Anabaptist origins. All aspects of their way of life are guided by their religious beliefs, including their agriculture. This has resulted in them prohibiting the use of the internal combustion engine, so they famously, use livestock to pull farm equipment and also for transport, but they do use agrichemical pesticides. However, no amount of new scientific knowledge will change these views, as they are determined by faith not evidence. (For the purpose of this report, the Amish are not considered to be an alternative agriculture, as to some extent they are still practising farming as their Swiss-German ancestors did, so they are more a pre-industrial agriculture rather than an alternative agriculture.)

Biodynamics was created by Rudolf Steiner, an Austrian philosopher, social reformer, architect and esotericist, who founded the esoteric spiritual movement 'Anthroposophy' (from *anthropo-*, human, and *sophia*, wisdom), on which biodynamics is based. Steiner laid down the foundations of biodynamics in a series of eight lectures in 1924, now simply called the 'agricultural lectures' and which are reprinted to this day (e.g., Steiner 1993). While the meaning and interpretation of the lectures can and does change, the fundamentals Steiner laid down in the lectures, and the Anthroposophy underpinning biodynamics, cannot be questioned. As the foundations of biodynamics are therefore effectively immutable, new scientific knowledge cannot be used to revise them.

These two agricultures therefore do not evolve and change in light of new scientific knowledge, nor do they use experimentation to prove or disprove practices and beliefs. For example, in biodynamics 'peppering' is a technique created by Rudolf Steiner for pest and weed control, whereby specific parts of the weed or pest are burnt under particular astrological and physical conditions and the ash is 'potentised' and applied to the land with other homoeopathic preparations to control the pest or weed. The technique was not devised through experiment: it was provided by Steiner in its entirety based on his personal intuition, and even when experiments fail to show that peppering works, this is insufficient evidence for biodynamic practitioners to abandon its use because they *believe* that the technique works, rather than requiring scientific *evidence* that it works.

The situation for Māori agriculture is more complex. There has been a constant erosion of Maori belief systems due to colonisation so Māori tend to have a residual belief system and use science to confirm and give them confidence in reviving or continuing their traditional practices. Today Maori are tending away from a reliance on science to confirm what they know and towards a confidence in confirming for themselves what they believe.

These agricultures are therefore considered fundamentally different from the science-based agricultures, as they are founded in religious, spiritual, philosophical and other non-scientific knowledge systems, some of which are part of the non-natural/supernatural world and therefore outside the remit and reach of the scientific method (Barrow 1999). So while they may appear to be similar to other agricultures, particularly at a practical level (e.g., biodynamics and organics are often considered to be the same by many people), fundamentally they are utterly different.

2.8 Conclusion: agriculture, values and science

We therefore consider that much of the misunderstanding of the relationship between industrial/intensive/mainstream agriculture and the alternative agricultures to be due to a failure to understand the relationship between agriculture, science and values/ethics. Claiming that the alt-ags are 'unscientific' is a 'category error' (Ryle 1949, 2020) in that all agricultures are fundamentally ethical and political systems which the scientific method is unable to question.

We also argue that many of the disagreements between mainstream farming and the alt-ags is a manifestation of the deeper, ongoing debate between anthropocentrism and biocentrism and ecocentrism.

Most of the alt-ags are in fact 'science based' in that they use scientific knowledge to inform their value systems, and also use experimental evidence to decide how best to achieve and implement their value systems. However, there are a small number of agricultures, such as biodynamics and Amish agriculture, that are not science based, but are based in religion, philosophy and supernatural realms. In its purest from Māori agriculture sits in this non-science realm. These non-science-based agricultures are therefore fundamentally different to the science-based systems.

3 A brief history of agriculture[8]

What is considered to be 'normal' (mainstream) agriculture and horticulture in the developed, and much of the developing, world is a very recent phenomenon. To fully understand mainstream agriculture and its counterpoints, the alternative agricultures, it is necessary to understand the history, and particularly the key developments, of agriculture as a whole, and how these have modified the biogeochemical processes and cycles that underpin life on earth.

3.1 The evolution of *Homo sapiens*

Homo sapiens evolved approximately 500,000 years before present (BP), with what are described as 'cognitively modern humans' (i.e., humans that are indistinguishable from people living today) appearing some 50,000 years BP. Humans only invented agriculture some 12,000 years BP, so modern humans existed as hunter-gathers for nearly 40,000 years, four times the length of time we have been farmers. For many cultures hunting and gathering co-existed and complimented agriculture (rather than being rapidly supplanted) for many centuries, including up to current times. Agriculture as a whole is therefore still something of a novelty in human history.

3.2 The start of agriculture: 12,000 years BP

Agriculture developed about 12,000 years BP in multiple locations around the globe, and is described as the Neolithic or first agricultural revolution. Called pre-industrial or subsistence agriculture, the primary aim of these first farms was to provide food, fibre and other materials to the farmer and their kin. Many staple crops, such as rice, wheat and maize, were first domesticated and bred during this period. The only resources available for subsistence agriculture were those found in the natural environment: humans and animals to supply power, plant, animal and other natural (eobiotic) materials, such as wood, bone and stone, to make tools such as tillage tools, containers, storehouses, cutting utensils, and cooking facilities. Spiritual beliefs, deities and cultural world views were also universal and foundational in all early agricultures and remains so in most cultures, i.e., the act of farming was fully integrated within a culture's world view, and not something separate undertaken by a small proportion of a society.

Analysing these farming systems from a biogeochemical perspective, nutrient cycles were mostly circular, with all manure – human and animal – plus other biological 'wastes' being returned to the farmland. All the energy for the system came from the sun, captured by

[8] Acknowledgment to Stephen Hawkins.

plants via photosynthesis. Therefore all the materials, nutrients and power used in the first forms of agriculture came from the farm or nearby natural areas, such as woodlands, and all nutrients were returned as manure. The biogeochemistry of farming was therefore the same as natural ecosystems.

3.3 The second agricultural revolution: eighth to seventeenth centuries

The second agricultural revolution occurred in the Islamic world in the eighth to thirteenth centuries in the seventeenth century in Europe with the advent of metallurgy and machinery; the introduction of new crop species; improved techniques such as rotations with leguminous crops, irrigation, and better breeding of both livestock and crops; and many other techniques and technologies. Developments were also occurring in many other parts of the world at the same time, for example, selective breeding, rotations, fallow seasons, irrigation, were early technologies in many traditional cultures, with the Pacific being covered in new crops and animals transported from island to island by Polynesian settlers and Māori developed new technology in the context of their new Aotearoa New Zealand home. While these periods saw large improvements in efficiency and productivity, from a biogeochemical perspective all energy still came from the sun, nearly all power came from muscle (with the exception of some waterwheels and windmills), and nutrient cycles were still mostly local and closed, so from the biogeochemical perspective there was no revolution and farming continued to function similarly to natural ecosystems.

3.4 Industrialisation and the Enlightenment: the 1800s

Within this analysis the Enlightenment – the age of reason and science – and its the industrial age which followed it are considered to be the most dramatic transformative change in human history since cognitively modern humans first appeared. The Enlightenment, therefore, has not only affected agriculture, but has fundamentally created the 'modern world', the age we still exist in.

'Industrial agriculture' takes its name from the industrial revolution, as they co-occurred and were co-dependent, and farming also started using the techniques pioneered in the industrial factories (e.g., linear production systems). There is no precise start time for this period, partly as the legal structures and mindset required for industrial ag developed as early as the 1600s with the aim of increasing yields originating at that time (Meiksins Wood 2016) with industrialisation allowing this aim to be achieved with increasing vigour. In addition the tail end of the second agricultural revolution in Europe blends into the start of industrial agriculture making meaning there is no precise date, but 1800 is taken as an approximate date for the purposes of this report.

This period is where fundamental changes to biogeochemical systems first start to occur in those parts of the globe impacted by industrialisation. The first change is that muscle (and some water and wind) power starts to be replaced by machine power, initially in the form of steam engines. For example, the first steam-powered threshing machines appeared around 1810 (Hodge 1973), the first steam traction engines in 1860 (Bonnett 1975), and the first internal combustion engine tractor in 1892 (Sanders 1996). Initially steam engines were powered from plant matter (i.e., trees turned into charcoal), but, as demand grew this was quickly supplanted by coal, a fossil fuel. For the first time in human history the power used by farming was decoupled from the energy supplied by the sun via plants, and also water and wind.

The profundity of the impact this has created is difficult to describe. Prior to fossil fuels, energy was as just as important a product of agriculture as matter / chemistry (i.e., the nutrients in food), because farms were the source of nearly all energy for civilisation (the exceptions being wind and water mills and wild harvested food). Farms therefore had to produce a net energy 'profit' to firstly power itself, i.e., through muscle power of draft animals and humans, and, to provide energy (in the form of produce), for its customers / consumers. The use of fossil fuels in agriculture means that agriculture is now often a net consumer of energy because more energy – in the form of electricity, fuel for machinery, fertilisers (especially nitrogen), pesticides etc. – is used to produce food than the food contains, i.e., the energy yield is negative. Ratios of 1:10 of output food energy to input energy are not uncommon (Hall et al. 1986; Pimentel and Pimentel, 1996; Heller and Keoleian, 2000). This is akin to planting 10 kg of seed and only harvesting 1 kg! Clearly without the input of energy from outside the farm system, the current negative energy yield of agriculture would be impossible.

The second major change was to nutrient cycles. As farm workers moved from the countryside to the cities to work in factories, their food supply followed them. However, unlike in the countryside, where most manure – both livestock and human – was returned to the fields, in the cities it ended up being lost, often into stream and rivers, and so circular nutrient cycles turned into linear streams, resulting in what today is called nutrient depletion/deficiency. This was not a trivial issue, and between 1830 and 1870 depletion of nutrients, and therefore soil fertility, was the central ecological concern of industrial societies in both Europe and North America. This resulted in 'guano imperialism' as rich nations scoured the globe for natural fertilisers (Foster and Magdoff 1998). Even Karl Marx, who was a political economist not a soil scientist, wrote in 1867:

> *Capitalist production collects the population together in great centres, and causes the urban population to achieve an ever-growing preponderance. This has two results. On the one hand it concentrates the historical motive force of society; on the other hand,* ***it disturbs the metabolic interaction between man and the earth, i.e., it prevents the return to the soil of its constituent elements consumed by man in the form of food and clothing; hence it hinders the operation of the eternal natural condition for the lasting fertility of the soil****...* (Marx 1976, p505–506); emphasis added)

The arrival of fossil energy and the turning of nutrient cycles into streams are considered to form the fundamental break between pre-industrial and industrial agricultures.

3.5 Justus von Liebig and inorganic plant nutrient uptake: 1840

Justus von Liebig (1803–1873) was a scientific titan who made major contributions to agricultural and biological chemistry. He is one of the principal founders of organic chemistry, and is called the father of agricultural chemistry and the fertiliser industry. Liebig disproved the dominant belief that plants take up nutrients from the soil in the form of biological materials such as manure, which was based on the simple observation that applying manure and other organic/biological materials to the soil boosted crop growth. Liebig instead showed that plants take up nutrients in the inorganic/mineral forms, and also identified a range of macro- and micronutrients. Liebig also promoted the 'law of the minimum', which described how plant growth was limited by the scarcest nutrient, rather than the total amount of nutrients available.

Liebig's book *Organic Chemistry in its Application to Agriculture and Physiology*, published in 1840, promoted chemistry as a means to revolutionise agriculture by increasing yields and lowering costs. It was translated widely, vociferously critiqued, and highly influential (Brock 1997). Liebig's work is among the first where scientific knowledge directly affects how farming is done. However, it had limited practical impact in his lifetime and until the 1940s due to the low availability and high cost of mineral fertilisers compared with manure and other biological nutrient sources. The turning point for mineral fertilisation came with the invention of synthesised nitrogen fertiliser.

3.6 Haber–Bosch nitrogen: 1909

In 1909 two Germans, Fritz Haber and Carl Bosch, developed an artificial process to fix chemically unreactive, atmospheric di-nitrogen into ammonia, the simplest form of reactive nitrogen, which is the precursor of all nitrogen fertilisers. No better means of reactive nitrogen synthesis was found in the subsequent century, and it is only in the last decade that alternatives have been developed. The Haber–Bosch process is considered one of the most important technological discoveries of the 20th century, and is estimated to be responsible for producing around half of the reactive nitrogen in the biosphere, and half the world's population only exists due to the increase in yield that nitrogen fertiliser produced (Smil 1999; Sutton et al., 2011). Its production is also currently almost entirely dependent on fossil fuel, particularly natural gas (methane), consuming 1.2% of the world's total energy on an annual basis, meaning its manufacture is a significant direct contributor to global heating.

Nitrogen is the plant nutrient, taken up from the soil (as opposed to being taken from the atmosphere e.g., carbon dioxide) that is needed in the largest amount by plants, and is typically the one that limits growth (Liebig's law of the minimum). Prior to artificial nitrogen, the main method of increasing on-farm nitrogen was to grow leguminous crops, such as peas, beans and clovers, as these have a symbiotic relationship with particular bacteria that can fix atmospheric nitrogen (called diazotrophs), and therefore increase soil nitrogen levels. However, most crops are not legumes, so, rotations are required to alternate between nitrogen-fixing and nitrogen-depleting crops, which limits farm productivity.

In the same way that fossil fuels created fundamental changes to farming, being able to import nitrogen onto the farm, instead of having to produce it *in situ,* released agriculture from another critical limiting factor, resulting in massive yield increases and the simplification of the farm system. This is why Haber–Bosch nitrogen is considered the starting point when industrial agriculture beings to transform into intensive agriculture. The massive changes that Haber–Bosch nitrogen created were then even further accelerated by the advent of the agrichemical pesticides.

3.7 The agrichemical pesticides: 1940s

What are recognised today as the artificial or synthetic agrichemical (a contraction of agricultural chemical) pesticides (in the broad meaning, including insecticides, herbicides, fungicides, bactericides, nematicides, etc.) were first developed around the 1940s. Prior to this a small range of inorganic chemicals were in use (e.g., copper sulphate-based Bordeaux mixture for control of fungal diseases on grapes, developed in 1885), but these were chemicals that could be found in nature (eobiotic). The fundamental change in the 1940s was the creation of the xenobiotic pesticides (*xeno* = alien, *biotic* = of biology); in other words, chemicals that were alien to or did not exist in nature.

It is difficult to appreciate, some 80 years since the advent of the pesticides, just how profound a technology they are. Perhaps Arthur C. Clarke's statement that 'Any sufficiently advanced technology is indistinguishable from magic' gives a sense of the astonishing power of the agrichemicals. What had often been hard, difficult work, or even impossible (e.g., killing all broadleaf weeds among a cereal crop), was now as simple and easy as spraying 'magic water' (after Clarke).

The agrichemicals therefore created another fundamental step-change in agriculture. Not only were many existing tasks simplified and needed much less labour; entirely new possibilities were created. For example, being able to control pests, diseases and weeds through chemicals meant that rotations were much less important, and therefore farm systems could be simplified, sometimes dramatically, down to just a few, or even a single crop grown year on year. Agrichemicals are therefore another core driver of the shift from industrial to intensive agriculture.

3.8 The third agricultural revolution: intensive agriculture and the green revolution: 1950s

The post Second World War period, from the late 1940s through the 1950s and into the 1960s, is when all of the nascent technologies combine to complete the transformation of industrial agriculture into intensive agriculture and the green revolution. It is called intensive agriculture because of the high levels of inputs (e.g., energy, mechanisation, fertiliser, pesticides) and high level of outputs (yield per hectare). The core technologies of intensive agriculture include:

- mechanisation powered by fossil energy, replacing muscle power – both human and animal
- widespread and dramatically increased use of inorganic/mineral fertilisers, especially Haber–Bosch nitrogen
- the widespread and intensive use of the xenobiotic pesticides
- crop breeding to maximise yield under high fertilisation and pesticide regimes (e.g., short-straw cereals and rice)
- livestock breeding to maximise growth, where feed is unlimited and their pests and diseases can be controlled through vaccines, antibiotics and agrichemicals
- a dramatic increase in the use of irrigation.

Agriculture as practised in most of the developed world, and in significant areas of the developing world, is based on these technologies and the aim of maximising yield and/or profit with limited or no regard to non-target outcomes. While intensive agriculture is now the mainstream form of agriculture, and for many feels like the only way agriculture has ever been done. However, based on starting in 1940, it has been in existence for just 80 years out of a total of 12,000 years for agriculture as a whole. From this perspective, intensive agriculture is not so much normal as a novelty, and still a work in progress.

While intensive agriculture is very new in the overall scheme of farming, the massive increase in yield and technical achievements of industrial and intensive agriculture cannot be disputed, and are quite astonishing considering the timescale they were achieved in. However, the side-effects – such as soil loss, biodiversity loss, eutrophication of waterways, climate heating, negative social impacts, and poor food quality – are now also scientifically unarguable (Hendriks et al., 2021; Herrington, 2021; Rahmann et al., 2021; Sandhu, 2021).

Further, despite the core aim of intensive agriculture and the green revolution being to end hunger, globally approximately a billion people are still hungry, with about half of them malnourished, while a similar number of people are overweight, with again, about half of them clinically obese[9]. Further, some of the obese have nutrient deficiencies that previously were only associated with significant food deprivation, due to diets that are very high in energy sources (e.g., sugars) but very low in nutrients. As the fundamental aim of intensive agriculture was to end hunger, the fact that hunger, malnutrition and famine still exist and have been joined by obesity means that not only has intensive agriculture caused many negative side-effects, it has also failed to achieve its primary aim after 80 years. This is why there are ever-increasing calls for a new agricultural revolution to address the problems created by intensive agriculture, while at the same time trying to achieve its original goal of feeding humanity.

It is therefore the paradigm of intensive agriculture that the alternative agricultures are providing an alternative to.

[9] www.who.int/en/news-room/fact-sheets/detail/obesity-and-overweight

4 The alternative agricultures

4.1 A rose by any other name[10]

There is no agreed description or definition for what this discussion, and others, calls the 'alternative agricultures'. As noted above, they are called alternative because they all aim to be different from, or offer an alternative to, the current mainstream agricultural paradigm of industrial/intensive agriculture. Another term commonly used to describe many of these forms of farming is 'sustainable agriculture', where sustainability principally refers to environmental sustainability, rather than economic sustainability, and carries the implication that the farming system can be sustained over a long period of time.

However, defining the alt-ags as everything that stands apart from mainstream agriculture produces an eclectic set, where some of the members are more different from each other than they are from mainstream agriculture. For example, no-till only differs from intensive agriculture in terms of its core focus of eliminating tillage. Moving along the spectrum, some alt-ags also include the consumption and distribution side of agriculture, as well as the production system. Others go beyond agriculture; for example, permaculture also encompasses the lived environment and social systems. Some make ethical statements about what they consider to be the 'right way for humans to farm' (i.e., they are based on a philosophy). A few, as outlined above, are also non-science-based and include or are based on aspects such as spirituality and religion.

At the same time, mainstream farming is not monolithic. It ranges from highly intensive systems, such as concentrated animal feeding operations (CAFOs) and cropping systems that may only grow one or a few different staple crops over many thousands of hectares, with the aim of squeezing every last drop of productivity from the system; through to traditional mixed farms with livestock and crops, often operating at scales of tens of hectares, probably family owned, and with equally diversified aims, including intergenerational land stewardship.

There is therefore no clear separation between intensive mainstream farming and the alt-ags. It is a continuum, from the hyper-intensive at one end that focuses only the farm and not the wider systems (particularly environmental) it is embedded in, through to the bio-eco-socially focused holistic systems that view the farm as an integral part of the whole biosphere (e.g., a Gaian view, Lovelock 1979; Lovelock 2006), at the other end. Some people would not consider farming systems such as conservation agriculture and no-till as sustainable or alternative, but they are covered here because this report is principally a

[10] Acknowledgements to Shakespeare.

guide for those perplexed by the plethora of alt-ags and what 'it all means', and an attempt to give as broad a perspective as possible, not a definitive analysis and critique.

The following alt-ags are therefore presented in a rough order of their 'importance', which is guided by how big they are, such as area of land under the system, its global presence, and how long they have been in existence. Again, the aim is to provide a description rather than a critique and analysis, so if a statement can be read as both (i.e., a factual description and a critique) then assume the former is meant.

4.2 Agroecology

Agroecology is a contraction of the terms 'agriculture' and 'ecology'. Fundamentally agroecology is about treating agriculture as an ecosystem; or, to put it another way, using an ecological lens to view, analyse, critique and create farm systems.

Agroecology as a term and concept was first coined in the late 1920s (Gliessman et al. 1998; Francis et al. 2003; Wezel et al. 2009; Wezel and Soldat, 2009). However, it was not until the 1980s that it moved into the mainstream and interest and publications started to increase exponentially (Wezel and Soldat 2009). Initially, agroecology was purely a scientific discipline studying agriculture through an ecological lens. However, over time its boundaries have progressively expanded, first to a system of agriculture, then to food systems (i.e., combining not only the production of food but also its distribution and consumption), and finally into a social and political movement.

As a scientific discipline, agroecology is the study of agriculture as an ecosystem: it uses ecological science and principles to study and understand agriculture. It is also inherently multi- and inter-disciplinary, and includes agronomy, ecology, environmental science, sociology, economics, history and many other sciences, as well as the humanities. However, agroecology does not just analyse agriculture to understand how it works, standing neutrally outside the system, as a physicist does with the laws of physics. Agroecologists started to actively intervene in the subject of their research and propose new ways to do agriculture based on the results of their scientific study. Agroecology thus moved from being purely a science, to a practice, informed by the science of ecology.

As with many of the alt-ags, its practitioners concluded that it is impossible to address sustainability in agriculture by only working only with the production system, and that distribution and consumption also have to be addressed. Therefore agroecology expanded outside the farm gate to encompass the food system as a whole, and from there it ultimately became a social movement. Agroecology has been particularly prominent in South America due to the period of structural adjustment policies in the 1970s (Altieri and Toledo 2011) and to the fact that many of the traditional and subsistence farming systems already used agroecological approaches.

The High Level Panel of Experts on Food Security and Nutrition of the FAO Committee on World Food Security (HLPE 2019) has distilled 13 key principles of agroecology (Table 1.).

Table 1. The 13 key principles of agroecology of the FAO Committee on World Food Security, High Level Panel of Experts on Food Security and Nutrition

Improve resource efficiency
1. Recycling. Preferentially use local renewable resources and close as far as possible resource cycles of nutrients and biomass.
2. Input reduction. Reduce or eliminate dependency on purchased inputs and increase self-sufficiency.
Strengthen resilience
3. Soil health. Secure and enhance soil health and functioning for improved plant growth, particularly by managing organic matter and enhancing soil biological activity.
4. Animal health. Ensure animal health and welfare.
5. Biodiversity. Maintain and enhance diversity of species, functional diversity and genetic resources and thereby maintain overall agroecosystem biodiversity in time and space at field, farm and landscape scales.
6. Synergy. Enhance positive ecological interaction, synergy, integration and complementarity among the elements of agroecosystems (animals, crops, trees, soil and water).
7. Economic diversification. Diversify on-farm incomes by ensuring that small-scale farmers have greater financial independence and value addition opportunities while enabling them to respond to demand from consumers.
Secure social equity/responsibility
8. Co-creation of knowledge. Enhance co-creation and horizontal sharing of knowledge including local and scientific innovation, especially through farmer-to-farmer exchange.
9. Social values and diets. Build food systems based on the culture, identity, tradition, social and gender equity of local communities that provide healthy, diversified, seasonally and culturally appropriate diets.
10. Fairness. Support dignified and robust livelihoods for all actors engaged in food systems, especially small-scale food producers, based on fair trade, fair employment and fair treatment of intellectual property rights.
11. Connectivity. Ensure proximity and confidence between producers and consumers through promotion of fair and short distribution networks and by re-embedding food systems into local economies.
12. Land and natural resource governance. Strengthen institutional arrangements to improve, including the recognition and support of family farmers, smallholders and peasant food producers as sustainable managers of natural and genetic resources.
13. Participation. Encourage social organization and greater participation in decision-making by food producers and consumers to support decentralized governance and local adaptive management of agricultural and food systems.

The 13 principles are by no means exhaustive, but they do illustrate the depth and breadth of agroecology, and in particular highlight the social equality and equity aspects of agroecology that other alt-ags do not address.

'Agroecology' is also increasingly used as an overarching term for many or all of the sustainable agricultures. This is in part due to terminology, in that mainstream agriculture is also referred to (often pejoratively) as 'chemical agriculture' due to 'chemicals' (i.e., inorganic chemicals such as mineral fertilisers and the xenobiotic agrichemical pesticides) being a core part of the intensive agricultural system. In contrast the sustainable agricultures are referred to as biological and ecological agricultures, as working with biology and ecology are essential to their systems, and they often eschew agrichemicals and even some mineral fertilisers. Under this nomenclature, agricultures such as organic, agroforestry, conservation agriculture, and permaculture can be considered to be particular forms of agroecology.

4.2.1 Further agroecology resources

Altieri MA. 1996. Agroecology: the science of sustainable agriculture. 2nd edition. Boca Raton, FL, USA, CRC Press.

Altieri MA, Nicholls CI. 2005. Agroecology and the search for a truly sustainable agriculture: United Nations Environment Programme. www.agroeco.org/doc/agroecology-engl-PNUMA.pdf

De Schutter O. 2010. Agroecology and the right to food. Food and Agriculture Organisation. www.srfood.org/en/report-agroecology-and-the-right-to-food

FAO Agroecology knowledge hub: www.fao.org/agroecology/overview/en

Gliessman SR. 2014. Agroecology: the ecology of sustainable food systems. 3rd edition. Bosa Roca, USA, Taylor & Francis Group.

Rosset P, Altieri MA. 2017. Agroecology: science and politics. Warwickshire, UK, Practical Action Publishing.

Wezel A, Bellon S, Doré T, Francis C, Vallod D, David C. 2009. Agroecology as a science, a movement and a practice: a review. Agronomy for Sustainable Development 29: 503–515.

4.3 Conservation agriculture

Conservation agriculture emerged as a response to the degradation of soils caused by the intensification of agriculture, and also from using farming and tillage systems from northern Europe; i.e., inversion ploughing in places where it is unsuitable, such as the prairie grasslands of America, which resulted in the dust bowl in the 1930s (Worster 2004). Approximately one-third of the planet's soils are now degraded, in large part due to intensive crop production, and to such an extent that future production in many of these areas is jeopardised[11]. The aim of conservation agriculture is to address this land/soil degradation.

The FAO is the global promotor, sponsor and driver of conservation agriculture. Its current definition is:

> ***Conservation Agriculture*** *is a farming system that promotes minimum soil disturbance (i.e., no tillage), maintenance of a permanent soil cover, and diversification of plant species. It enhances biodiversity and natural biological processes above and below the ground surface, which contribute to increased*

[11] www.fao.org/conservation-agriculture/en/

water and nutrient use efficiency and to improved and sustained crop production.[11]

This is underpinned by the 'three principles of conservation agriculture':

- minimum mechanical soil disturbance
- permanent soil organic cover
- species diversification.

The following looks at each of these in turn.

Minimum mechanical soil disturbance is a reaction to, and reversal of, the traditional tillage approaches of northern Europe, which included inversion ploughing, followed by several further tillage passes (e.g., with spring tines, harrows and rollers to produce a 'good' seedbed). This causes significant damage to the soil structure, as well as compaction, which results in soil degradation. On more vulnerable and 'delicate' soils it can result in complete destruction and even total soil loss, as in the American dust bowl. The aim is to reduce mechanical soil intervention to the absolute minimum required to terminate one crop and establish the following crop. Technically the FAO states:

The disturbed area must be less than 15 cm wide or less than 25% of the cropped area (whichever is lower). There should be no periodic tillage that disturbs a greater area than the aforementioned limits. Strip tillage is allowed if the disturbed area is less than the set limits.[12]

Permanent soil organic cover is the aim of always having either living plants or crop residues covering the soil surface to protect it from sun, wind and rain. This links back to minimum soil disturbance, as the main aim of ploughing is to bury residue/soil cover. The FAO has precise requirements for organic soil cover: 'Three categories are distinguished: 30–60%, >60–90% and >90% ground cover, measured immediately after the direct seeding operation. Area with less than 30% cover is not considered as conservation agriculture.[12]

Species diversification is also a reaction to, and reversal of, mainstream farming's simplification of the farming system, with monocultures of a small range of crops, even a single crop such as maize. At a minimum, species diversification is about diversification of crop species through rotations: 'Rotation/association should involve at least three different crops.'[12] However, the higher aim of species diversification would include a much greater range of crops in rotation than three, potentially including a pasture phase due to its large benefits for soil health and cover cropping,[13] and also growing different plant species at the same time, particularly in pasture and cover crops.

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[12] www.fao.org/conservation-agriculture/overview/principles-of-ca/en/

[13] en.wikipedia.org/wiki/Cover_crop

The FAO states that conservation agriculture provides a number of advantages at global, regional, local and farm level:[14]

- **Sustainability**. It provides a truly sustainable production system, not only conserving but also enhancing the natural resources and increasing the variety of soil biota, fauna and flora (including wild life) in agricultural production systems without sacrificing yields on high production levels.
- **Enhanced biodiversity**. CA depends on biological processes to work, it enhances the biodiversity in an agricultural production system on a micro- as well as macro level.
- **Carbon sequestration**. No till fields act as a sink for CO_2 and conservation farming applied on a global scale could provide a major contribution to control air pollution in general and global warming in particular. Farmers applying this practice could eventually be rewarded with carbon credits.
- **Labour savings**. Soil tillage is among all farming operations the single most energy consuming and thus, in mechanized agriculture, air-polluting, operation. By not tilling the soil, farmers can save between 30 and 40% of time, labour and, in mechanized agriculture, fossil fuels as compared to conventional cropping.
- **Healthier soils**. Soils under CA have very high water infiltration capacities reducing surface runoff and thus soil erosion significantly. This improves the quality of surface water reducing pollution from soil erosion, and enhances groundwater resources. In many areas it has been observed after some years of conservation farming that natural springs that had dried up many years ago, started to flow again. The potential effect of a massive adoption of conservation farming on global water balances is not yet fully recognized.
- **Increased yields**. Conservation agriculture is by no means a low output agriculture and allows yields comparable with modern intensive agriculture but in a sustainable way. Yields tend to increase over the years with yield variations decreasing.
- **Reduced costs**. For the farmer, conservation farming is mostly attractive because it allows a reduction of the production costs, reduction of time and labour, particularly at times of peak demand such as land preparation and planting and in mechanized systems it reduces the costs of investment and maintenance of machinery in the long term.[14]

For the FAO, at least, conservation agriculture has moved beyond its original narrower remit of soil protection and into wider sustainability goals, including climate heating mitigation and adaptation, addressing biodiversity loss, while maintaining – even enhancing – yields and reducing costs; in other words, better economic outcomes for the farmer. However, these are still achieved via the three principles addressing soil health.

[14] www.fao.org/conservation-agriculture/overview/why-we-do-it/en/

4.3.1 Further conservation agriculture resources

FAO documents, available at: www.fao.org/conservation-agriculture/en/

4.4 No-till

The aim of no-till is to eliminate tillage / soil disturbance as much as feasibly possible, reducing it to the absolute minimum required to drill seed into the soil and get it to successfully germinate and establish. No-till is therefore a key part of conservation agriculture by providing the technology for conservation agriculture to fully achieve its first two principles of 'minimum mechanical soil disturbance' and 'permanent soil organic cover'. No-till and conservation agriculture therefore go hand-in-hand, so the FAO is also a strong supporter of no-till and publish a range of information on it, including the no-till 'bible', *No-tillage Seeding in Conservation Agriculture* (Baker and Saxton 2007). As an indication of the high regard in which no-till is held in by its proponents, Chapter One of Baker and Saxton 2007 starts with:

> *No farming technique yet devised by humankind has been anywhere near as effective as no-tillage at halting soil erosion and making food production truly sustainable.* (Baker and Saxton 2007, pp. 1)

No-till was developed as a direct response to the difficulties farmers were having with conservation agriculture, and particularly the difficulty they were having successfully establishing crops with minimal amounts of tillage. It is also an example of the 'big agricultural science' that drove the intensification of agriculture, in that a major problem was identified, and a large, long-term, system-level project was instigated to solve the problem, which continued until the problem was fully solved – not until the funding ran out. This often required the whole system to be 'taken apart' with all aspects of the problem studied and no prior assumptions made (with many long-held beliefs found to be incorrect). Finally, the systems were to be put back together in a fully functioning final form that farmers could implement, with no further research required.

In the case of no-till this was exactly what was done over a period of about two decades (Baker and Saxton 2007, p. xiii). It is therefore considered an exemplar in terms of agricultural science fully addressing and solving a practical issue faced by real-world farmers and providing the solution in a form that farmers could immediately implement. Just for this facet alone, no-till is worth understanding. That many common and long-held beliefs were also shown to be incorrect (e.g., the common belief that crop seeds need good soil-to-seed contact so they can take up liquid water to germinate, which no-till research has unequivocally demonstrated that seeds take up water in the vapour phase) is further justification to study no-till.

No-till is therefore a very tightly defined and focused farming system, in that it is only concerned with how to drill crops into untilled ground, with potentially high levels of crop residues, and to get them to emerge and successfully establish as part of conservation agricultural approaches. It has little or nothing to say about how the rest of the farming system should work (e.g., the use of rotations), and particularly wider issues (e.g., the consumption side of agriculture).

At a practical level, tillage has been replaced in no-till systems by 'chemical ploughing'. The main purpose of inversion ploughing is to kill existing vegetation (both crop and weeds), followed by burial of residues, and lastly by the modification of soil properties (many incorrectly think the importance is the reverse of this order). Chemical ploughing, therefore, refers to the main purpose of inversion ploughing: killing existing vegetation, but using the chemistry of herbicides, not the physics of steel. To be an effective chemical plough, a herbicide needs to kill all standing vegetation, which means it needs to be 'broad spectrum' (kill all plants) and 'systemic' (once applied to the foliage, the herbicide is translocated throughout the plant, such that it kills the whole plant, including the roots).

However, there are very few herbicides that can achieve this, particularly by themselves, and the most effective one is glyphosate. No-till is therefore highly dependent on glyphosate based herbicides, which, with the growing issue of herbicide resistance (see www.weedscience.org) and growing social and political concerns about the agrichemicals as a whole, means the continued effectiveness and acceptability of glyphosate is not guaranteed, and is therefore a significant future challenge for no-till systems.

4.4.1 Further no-till resources

Baker CJ, Saxton KE. eds. 2007. No-tillage seeding in conservation agriculture. 2nd edition. Wallingford, UK, Food and Agriculture Organization of the United Nations. www.fao.org/3/al298e/al298e00.htm

4.5 Organic agriculture

Organic agriculture is a broad church among the alt-ags and has undergone significant changes in its now 100-year lifespan. To the average citizen of developed countries, organic agriculture today is best known for being 'chemical'-free food and the main, probably only, alt-ag they would see differentiated in the shops, and probably the only alt-ag they have heard of. Its origins and history are, however, far more complex than these simple views and visibility indicate. To understand organic agriculture it is necessary to understand its history, which is divided into three main phases:

- V1: soil and health organics, from c. 1920s to the 1950s
- V2: anti-pesticide organics, from 1960s to present
- V3: a future vision for organic agriculture, from 2015 onwards.

4.5.1 Organic agriculture V1

The foundations of organic agriculture were being laid at the end of the nineteenth century and into the start of the twentieth century. The foundations were many and multi-faceted, with a large proportion being the result of fundamental advances in scientific knowledge; for example, the early twentieth century was when biological nitrogen fixation and mycorrhizal associations with plants were discovered. The creation of organic agriculture was therefore driven by new scientific information changing people's understanding and perception of agriculture.

There are a considerable number of scientists, philosophers and other thinkers whose ideas were amalgamated to create organics V1. Three of the most famous are briefly described below to give a flavour of the ideas fermenting at the time.

Professor Franklin King's (1848–1911) book *Farmers of Forty Centuries, or Permanent Agriculture in China, Korea, and Japan* (King 1911) is a scientific travelogue of the pre-industrial agricultures of the orient. It describes how these agricultural systems had persisted on the same land for over 4,000 years, which no other civilisation has achieved (Montgomery 2007). King used what he learned in order to argue that replacing nutrients removed in agricultural produce is essential for the permanence of agriculture.

Sir Albert Howard's (1873–1947) capstone publication *An Agricultural Testament* (Howard 1940) promoted the importance of soil biology and organic matter (which was referred to as 'humus' at that time), plus the critical role of nutrient cycles in the health of the soil and the health-giving properties of the food grown in the soil. It was also, to an extent, a repudiation of Liebig (see section above, 'Justus von Liebig and inorganic plant nutrient uptake: 1840'). Howard is also responsible for the high value attached to hot, aerobic composting in organics, which he learnt from indiginous Indian farmers when he was stationed in Indore, India, hence the name 'Indore method' of composting. Howard also coined the organic mantra "The health of soil, plant, animal and man is one and indivisible".

Sir Robert McCarrison (1878-1960) carried out pioneering experiments demonstrating the effect of nutrition on the epidemiology of disease by studying the impact different diets had on the fighting men of India. Two key publications that are considered organic foundation texts are *Studies in Deficiency Disease* (McCarrison 1921) and *Nutrition and Health* (McCarrison 1944). Before McCarrison there was little understanding of the linkage between diet and health. The importance of what would be now be considered a healthy wholefood diet, consisting largely of plants (e.g., fresh fruit and vegetables, nuts, grains, seeds etc.) with smaller amounts of animal products was a key component of organic agriculture, i.e., organic food meant what today would be called a wholefood or healthy diet. The concept of organic confectionary for example, would be a complete contradiction, even an anathema, in V1 organic agriculture.

Based on a diverse range of new scientific information, and social and political issues and ideas, the pioneers of organic agriculture came to a number of conclusions.

- Liebig's mineral theory of plant fertilisers was too reductionist in scope and failed to take into account the importance of soil biology and closing the nutrient cycles.
- Studies of a wide range of cultures – industrial, pre-industrial agrarian and pre-agrarian – showed a strong link between diet and health.
- The food the urban poor were eating in industrial countries (refined flour and fatty meat, few vegetables) was making them ill.
- There is a direct link between soil health, the healthfulness of food grown in healthy soil, and the health of the people and animals eating that food.
- There were many other social problems associated with the urbanisation of the rural poor to work in factories.

Organic agriculture V1 therefore had a very wide base of issues, and proposed solutions. At its core was the belief that industrial agriculture was fatally flawed and must be replaced with organic agriculture. Beyond how food should be grown, organic V1 was also very concerned about diet as a whole, and promoted what today would be considered a fresh, minimally processed, wholefood diet. It was also very active in social issues, including health care systems and social structures.

From the perspective of today's organic movement there were also some quite surprising components. Much of the politics were of the right/Conservative due to many of the proponents of organics coming from the English upper classes. There were strong Christian religious groupings within the movement, and some of the social experiments could today be considered social engineering. Organics V1 was therefore a very diverse melting pot of sometimes contradictory ideas, hopes and aspirations (Conford 2001).

The 1940s saw the establishment of the key organic associations, such as Soil & Health in New Zealand (1941), the Soil Association in the United Kingdom (1946), and the Rodale Institute in the USA (1947), originally also called Soil & Health. None of the foundational organisations have the word 'organic' in their name, as the term 'organic' was coined by Lord Northbourne (1896–1982) in his book *Look to the Land* (Northbourne 1940), where he proposed that the farm should be considered a holistic entity, like an organism. Therefore the term 'organic' is a contraction of the word 'organism', not 'organic chemistry', as is often thought. It took some time for the term to catch on, which is why the first organic associations don't use the word 'organic'. The terms 'soil' and 'health' in the association names also show the core issues on which they were founded, and hence todays organic mantra, 'Healthy soil – healthy food – healthy people', reformulated from Howard's quote above. However, the term 'organic' tends to be restricted to the English-speaking world. In much of continental Europe the terms 'bio' or 'eco' (short for biological and ecological) are used as prefixes to the local word for farming or agriculture to denote they are organic. This is partly a reflection of the fact that Northbourne's book was little read much beyond English-speaking countries, but also indicates that organic agriculture is a biological and ecological form of farming. There were also a wide range of parallel drivers of organic / bio / eco agriculture in Europe. For example, Rudolf Steiner's teaching (see the Biodynamics section) was a major influence, particularly in the Germanic countries. Hans Muller, a Swiss politician who advocated circular systems with short consumer-producer loops and Prof. Hans Peter Rush who published 'La fécondité du sol pour une conception biologique de l'agriculture' (Fertility of the ground for a biological conception of agriculture) (Rusch, 1986). A key point of opposition to industrial agriculture was primarily about circular systems – closing the loop – and opposing the expanding length of supply chains. This again highlights the many threads that composed the cloth of V1 organic agriculture.

It is also worth noting that at the farm level the difference between organic V1 and contemporary industrial farming was not at all obvious, while both are utterly different from modern intensive agriculture characterised by huge farms with few staff and a high level of mechanisation, e.g., 500 kW tractors. Prior to the 1940s there are virtually no synthetic pesticides, steam engines and tractors are still mostly the preserve of the larger farms, smaller scale farms are using draft animals, the use of mineral fertilisers, especially nitrogen is still very limited, most applied nutrients are in the form of manure from livestock. So, the fact that organics, and other early alt-ags already discerned problems with the industrial model as early as the end of the 19th century and started plotting a new course is an indication of the foresight of these agricultural pioneers.

While organic agriculture made considerable progress through the 1940s, the post Second World War (1939–1945) period saw the near demise of organics. Beyond the immediate carnage and vast loss of life in the fighting itself and bombing of civilian populations, much of Europe faced massive food shortages and even starvation. The population and politicians wanted farming to dramatically increase food production to feed the hungry. Industrial agriculture responded to this by evolving into intensive agriculture (see the above section, 'The third agricultural revolution: intensive agriculture and the green revolution: 1950s') with the introduction and rapid update of the agrichemical pesticides, and a dramatic increase in the use of mineral fertilisers, especially nitrogen, resulting in dramatic yield increases. In comparison, organic agriculture was still promoting somewhat esoteric links between soil 'health', food quality, and human health, the importance of compost, etc. Organic agriculture simply lost the argument, and nearly ceased to exist (Conford 2001).

4.5.2 Organic agriculture V2

Unlike the foundation of organics V1, which was a labyrinth of evolving ideas, the transmutation from V1 to V2 of organic agriculture in english speaking countries has been clearly pinned to one event: the publication of *Silent Spring* by Rachel Caron (Carson 1962) (Conford 2011). *Silent Spring* launched the modern environmental movement, turning environmental science from an obscure academic discipline into an international political and social issue. For the failing organic movement, it created the paradigm change from the multiple issues of V1 to a much more narrow focus on the agrichemical pesticides, and their unpredictable harms, which were the core issue of Carson's book.

Modern organics (V2) can be boiled down to three key issues in terms of the production system:

- prohibition of synthetic (non-naturally occurring) materials in the production system
- prohibition of soluble mineral fertilisers
- prohibition of genetically engineered/modified/transgenic organisms.

These issues are reflected in the definitions of organic agriculture. The following is from IFOAM:

> *Organic Agriculture is a production system that sustains the health of soils, ecosystems, and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic Agriculture combines tradition, innovation, and science to*

benefit the shared environment and promote fair relationships and good quality of life for all involved. (IFOAM General Assembly 2008)[15]

There are a range of other issues that are also part of organics V2 that transferred over from V1 but at lower levels of importance, such as a concern about soil health, its impact on food quality and the health of animals, including people eating that food. Other issues, such as many of the social aspects, have been lost and the politics have mostly moved to the left / green end of the political spectrum.

Not only was there a revolution in the core issues that organic agriculture encompassed, but a social revolution also occurred, as the founders of organics, who were often from English societies' upper classes and to the right of politics, were pushed out by the young social revolutionaries of the 1960s, often from lower social classes with politics of the left. The change from V1 to V2 of organic agriculture was therefore a full social and political revolution within the movement (Conford 2011).

The three core issues listed above are codified in the 'Organic Standards', which are a detailed prescription of what is, and particularly what is not, permitted in organic farming and food processing. The standards are enforced through an auditing and quality assurance system called 'certification', which (it is believed) is the first time any form of agriculture has had such a quality assurance system.

At the same time, while the standards have the narrow focus described above, the principles of organic agriculture, as described in the section 'Examples of agricultural value systems', are much broader, more holistic, and more in keeping with the diverse aspects of organic V1. There is, therefore, something of a divergence between the narrower and highly practical focus of standards and the wider aims and aspirations of the principles. This, in part, is driving the desire from within the organic movement to further evolve into 'Organic 3.0', as described below.

A core impetus for the introduction of standards and certification was to facilitate commercialisation of organic produce. In V1 of organic agriculture, if you wanted to buy organic food you went direct to the farmer or a small number of specialist wholefood retailers, who bought directly off the farmer themselves. Trust in the system was maintained by direct social interactions, and reinforced by both producers and consumers being part of the 'organic movement'. However, as the number of producers increased in organic V2, processing of food increased and the number of consumers expanded, and the direct trust model started to fail. In response, the certification system was created to provide third-party verification of organic farmers and food processors, and traceability through the processing and retail chain. Typically, the third party was an existing organic association.

[15] www.ifoam.bio/why-organic/organic-landmarks/definition-organic

This has resulted in a considerable number of outcomes. The primary one is that organic agriculture is nearly the only alt-ag that has monetised its values, and it is the only one that has done so at scale and systematically across the globe (the other main one being Biodynamics, but at much smaller scale). Organic produce frequently attracts a price premium over the equivalent non-organic produce, and so in some cases the premium is essential to maintain profitability against often lower-cost mainstream farming systems. In part the higher cost of organic production incorporates a greater level of economic externalities (e.g., wildlife protection) than mainstream farming, so needs some means of recouping the extra costs (Kristiansen and Merfield, 2006). A flow-on effect of price premiums, and therefore higher profitability in organic agriculture, is that economics has become at times a significant driver of the uptake of organics, as opposed to being solely driven by the value system (the IFOAM principles), which can result in tension between the values and economics. Organic agriculture V2 contains a large diversity of values, ideas and passions about how agriculture should be done, as much as being a system of farming.

4.5.3 Organic agriculture V3

From the mid-2010s there was a growing realisation within the organic movement that there was need for reform and to evolve organic agriculture. This realisation became formalised by the International Society of Organic Agricultural Research (ISOFAR[16]), which ran the symposium 'Organic 3.0 is Innovation with Research' (20–22 September 2015, Republic of Korea) (Rahmann et al. 2016). This resulted in IFOAM picking up and developing the concept, resulting in the concept of "Organic 3.0" being approved by the IFOAM General Assembly in New Delhi in 2017. According to Arbenz et al. (2016):

> *The overall goal of Organic 3.0 is to enable a widespread uptake of truly sustainable farming systems and markets based on organic principles and imbued with a culture of innovation, of progressive improvement towards best practice, of transparent integrity, of inclusive collaboration, of holistic systems, and of true value pricing.*

Organic agriculture therefore continues to evolve and adapt to the changing societal and agricultural environment, with the aim of keeping itself relevant and at the forefront of the alternative agricultures.

Of relevance in Aotearoa NZ is the Hua Parakore system, an indigenous verification and validation system for mahinga kai (food) was launched in 2011. With support from Māori communities and Te Waka Kai Ora (National Māori Organics Authority of Aotearoa) it has become a hallmark of influence in terms of promoting the re-establishment of diverse, vibrant and food secure indigenous economies (Hutchings et al 2012; 2018).

[16] www.isofar.org

4.5.4 Organics at the farm level

At a practical farm level, organic agriculture's key difference from mainstream agriculture is the prohibition of the synthetic agrichemical pesticides, nitrogen fertiliser, and genetic engineering. This has required non-chemical approaches to pest disease, and particularly weed management, to be developed. Some of this management is achieved at a system level, the use of rotations being a key example, and also illustrates how organic agriculture has resurrected/continued farming techniques that were in use before the introduction of pesticides and the widespread use of nitrogen fertilisers, in particular.

However, organic agriculture does not just look backwards in time: it is also responsible for significant innovation, for example, in physical/mechanical weed control techniques. Indeed, with the inescapable rise in herbicide-resistant weeds, many of the significant advances and achievements in organic weed management are being taken up by intensive agriculture as part of the vital move to integrated management systems[17]. For example the use of computer-guidance of machinery such as drills and interrow hoes, using computer vision and the highly accurate real-time kinematic global positioning system (RTK GPS) allows much larger weeding machinery to be used at much greater precision and speed than was possible using human controlled equipment (PAN Europe et al. 2018). In addition, insect and disease management in organic agriculture have been a vital test-bed and economic driver for a wide range of biological control solutions; for example, the use of the bacteria *Bacillus thuringiensis* for the control of caterpillars on vegetable crops.

As a replacement for nitrogen fertilisers, organic agriculture is mostly reliant on the use of leguminous crops or pasture species, which have a symbiotic relationship with nitrogen-fixing bacteria. This obliges the use of rotations in cropping systems whereby non-leguminous, nitrogen depleting crops, are alternated with nitrogen fixing leguminous crops. While more sophisticated techniques such as intercropping leguminous and non-leguminous crops (which includes mixed species pastures) could reduce the need for such rotations, however rotations have many other on-farm benefits, such as pest and disease management, and also benefits to the wider environment (e.g., biodiversity and nutrient loss to water) so are valuable for a wider range of positive outcomes (Merfield 2019b). With the growing understanding of the multiple, negative, cradle-to-grave effects of nitrogen fertilisers (Sutton et al. 2011), mainstream farming is also increasing its use of biologically fixed nitrogen to help address these issues.

In regard to genetic engineering (GE), a technology that was only introduced to agriculture in the 1990s, organic agriculture has simply continued to use pre-GE techniques. In addition, many GE traits are designed to be used with agrichemicals (e.g., herbicide-resistant crops), so are irrelevant to organic agriculture because the agrichemicals are prohibited in organic farming.

[17] en.wikipedia.org/wiki/Integrated_pest_management

While there are significant practical differences between organic and mainstream agriculture, in many instances organic farms can appear similar to the same farm types in the same regions, at least to the untrained eye (e.g., an organic cereal farm in the south of the UK looks very similar to its mainstream neighbour, except for the absence of tramlines from spraying). This is partly a reflection that not all mainstream farm systems have not become highly simplified (e.g., they still have rotations of crops or mixed farming) while the organic farms may only be implementing the minimum requirements of standards, and have not implemented more advanced techniques such as intercropping, agroecology and agroforestry that are visually different. This is in contrast to an alt-ag such as permaculture, where a radical redesign of the production system is inherent to the system. So, to an extent, organic agriculture is a variation on the theme of mainstream agriculture, in that organic farmers still use tractors, cultivate the ground, and even use spraying equipment, but to apply organic approved materials such as biological pesticides, rather than synthetic agrichemical pesticides.

4.5.5 Further organic agriculture resources

Conford P. 2001. The origins of the organic movement. Edinburgh, UK, Floris Books.

Conford P. 2011. The development of the organic network: linking people and themes, 1945–95. Edinburgh, UK, Floris Books.

IFOAM (The International Federation of Organic Agricultural Movements): www.ifoam.bio

Kristiansen PE, Taj A, Reganold JP. eds. 2006. Organic agriculture: A global perspective. Collingwood, Australia, CSIRO Publishing.

Lampkin N. 1994. Organic farming. Ipswich, UK, Farming Press Books.

Lockeretz W. ed. 2007. Organic farming: An international history. Cambridge, Massachusetts, USA, CABI.

Organic 3.0 for truly sustainable farming & consumption, 2nd edition, 2016 www.ifoam.bio/organic3zero

Rahmann G, Reza Ardakani M, Bàrberi P, Boehm H, Canali S, Chander M, David W, Dengel L, Erisman JW, Galvis-Martinez AC, et al. 2017. Organic agriculture 3.0 is innovation with research. Organic Agriculture 7: 169–197. doi:10.1007/s13165-016-0171-5

4.6 Biodynamics

Biodynamics is placed immediately after organics due to the date of its origins being similar and its deriving from the same milieu as organic agriculture. Plus, many on-farm practices are quite similar. However, as discussed in the section 'The use, or non-use, of science in agriculture', it is nevertheless fundamentally different from organic agriculture and most of the other alt-ags due to being based on the esoteric spiritual movement Anthroposophy. Anthroposophy (from *anthropo-*, human, and *sophia*, wisdom) was created by Rudolf Steiner, an Austrian philosopher, social reformer, architect and esotericist. Steiner laid down the foundations of biodynamics in a series of eight lectures in 1924, now simply called the 'agricultural lectures' (Steiner 1993).

At a simple, practical level, the commonalities with organic agriculture include the prohibition of synthetic chemicals in the production system, instead using mechanical, ecological and biological approaches for pest, disease and weed management (e.g., rotations, inter-row hoeing and biological control). Biological fertilisers (e.g., animal manure and compost) are used instead of mineral fertilisers, and the farm is treated as a whole system, with a particular focus on traditional breeds and cultivars. In addition to organics, there is an emphasis on the importance of livestock in the farm system (i.e., mixed farming systems are preferred rather than stockless systems (e.g., solely horticultural units), and among the livestock, cattle (*Bos taurus*) have a particular importance and reverence. Local production and distribution systems are also more strongly emphasised than in organic agriculture.

There are also several areas where biodynamics completely branches away from organic agriculture at the farm level, such as the importance given to astrological influences on the farm, and the timing of sowing, planting and other activities by astrological events, including phases of the moon. The use of a range of 'homoeopathic preparations' (normally just referred to as 'the preparations') is obligatory to be considered biodynamic, and failure to apply them as required can result in loss of biodynamic status. Indeed, to achieve biodynamic certification a producer must farm using the biodynamic preparations and composting techniques developed by Rudolf Steiner. It is recommended but not necessary that producers follow the biodynamic calendar, regulated by the movements of the spheres. There are nine preparations prescribed by Steiner during the agricultural lectures numbered 500 to 508. Fox example, 500 is a humus mixture prepared by filling a cow's horn with cow manure and burying it 40–60 cm below the soil surface in the autumn. It is left to decompose during the winter and recovered for use the following spring, using prescribed dilution, stirring and application techniques. Homoeopathic medicines are also used for livestock health, and are typically used as the first treatment option.

Most countries where biodynamics is practised have a national association which runs the certification system, often called Demeter (named after the Greek goddess of the harvest and agriculture). The certification system is similar to that used in organic agriculture, in that there is a set of standards (rules) and an auditing/certification system.

Compared with organic agriculture, which has in part achieved its significant global size due to some participants (farmers, processors, retailers etc.) being involved for economic reasons, most people involved in biodynamics strongly believe in the system and its foundational system of Anthroposophy, and are involved for philosophical rather than economic aims.

4.6.1 Further biodynamics resources

Steiner R. 1993. Spiritual foundations for the renewal of agriculture: a course of lectures held at Koberwitz, Silesia, June 7 to June 16 1924. Creeger CE, Gardner M. Trans.). Kimberton, PA, USA, Bio-Dynamic Farming and Gardening Association, Inc.

Demeter International: www.demeter.net

4.7 Agroforestry

Agroforestry is a farming system where trees or shrubs (woody vegetation) are deliberately grown among crops (e.g., cereals or vegetables), which is called 'agrisilvicultural', or with livestock on pasture, which is called 'silvopastoral'. In most instances the woody vegetation is also itself a crop (e.g., for timber, nuts, fruit, medicines, etc.) and/or a host for other crops (e.g., symbiotic fungi such as truffles).

The origins of agroforestry are unclear, but techniques like it may well go back to the origins of agriculture, where small areas of land were cleared in existing woodland for crop and livestock production. A historical example that still persists to this day is the Spanish Dehesa / Portuguese Montad, which can be traced back to at least the early Middle Ages and covers some 20,000 square kilometres. It is particularly famous for both its cork oaks, which can reach 250 years of age, and for the black Iberian pig, which feed on acorns and from which Jamón ibérico ham comes. However, the Dehesa produces many more products, including wild game, mushrooms, honey, firewood, and Spanish fighting bulls.

Agroforestry is practised globally, with Canada, continental Europe (particularly France, Germany, Switzerland, Austria, Spain and Portugal) and China being notable, although agroforestry is also (re)gaining ground in many countries such as the USA and the UK, where it had fallen into disuse or regulations and agricultural subsidies actively worked against it over previous decades. In many parts of Africa, agroforestry systems prevail against monoculture-based production systems for various biophysical and socio-political reasons (Djurfeldt et al. 2005; Mbow et al. 2014). In Latin America, agroforestry now covers between 200 and 357 million hectares and has developed significantly, although unevenly (Somarriba et al., 2012).

Most modern agroforestry systems typically use straight rows of trees, with gaps of between 10 to 50 metres between them. Where large trees are grown (e.g., for timber), typically they are in a single row, while for smaller trees (e.g., fruit or bushes), there may be two to four rows. Straight rows are used to facilitate machinery use, particularly in the alleys between the tree rows, and are often sized to fit existing equipment such as sprayers and harvesters. For silvopastoral systems, the requirement for exactly spaced rows is much lower, and in some, like the Dehesa, the trees are 'naturally' spaced so that the landscape appears natural rather than man-made.

Agroforestry works by mixing woody vegetation with pasture/crops to create ecological diversity and an ecological succession-type environment, which enhances the functionality and sustainability of the whole system. It is therefore a form of intercropping, but with much greater diversity than intercropping of solely annual crops. The woody vegetation occupies different ecological niches to the pasture or the crops, both the roots and foliage, such that there is significant complementarity/symbiosis between them. Exceptions are agroforestry systems where different woody species are planted together, some for wood production and others for food production (e.g., Holt and Murphy, 2018). This means that the 'land equivalent ratio' (LER) is almost always greater than 1. LER describes the relative land area required under monoculture to produce the same yield as under intercropping. It is calculated by comparing the yield of the agroforestry system with the monoculture yield of its component systems:

LER = (tree agroforestry yield / tree monoculture yield) + (crop agroforestry yield / crop monoculture yield).

Therefore, it is almost always more productive (i.e., higher yields) to crop a fixed area of land under an agroforestry system than under separate monocultures (e.g., Niether et al. 2020)

Agroforestry also introduces diversity into the farming system, which, while this increases management requirements, also increases farm economic resilience and stability due to diversified income streams, both in type and in time. Often pests and diseases of both the pasture/crops and trees are reduced, because in a monoculture pests and diseases have nothing but their host present, while in diversified systems the different species act like a barrier or 'fire break', slowing spread and reducing the total amount of hosts for any given pest and disease (Bedoussac et al., 2015).

There are substantial pest and disease benefits from the altered microclimates, particularly for trees, where the extra light and airflow can dramatically reduce fungal diseases, for example. There are also benefits for livestock by providing shade and shelter from sun, cold and wind, which not only improves animal welfare but can also significantly increase animal growth and therefore profitability.

Where browsing is possible, the increase in forage diversity can have growth benefits beyond the direct dry matter intake, and many trees have well-documented medicinal benefits (e.g., willow is the original source of aspirin, and livestock have been clearly shown to be able to self-medicate when offered a range of suitable woody species; Johnson 2012). In addition, the right tree species can act as out-of-season fodder, such as during winter or droughts. Somewhat counterintuitively, the trees can boost crops and pasture in the alleyways even though they may shade the crop for part of the day, with the yield increase often due to reduced wind and water loss i.e., improve water use efficiency, as well as other benefits related to pests and diseases outlined above (Dagar and Tewari 2018; Staton et al. 2019; Wu et al. 2016).

However, beyond being more productive and profitable for the farmer, the multitude of positive environmental benefits from agroforestry are considered exceptional (see Easdale et al. 2021). At a general level agroforestry increases biodiversity far beyond the extra deliberately planted species, as perennial woody vegetation offers many ecological niches for a large diversity of species, from microbes, through invertebrates, to vertebrates as well as plants (e.g., understorey).

Planting woody vegetation can be an important climate-heating mitigation technique, but the benefits in an agroforestry situation can be greater than in monoculture forests, partly because the trees are forced to root deeper. This puts soil carbon at depth, where it is the most protected from release, and it also helps to increase soil carbon where annual crops are grown due to leaf litter (Kumar and Nair, 2019). In this respect the LER concept applies as much to mitigating climate change as it does to crop farming. Soil quality is often improved for a multiplicity of factors, such as the increased diversity of plant species, which directly benefits soil biology (Stockdale and Watson, 2012; Merfield and Shaw, 2013), the presence of perennial vegetation, and increased biomass production and cycling, to name a few.

The presence of pasture and annual crop roots in the alleys, particularly when tillage is used, 'forces' the trees' feeder roots deeper into the soil profile, which means they can 'catch' nutrients, particularly nitrate nitrogen, that have leached beyond the crop/pasture root zone. In addition, the presence of woody vegetation, especially with a permanent pasture or herbaceous understorey, acts as a physical barrier to soil and overland nutrient loss (e.g., phosphorus), particularly on steeper grazed land. Coupled with improved soil health, all of these factors mean agroforestry can significantly reduce nutrient and soil loss, via both water and wind erosion. Whilst Agroforestry has been relatively little researched, it has been shown to significantly reduce erosion on hill pastoral systems (Wall et al. 1997). It is worth noting that erosion mitigation potential of agroforestry differ between different agroforestry systems, species and their landscape configuration (e.g., Bregman, 1993).

Agroforestry is also a cross-cutting farming system in that it can be used in cropping, livestock, mixed farming, intensive agriculture, organic agriculture, conservation agriculture, no-till, etc., and in any climate where trees will successfully grow. Agroforestry is therefore considered to have enormous potential globally as a means to address many of issues related to food production, environmental degradation and adaptation to climate change (see Lavorel and Grelet, 2021). So, therefore, as for conservation agriculture and no-till, the FAO is a strong promotor of agroforestry.

4.7.1 Further agroforestry resources

AFINET (AgroForestry Innovation NETworks): euraf.isa.utl.pt/afinet/

FAO: www.fao.org/forestry/agroforestry/en/

World Agroforestry Centre (ICRAF): www.worldagroforestry.org/

4.8 Permaculture

The term 'permaculture' was coined by Bill Mollison and David Holmgren in 1978. Originally it was a contraction of 'permanent agriculture', but was later changed to stand for 'permanent culture', since social aspects and the lived environment are integral to permaculture.

Permaculture's roots and the concept of permanent agriculture can be traced back to writings such as Franklin King's *Farmers of Forty Centuries* (King 1911), Masanobu Fukuoka's natural farming (see section 'Masanobu Fukuoka's natural farming'), the writings of Stewart Brand, author of the *Whole Earth Catalogue*[18], and also P.A. Yeomans in Australia and his 'keyline plough' (e.g., Yeomans 1958, 1973). In the late 1960s, in Tasmania, Australia, Mollison and Holmgren started building on these thinkers, by developing their own ideas about permanent and stable agricultural systems, which turned into the publication *Permaculture One* (Mollison and Holmgren 1978), followed by

[18] www.wholeearth.com

Permaculture Two (Mollison, 1979) and *Permaculture: A Designer's Manual* (Mollison 1988), along with Mollison teaching his 'Permaculture Design Course'. The concept of permaculture was therefore consciously and deliberately designed as a whole entity, from theory to practical implementation. Somewhat pleasingly, this mirrors the way a permaculture site is deliberately designed and created as a whole system. This can be contrasted with organic agriculture, which slowly coalesced out of a large milieu of ideas from many different thinkers and practitioners, and likewise organic farms often evolve from their non-organic predecessor rather than starting with a clean slate.

Permaculture spread rapidly from its small beginnings as Mollison encouraged his direct students to set up their own permaculture design courses, so that it is now a significant global network across all the world's continents.

Permaculture is a set of deliberate design principles, based on a wide range of theories and sciences, such as systems theory (of complex systems), ecology, and sociology, with the aims of combining natural principles of resilience and synergies with cyclical nutrient cycles, using renewable resources and energy to create productive agro-ecosystems as part of the lived environment. To quote Geoff Lawton, one of Mollison's first students and now a global permaculture leader, permaculture is "A system of design that provides all the needs of humanity in a way that benefits the environment".

This broad definition has been codified in the 'Foundational Ethics' of permaculture:

- care of the earth: provision for all life systems to continue and multiply
- care of people: provision for people to access those resources necessary for their existence
- return of surplus: to those two goals – if there is extra of something, use it either to help people or help the Earth, never waste it. (Mollison 1988; Holmgren 2002; Fiebrig et al. 2020).

These were also discussed in the section 'Examples of agricultural value systems' on agricultural value systems.

Based on this foundation there are 12 design principles (Holmgren 2002):

> *Observe and interact:* By taking time to engage with nature we can design solutions that suit our particular situation.
>
> *Catch and store energy:* By developing systems that collect resources at peak abundance, we can use them in times of need.
>
> *Obtain a yield:* Ensure that you are getting truly useful rewards as part of the work that you are doing.
>
> *Apply self-regulation and accept feedback:* We need to discourage inappropriate activity to ensure that systems can continue to function well.
>
> *Use and value renewable resources and services:* Make the best use of nature's abundance to reduce our consumptive behaviour and dependence on non-renewable resources.

Produce no waste: By valuing and making use of all the resources that are available to us, nothing goes to waste.

Design from patterns to details: By stepping back, we can observe patterns in nature and society. These can form the backbone of our designs, with the details filled in as we go.

Integrate rather than segregate: By putting the right things in the right place, relationships develop between those things and they work together to support each other.

Use small and slow solutions: Small and slow systems are easier to maintain than big ones, making better use of local resources and producing more sustainable outcomes.

Use and value diversity: Diversity reduces vulnerability to a variety of threats and takes advantage of the unique nature of the environment in which it resides.

Use edges and value the marginal: The interface between things is where the most interesting events take place. These are often the most valuable, diverse and productive elements in the system.

Creatively use and respond to change: We can have a positive impact on inevitable change by carefully observing, and then intervening at the right time.

These design principles illustrate that permaculture is far more than a food production system: it is in many ways a philosophy of how humans should live in the world, in a way that is compatible with the planet's biophysical limits, which therefore allows humans to persist within nature over long time scales. This can also be viewed as having strong commonalities with indiginous approaches to agriculture.

Permaculture also draws on a very wide range of other ideas and concepts, such as agroecology, nature farming, rainwater harvesting, natural building, cell/mixed grazing, keyline design, hügelkultur (burying wood to improve soil water retention), and mulching. From this perspective, permaculture can be viewed as the highest-level integration of a wide range of other agroecological farming and living techniques.

At a practical level, the archetypal permaculture site is created by understanding the local environment (i.e., soil, topography, climate and designing a food production system), mostly using perennial vegetation, and also livestock, which also includes the lived environment, typically a home, in such a way that the home and the food production system are a single, integrated system, with the home at the centre.

Permaculture is therefore highly attractive to people interested in self-sufficiency, as self-sufficiency, along with diversity, closed-loop / circular systems and the deliberate inclusion of humans and their lived environment, are core objectives of permaculture systems. This means that permaculture-grown produce (food, fibre etc.) is rarely seen for sale, except at 'farm gates' (to generate a small income for items that cannot be produced on site), which contrasts with organic agriculture, where a significant driver of the success of organics has been monetising itself, which has driven the creation of certification systems to facilitate marketing and trade. Permaculture, while sharing the same underlying bio and ecocentric philosophy as organic agriculture, differs very considerably in its solutions.

4.8.1 Further permaculture resources

Holmgren D. 2002. Permaculture: principles and pathways beyond sustainability. Hepburn, Victoria, Australia, Holmgren Design Services.

Mollison B. 1979. Permaculture Two. Tagari Press

Mollison B. 1988. Permaculture: a designer's manual. Tagari Press

Mollison BC, Holmgren D. 1978. Permaculture One: a perennial agricultural system for human settlements. Melbourne, Australia, Transworld Publishers.

Permaculture Institute www.permaculture.org

Permaculture Research Institute www.permaculturenews.org

4.9 Masanobu Fukuoka's natural farming

'Natural farming' is an ecological approach to farming created by Masanobu Fukuoka (1913–2008) introduced by his book *The One-Straw Revolution*, originally published in 1975 and first translated into English in 1978 (Fukuoka et al. 2010). Fukuoka was a Japanese farmer and philosopher, who originally trained as an agricultural scientist specialising in plant pathology/microbiology, and then while recovering from pneumonia had a profound spiritual experience that totally transformed how he perceived agriculture. He then returned to the family farm to develop the ideas of natural farming, which is also referred to as 'the Fukuoka Method', 'the natural way of farming' or 'do-nothing farming', although the latter does not mean do nothing (as in be lazy), but rather minimise inputs. This means all inputs, not just the synthetic agrichemicals, but also the likes of labour.

Fukuoka asked why we do the things we do in agriculture and what happens if we simply stop doing them. To an extent this involves letting nature run its course and carefully altering its trajectory to partly meet the farmer's needs. This is encapsulated in Fukuoka's five principles:

- no tillage
- no fertiliser
- no pesticides or herbicides
- no weeding
- no pruning.

So, unlike permaculture, which is a set of very deliberate design principles and techniques, these principles encompass a more general philosophical view. Natural farming is therefore not so much a clearly defined farm system such as organic agriculture, with its principles, definitions and standards, as it is a perspective or world view. It is therefore as much an inspiration informing a wide range of other farming systems, such as permaculture, organic agriculture and Regenerative Agriculture (RA), as it is a farming system practised in its 'pure' form as promoted by Fukuoka.

Fukuoka's work continues to be promoted and expanded by new generations of proponents, and it continues to inspire new generations of alt-ag farmers, with all his works still in print and being reprinted and updated for modern audiences.

4.9.1 Further natural farming resources

Fukuoka M, Korn L, Berry W, Lappe FM. 2010. The one-straw revolution: an introduction to natural farming. New York, NY, New York Review Books.

Masanobu Fukuoka's Natural Farm: www.f-masanobu.jp

Akame Natural Farming School: www.akameshizennoujuku.jimdofree.com

4.10 Holistic management

Holistic management is a grazing management system that was developed by Allan Savory and is a registered trademark of Holistic Management International. Savory developed his ideas in the 1960s while working as a wildlife biologist in his native Southern Rhodesia. He was concerned about increasing desertification and worked to understand the problem within an environmental framework. He was particularly influenced by the writings of André Voisin (Voisin 1959, 1960; Voisin and Lecomte 1962), a French biochemist and farmer and known best for developing rational/intensive grazing. Savory's analysis was that the loss of the large, freely moving herds of herbivores had significantly degraded ecosystem processes. He then promoted the idea that grazing should be done by high-density herds that are rapidly moved from one piece of pasture to the next, imitating the way large herds of grazing animals on the savannah and temperate grasslands naturally behave. The aim is to repair the damage done by 'set stocking'[19] grazing management, and rebuild soil health (particularly soil organic matter / carbon) to address the climate crisis, resilience, productivity and farming viability. According to Savory, "Holistic Management restores grasslands. Healthy grasslands lead to carbon sequestration, drought resilience, food security, and financially viable communities"[20].

Holistic management takes this analysis and solution and turns it into a management system. At its heart, holistic management is a form of rotational grazing, as pioneered by Voisin. However, it extends it to take into account four ecosystem processes: the water cycle, the nutrient cycles (including carbon), energy flows, and community dynamics. It does this through the four principles of holistic management:

- Nature functions as a holistic community with a mutualistic relationship between people, animals and the land.

[19] Set stocking is where livestock are left on the same pasture for extended periods of time and is the opposite of rotational grazing.

[20] https://savory.global/holistic-management/

- Agricultural planning systems must be flexible enough to adapt to nature's complexity.
- Domestic animal species can be a substitute for lost keystone species.
- Time and timing is the most important factor when planning land use. (Savory 1988; Butterfield et al. 2006)

Based on these principles, there is a framework to guide decision-making. In brief the framework is:

- define in its entirety what you are managing
- define what you want now and for the future
- watch for the earliest indicators of ecosystem health
- don't limit the management tools you use
- test your decisions with questions that are designed to help ensure all your decisions are socially, environmentally and financially sound, for both the short and long term
- monitor proactively, before your managed system becomes more imbalanced.

Like all of the alt-ags, the principles and framework have evolved over the years and continue to do so. The holistic management concept has also moved beyond grazing and has extended into whole-farm planning.

In its original form holistic management is focused on optimal grazing management and therefore pasture plant management, and flowing from that good soil management, which was the starting point of Savory's journey. As a form of grazing management, it is often a key component of other farming systems with significant livestock components (e.g., RA; see the section 'Regenerative Agriculture and biological and carbon farming'), though it is not a requirement of those systems.

4.10.1 Further resources:

Butterfield J, Bingham S, Savory A. 2006. Holistic management handbook: healthy land, healthy profits. Washington, DC, Island Press.

Savory A. 1988. Holistic resource management. Washington, DC, Island Press.

Savory Institute: savory.global and www.savoryinstitute.com

4.11 Carbon farming

Carbon farming aims to sequester and store atmospheric carbon dioxide in the soil, mostly as soil organic matter, white retaining current production systems, e.g., livestock, arable, vegetables. This therefore differs from planting forests which aims to sequester and store a significant proportion of carbon in the wood of the trees as in the soil. Carbon farming is based on manipulating the natural carbon cycle, whereby through photosynthesis, plants capture carbon dioxide from the atmosphere and store it in their tissues. When they die, this carbon can either released back into the atmosphere through respiration or it can be stored for long periods of time in the soil under the right conditions. Carbon farming uses a broad set of practices to maximise the amount of carbon sequestered by plants in the soil thereby, such as cover cropping[21], crop residue retention, reducing or eliminating tillage (cultivation), using diverse plant mixtures, diversified crop rotations and adding materials such as biochar[22]. This contrasts with standard / traditional farming practices that reduce soil carbon, such as fallow (where soil is not planted but repeatedly tilled to kill vegetation leaving the soil bare), removing or burning crop residues, inversion ploughing based tillage, monocultures, and simplified or no rotations.

'Carbon farming' as a concept originated in the late 1990s and early 2010s as a response to climate change (warming) and the benefits that come from rebuilding soil carbon through removing it from the atmosphere. Initiatives such as the '4 per mille'[23] are an example of this approach (Minasny et al. 2017; Arrouays and Horn 2019). Carbon farming was also seeking to take advantage of 'carbon credits' through the global carbon trading/taxation systems being conceived at that time.

Carbon farming is still being actively pursued, for example, in the European Union, the European Commission has tabled an in depth review of the EU's energy and climate laws the "Fit for 55 package"[24] which includes carbon farming as part of the strategy[25]. In the USA President Biden's Green Plan may include carbon farming[26] and a range of companies are already paying farmers for practices that increase soil carbon[27]. In Australia carbon farming is often based on reforestation using native trees[28, 29.] Beyond farming there is a strong push to increase carbon sequestration and storage in other biological systems e.g., via reforestation of natural woodlands and wetland restoration[30].

4.11.1 Further carbon farming resources

Lal R. 2004. Soil carbon sequestration impacts on global climate change and food security. Science 304:1623–1627. doi:10.1126/science.1097396

Montgomery DR. 2017. Growing a revolution: Bringing our soil back to life. New York, USA: W.W. Norton & Company.

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[21] en.wikipedia.org/wiki/Cover_crop

[22] en.wikipedia.org/wiki/Biochar

[23] www.4p1000.org

[24] ec.europa.eu/commission/presscorner/detail/en/ip_21_3541

[25] www.euractiv.com/section/agriculture-food/news/eu-sets-the-scene-for-carbon-removal-actions-in-farming/

[26] www.bloomberg.com/news/articles/2021-04-20/the-carbon-market-gold-rush-in-american-agriculture

[27] www.reuters.com/business/sustainable-business/cargill-launches-us-carbon-farming-program-2022-season-2021-09-16/

[28] carbonpositiveaustralia.org.au/

[29] www.cleanstate.org.au/unlocking_our_carbon_farming_potential

[30] www.theguardian.com/environment/2021/sep/27/planting-a-vision-why-the-secret-to-rewilding-success-is-about-people-not-trees-aoe

Toensmeier E. 2016. The carbon farming solution: A global toolkit of perennial crops and regenerative agriculture practices for climate change mitigation and food security. Chelsea Green Publishing.

www.agriculture.gov.au/water/policy/carbon-farming-initiative

www.4p1000.org

carbonfarmersofaustralia.com.au/carbon-farming

4.12 Biological farming

Biological farming/agriculture is considered to have evolved out of carbon farming, because many of the farmers, growers and organisations involved in carbon farming progressed to biological farming. For example the Aotearoa New Zealand Carbon Farming Group was introducing Biological Farming to its members in 2011[31]. In addition there is a straight forward progression from carbon to biological farming because building soil carbon means building soil organic matter, and building organic matter means farming more biologically and less chemically.

The key focus of biological farming is on soil health, which correlates with the focus of carbon farming on soil carbon / organic matter, as building soil organic matter is highly likely to increase soil health (Montgomery 2017). But the interest in soil health in biological farming is considered to be much broader than the focus on soil carbon in carbon farming, with a particular focus on soil biology, especially microbial biology such as mycorrhizal fungi. Specialist soil analysis systems such as Dr Elaine Ingham's 'Soil Food Web'[32] provided farmers and growers with means to measure their soil biology with the aim of improving it. Consultancy services focused on biological farming were also established, e.g., Integrity Soils[33], and in Aotearoa New Zealand the Association of Biological Farmers was established[34].

In addition to the focus on soil biology, differing view on soil chemistry / plant nutrients to mainstream soil analysis (Kopittke and Menzies 2007) were being investigated, often based on the concept of base-cation saturation ratio[35] e.g., the Albrecht - Kinsey system[36] (Kinsey and Walters, 1993).

The focus on soil required re-evaluation of a range of standard farm practices that impact soil, particularly tillage, and a focus on minimum and no-tillage became important in biological farming.

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[31] www.carbonfarming.org.nz/wp-content/uploads/Biofarmingsystemssml.pdf

[32] www.soilfoodweb.com/

[33] www.integritysoils.co.nz/

[34] www.facebook.com/nzbiofarmers/

[35] en.wikipedia.org/wiki/Base-cation_saturation_ratio

[36] kinseyag.com/about/

Another aspect of biological farming was the desire to move away from synthetic farm inputs, especially pesticides (broad meaning, incl. herbicides) and to a lesser extent mineral fertilisers, especially soluble nitrogen, and to use biological (as in carbon based chemistry) inputs such as biopesticides, biostimulants and biofertilisers (Merfield and Johnson 2016).

These changes meant that biological farming moved from the narrow focus of carbon farming to a much wider focus around the biological (and ecological) aspects of agriculture and horticulture to such a degree, that biological farming became a whole farming system, rather than just a collection of tools and techniques.

The terms 'biological agriculture' 'biological farming' are also a potential source of confusion, because organic agriculture is often called bio-/biological farming/agriculture (and eco-) in many continental European countries (see the section 'Organic agriculture V2').

4.12.1 Further biological farming resources

Zimmer GF. 2000. The biological farmer: a complete guide to the sustainable & profitable biological system of farming. Greeley, Colorado, USA: Acres USA.

Zimmer GF, Zimmer-Durand L. 2011. Advancing biological farming: practicing mineralized balanced agriculture to improve soils & crops. Austin, Tex: Acres U.S.A.

learn.acresusa.com/courses/Zimmer-Biological-Farming-System

4.13 Regenerative Agriculture (RA)

Regenerative Agriculture (RA) is a relatively new name among the alternative agricultures, having gained its current visibility in the last decade. Interest in the RA 'movement' and its adoption is growing worldwide. This growth is driven by farmer-led initiatives, and increasingly supported by brands, investment and policy schemes. RA protagonists promote RA as a solution to many of the global issues linked to our food systems, such as the emissions of greenhouse gases accelerating climate change, soil losses accelerating habitat loss, desertification and the decline of freshwater ecosystem heath, the widespread use of agricultural chemicals causing various types of environmental toxicity and even changes in diet, lifestyle and rural-urban connectivity, all linked to increased instances of diet-related illnesses, weakened immunity and poor mental health. The RA movement is still young, evolving and expanding.

RA is strongly focussed on soil health (Schreefel et al. 2020). It embraces at its core the five principles of soil health: soil armour, minimizing soil disturbance, plant diversity, continual live plant/root, and livestock integration[37].

[37] www.nrcs.usda.gov/wps/portal/nrcs/detailfull/nd/soils/health/

RA is currently not well defined (Burgess et al., 2019; Newton et al. 2020); draws upon many different alt-ags and is being shaped by multiple sources of influence, from local contexts to various national or global socio-political and economic agendas (Newton et al. 2020; Giller et al. 2021; Dachelet 2020).

In terms of its social evolution, RA could at first glance be viewed as being where organic agriculture was in the 1920s-40s (see the section 'Organic agriculture V1'), in that it is a loose but coalescing group of like-minded people, mostly farmers and growers, the first formal associations are starting to be formed, and the message is spreading globally (clearly a lot quicker in 2020 than in 1920 with the internet particularly social media). Like organic agriculture in the 1920s, there are no unified definitions or agreed standards yet, although individual national / global industries and brand partners are beginning to define their own RA scorecards / indexes ([38], Danone 2021; Nestlé 2021).

However compared to organic agriculture in its early days, the RA movement is gaining in momentum much faster and more widely for two reasons: first, RA is posited as a tangible multi-facetted, adaptable solution for many of the challenges faced by humanity today, including climate change (via both carbon and water-mediated pathways), biodiversity loss and preserving indigenous food ways and food sovereignty – which are major issues worldwide not specifically accounted for by organic agriculture. Second, the wicked problems RA seeks to solve, as well as the solutions proposed by RA, are amplified by the globalisation and democratisation of communication networks operating at speed and in a largely unregulated manner. Hence a wealth of newly generated or transferred knowledge / information is being shared daily across the globe by practitioners and various supporters of RA outside the realm of conventional knowledge platforms (e.g., governmental agricultural extension services, academia).

Here, a simplified overview of the historical development of the RA concept, and its different trends is presented. This overview does not supersede but rather complement other analyses of what RA is (or is not) and is designed to provide the readers with a variety of insights they can further investigate more deeply, should they wish to do so. Moreover, as stated at the start of this report, this overview is strongly biased in an British heritage.

4.13.1 The multiple origins of RA:

There are multiple lines of influence on the emergence of RA. These various influences are not mutually exclusive and not exhaustive. Moreover they can be more or less present depending on the country, region, and the culture of the individual farmer adopting RA. They are provided here as pointers – with the recognition that their identification is inherently linked to the author's own cultural bias.

[38] www.nzmerino.co.nz/zqrx

The first line of influence is organic agriculture. The name Regenerative Agriculture can be traced back to the mid-1980s, when it was used a small number of times in the academic literature, and also its conception and promotion by Robert D. Rodale, who was the son of the founder of the Rodale Institute in the USA, one of the key pioneering organic associations in North America (Merfield 2019a). The Rodale Institute is still a key organic research and extension organisation, and it also continues to promote the concept of RA in an organic-regenerative hybrid, promoting an advanced version of organics, called 'Regenerative Organic Agriculture' (ROC)[39]. Additionally, with the current traction RA is gaining, a growing number of organic groups and associations are starting to include the term 'regenerative' in their branding and communications – with some of them actively engaging with the RA movement with a view to collaboration. Many influential figures in RA, such as the late Robert Rodale and Dr William Albrecht (see the Albrecht papers, Albrecht 2005) are also pivotal figures in organic agriculture, particularly in the USA. However, organic agriculture has become highly prescriptive due to the development of detailed rules, called 'the standards' listing what is, and is not, permitted inputs and practices.

In contrast, the second line of influence is strongly anchored in no-till and conservation agriculture which are much less prescriptive in terms of pesticides and fertiliser usage, although conservation agriculture aims to reduce their use. Minimising and ideally eliminating tillage is promoted as essential for the building of soil carbon and to avoid disturbing the soil fungal network underpinning key soil functions. This foundation of RA originated in the mainstream (non-organic) farming community, principally the more extensive cropping and grazing systems in the USA. From there it has rapidly spread globally, particularly in mixed farming systems in dryer climates. It embraces principles contained in holistic management, particularly principles pertaining to adaptive multi-paddock grazing. Key notable influencers for this emergence of RA include Gabe Brown [40](Brown 2018). All the above RA forms promote building soil carbon as both a form of climate change mitigation (removal of atmospheric carbon dioxide from the atmosphere) and climate change adaptation (increased resilience). This climate change focus is also found in 'biological farming / biological agriculture' and 'carbon farming', which are also foundational for RA.

A third line of influence, inherited in part from biodynamics, is linked to farming and land management philosophies that consider explicitly in their decision-making process the possible influence of 'subtle energies' (e.g. Wright 2021, [41, 42]). Under this alternative version of RA (which is by no means mainstream), lunar and solar cycles, or other subtle changes in the environment, are considered to have an influence (even if small) on the farm system A limited amount of scientific investigations have been undertaken on this

[39] regenorganic.org/

[40] youtu.be/QfTZ0rnowcc

[41] permacultureprinciples.com/post/planting-by-the-moon/

[42] www.biodynamic.org.uk/biodynamicbasics-tuning-into-natures-rhythm/

topic, with some studies providing evidence for some detectable effects of the geomagnetic field and astro-cycles on plant growth and animal performance (particularly reproduction), whilst others found no effect (Alberghina et al. 2021; Andreatta and Tessmar-Raible 2020; Breitler et al. 2020; Erdmann et al. 2021; Maffei 2014; Matsumoto and Shirahashi 2020; Mayoral et al. 2020; Mironov et al. 2020; Morton-Pradhan et al. 2005; Palacios and Abecia 2014; Sukhov et al. 2021).

A fourth line of influence originates from the 'living systems principles'[43] and 'living systems design'[44], which emphasizes the farm as a living complex system interconnected and nested in interdependent systems, within which diversity, adaptation and collaborative mutualistic relationships are key to success (Corning 2014, Reed 2007; Robinson and Cole 2015). Under this influence, RA is considered as a socio-political movement seeking to transform not only the way food is grown, but also the societies in which the food is produced or consumed (see Kearnes and Rickards 2020; Gosnell et al 2019; Ikerd 2021, Dachelet 2020; Seymour 2021). Key influencers include for example Daniel Christian Wahl and his book "designing regenerative cultures" (Wahl et al. 2016).

4.13.2 RA is continuously evolving, and embeds progressive, continuous transformation in its different forms

Transformation in the context of New Zealand

The last line of influence identified in the previous section (i.e. 'Living systems design/principles') introduces the concept of societal transformation. One possible driver of transformation is the examination of connections between RA and indigenous land management practices and principles. The 'alignment' between regenerative agricultural practices and Australia's first nations peoples' land management has been highlighted by prominent Australian thought leaders (e.g. First peoples' descendant Pascoe 2014, Massy 2017, [45]). More crucially, the distinct recognition of indigenous philosophies, values and knowledge that underlie inter-connection to natural ecosystems and wellbeing and often regarded as a precursor to regenerative agricultural philosophies is being recognised. For example in Aotearoa New Zealand, much knowledge (mātauranga Māori) at the tribal iwi/hapū level has translated through centuries of connection to whenua (land) through whakapapa (genealogy) to modern Māori practices and protocols (tikanga) for agriculture and horticulture. Whilst only very few regenerative agriculture entities explicitly and genuinely express this recognition[46] (Petro and Haslett-Marroquín 2020), several indigenous leaders and organisations (including Māori) also invite the RA movement to question the inherited long history of current land tenure systems upon which it evolved

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[43] https://reallyregenerative.org/living-systems/

[44] https://www.nrhythm.co/regenerative-design-principles

[45] orfc.org.uk/session/how-australian-first-nations-peoples-land-and-food-management-and-regenerative-agricultural-practices-are-closely-aligned/

[46] www.regenagalliance.org/blog/what-is-regenerative-agriculture

(by default, not by choice), which often involved wrongful acquisition of land and the systemic annihilation of indigenous culture[47, 48, 49, 50]. This invitation is by no means a homogeneous and representative view amongst all indigenous businesses and communities, including Māori. However it is an absolutely new and significant influence on the growth and future development of RA in Aoatoroa New Zealand, and highlights the crucial need for a much larger debate and discussion on the intersection of Te Ao Māori worldview and Māori sovereignty rights with RA and agriculture in general, to be led first and foremost by Māori. In fact, to engage meaningfully with Regenerative Agriculture and other emerging food and fibre production systems, Māori entities and tāngata whenua require equity in the allocation of resources to (i) work in culturally appropriate ways and (ii) establish collective understandings of what tikanga-led food and fibre production systems and practices in the 21st century can look and feel like (Letica 2021).

Somewhat confusingly, in the past few years, the term 'Regenerative Agriculture' has also been used by certain agricultural sectors as a substitute for the term 'sustainable agriculture'. However, RA proponents often contrast the two terms 'sustainable' and 'regenerative', pointing out that it is possible to sustain something at a degraded level and that RA goes beyond sustainability into repairing/regenerating the damage that intensive agriculture has caused. At some level this is mere semantics, in that for the proponents of sustainable agriculture the idea of sustaining meaning 'maintaining in a degraded state' is nonsense, and the core of sustainable agriculture is to maintain systems at optimal health levels. So on the one hand, the apparent contrast between 'sustainable' and 'regenerative' might be only semantic. On the other hand, 'sustainable agriculture' and RA might take different perspective on baselines upon which health is assessed – with RA's perspective often spanning over much longer timescales (up to centuries or even millennia), hence exposing and seeking to reverse decadal to centurial ecological damages caused by farming. This difference in baseline is key to framing RA in the New Zealand context, compared to other countries. In the USA, for example, where the term RA was first coined, a return to century-old ecological baseline can include the re-establishment of native plants and animal species that are also fully integrated into the farm system – for example, some US ranchers are including herds of bison as part of their regenerative ecosystem management (Hillenbrand et al 2019). In New Zealand however, the plant and animal species that are grown for production purposes are almost entirely exotic. Hence if the baseline chosen is that of the near-natural state of New Zealand native ecosystems, then for farming systems to be 'regenerative' in New Zealand, they must also nurture habitats to native new Zealand species. Options for integrating native species as part of the production system itself are sparse, and therefore the concept of 'regenerative agriculture' and New Zealand's own RA narrative might have to explicitly evolve the role and place of 'regenerative' farms in relation to its native flora and fauna (see Grelet et al. 2021).

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[47] www.culturalsurvival.org/news/whitewashed-hope-message-10-indigenous-leaders-and-organizations

[48] www.greenamerica.org/native-growers-decolonize-regenerative-agriculture

[49] civileats.com/2021/01/05/does-regenerative-agriculture-have-a-race-problem/

[50] bioneers.org/decolonizing-regenerative-agriculture-indigenous-perspective/

RA as a continuum

RA can also be viewed as a continuum, in contrast with organic agriculture for example where certification can be viewed as a bar, whereby a property is either certified and therefore organic or is uncertified and is not organic (Merfield 2021). RA has no such barrier to entry, and, it simply requires that a producer start to implement some regenerative practices and start their learning process. This continuum can be measured in parameters such as soil organic matter, water infiltration, plant communities, pest populations and profit (Fenster et al. 2021).

Others view RA has having levels, for example LeZaks and Ellerton (2021) describe four levels of RA food:

- Level 1: Replacement, where processed (junk) food is replaced by healthy food;
- Level 2: Free from chemical and drug inputs, where synthetic agrichemicals are prohibited (which is one of the main foci of organic agriculture (Merfield 2021);
- Level 3: Differentiated nutrient density, aims to increase the concentration of nutrients and other health promoting chemicals in food;
- Level 4: Microbiome-centric, whereby the soil's microbiome influences the human microbiome.

Soloviev and Landua (2016) also have four levels of RA:

- Level 1. Functional, which has the main aim of regenerating soil;
- Level 2. Integrative, has the goal of multi-factor regeneration to grow the health and vitality of whole living ecosystems, beyond the soil;
- Level 3. Systemic, where RA is a way of thinking, not just a set of practices or design strategies;
- Level 4. Evolutionary, comes from a pattern understanding of the place and context of the agricultural system.

The concept of "levels" is also seen in the Rodale Regenerative Organic Certification (ROC)[51] (Merfield 2021) and Danone RA score cards (Danone 2021).

The existence of a continuum and levels of improvement in RA indicate that RA is following more of a continual improvement rather than fixed benchmark type approach (e.g., as used in organic agriculture) (Merfield 2021). This may allow RA to avoid the stagnation that organic agriculture finds itself in now that the standards are difficult to significantly alter due to multiple government to government and international standardisation via IFOAM (Merfield 2021). This flexibility in RA promotes adaptation, which is key in climate and global trade change context.

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[51] regenorganic.org/

4.13.3 Further RA resources

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5 Conclusions

The alternative agricultures described in this report are not the only ones, but they are considered to be the main ones influencing the concept of regenerative agriculture in New Zealand at this point in time. Many share foundations, such as texts like *Farmers of Forty Centuries* (King 1911); there are a great number of commonalities, such as 'health' (particularly soil health); and they interweave (e.g., holistic management as part of regenerative agriculture, agroforestry as part of permaculture).

So, despite them being a rather eclectic group (see section 'A rose by any other name'), there is a lot more kinship than just their joint opposition to intensive agriculture. It is also clear that they are now a fount of ideas that are permeating into intensive agriculture as it starts to address its negative impacts and side-effects that have been ignored for many decades. It is therefore not only the alternative agricultures promoting change: change is happening within intensive agriculture as well. We many now therefore be in the paradigm shift that is the fourth agricultural revolution.

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