TOHA
Science

Regenerative Agriculture Literature Review

DECEMBER 2021

Regenerative Agriculture Literature Review

The purpose of this document is to provide an overview, through the existing scientific literature, of the field of regenerative agriculture. It will address the development and history of the term, the current state of research, and the way current knowledge informs the development of a Toha Network Catalyst Framework and Claims Forecast. It will also address grey literature and other non-academic work where this informs the current state of practice in Aotearoa New Zealand.

The target audience for this document is the research community and others interested in the scientific basis for regenerative agriculture, and the decision-making process for Toha and particularly Toha Science in choosing this as the first area of market development. It will also provide a baseline for assessing the scientific veracity of regenerative agriculture Claims produced on the Toha Network.

Authorship and Citation

This review was researched and written by Lucy C Stewart and reviewed internally by Shaun Hendy. We thank our colleagues at Toha for their constructive feedback, and our three anonymous external reviewers for their thorough peer review.

It may be cited as: Toha Science. 2021. *Regenerative Agriculture Literature Review*. Wellington: Toha Foundry Ltd.

Disclaimer

This Literature Review is intended to provide a snapshot of the research on this topic, as of July 2021, for those wishing to familiarise themselves with the current state of the research. It is not intended as a recommendation to adopt any of the practices described therein and we provide no assurance nor opinion on effective results of the adoption of those practices. Whilst every effort has been made to ensure this is a comprehensive review of the available literature on this subject, including through the use of expert peer review, there may be areas or publications that we have omitted.

Copyright

Published in December 2021 by
Toha Foundry Ltd
PO Box 3002
Kaiti
Gisborne, 4010

ISBN: 978-0-473-60593-3
Publication number: TS0001

This document is available at www.tohascience.org

Contents

Executive Summary

Modern agriculture has been highly successful when viewed through the lens of productivity, but has repeatedly failed to account for externalities including impacts on water, soil, biodiversity, and society. In response, various ‘alternative’ agricultures have developed, with the largest uptake occurring for those which are otherwise compatible with an industrial scale and approach to agriculture, such as organic and conservation agriculture.

Regenerative agriculture, which has gained significant prominence in the last decade, originated as a term in the 1970s. Its goal is to regenerate agriculture itself, by internalising its external impacts and identifying sets of practices which restore and sustain agricultural systems. It has developed principally out of English-speaking settler-colonial nations in the Americas and the Pacific, whose agricultural systems are characterised by large low-diversity farms which have imported European agricultural practices and agroecosystems. Regenerative agriculture’s practices and goals have developed in this context. In recent years the term has become closely associated with agricultural practices which can reduce carbon emissions and/or sequester carbon in soils, although there is significant variation in both claims of and evidence for this.

In many respects modern regenerative agriculture closely parallels the field of agroecology, which has developed largely in South America and Europe. Both include a focus on high-skill farm management and agroecosystem biodiversity, preferring ecological services over inputs wherever possible. There is a significant body of evidence supporting the benefits of many agroecological and regenerative agricultural practices and their overarching holistic approach. However, successful adoption usually requires significant shifts across many practices rather than individual uptake. Existing farm systems research has not yet translated to regenerative agricultural studies.

European-style farming in Aotearoa New Zealand has resulted in significant environmental impacts in a relatively short period of time, due to the development of modern industrial agriculture in close parallel to the European settlement of Aotearoa. However, the most significant impacts have been not on soils but on freshwater ecosystems and erosion-prone hill country, due to Aotearoa’s geography and climate. While there is a significant body of knowledge to draw on regarding regenerative agricultural systems, to address our own externalities, Aotearoa will have to identify the suites of regenerative practices which are most appropriate to our local landscape, climate, ecology, and the principles of mana whenua.

Introduction

By many metrics, agricultural production in the third decade of the twenty-first century is the most successful it has ever been. Thanks to the Green Revolution of the mid-twentieth century and subsequent advancements in plant and animal breeding, technology, genetics, and agronomy [1], we now produce on average 20% more food than we require to feed the current planetary human population [2] on only 30% more land than was being farmed when the population was two and a half times smaller [3].

However, stepping outside this narrow view - confined to productivity - the problems rapidly become apparent. Current industrial agricultural production does not adequately account for the myriad externalities associated with its practices. These include erosion and degradation of soils, pollution of water, depletion of groundwater, loss of non-agricultural biodiversity, loss of traditional agricultural biodiversity, greenhouse gas emissions, and social inequities [4]–[6].

In response to this, many 'alternative' forms of agriculture have been proposed and implemented. Some, such as conservation agriculture, address very specific problems (the loss/degradation of soil) [7]; others, such as agroecology, are social and political movements as well as fields of study [8]–[11]. In the last five years, the concept of 'regenerative agriculture' has begun to gain popular prominence, particularly in regards to its claimed potential to couple the sequestration of carbon in soil with the production of food in an environmentally friendly manner [12]–[17]. While the scientific literature on regenerative agriculture is limited [18], [19] there is an extensive body of grey literature [17], [18], and it has been promulgated primarily through and by practitioner-led communities [20]–[22]. In Aotearoa New Zealand over the last three years, regenerative agriculture has received extensive media and increasingly academic attention, some of it notably hostile [20], [23]–[28].

The purpose of this literature review is to contextualise the emergence and claims of regenerative agriculture, provide an overview of the relevant scientific literature, and arrive at a definition suitable for the agricultural context in Aotearoa . It was conducted by starting with existing review and definition papers on "regenerative agriculture" identified through Google Scholar and proceeding through their citations (forwards and backwards) until no new sources could be identified. Other fields discussed (such as agroecology) were searched for, looking for reviews and definitions published in the last five years, and using these to identify foundational papers defining the field. This review focuses on the academic literature available on regenerative agriculture and associated fields and practices. Grey literature, news articles, and other websites are referenced largely for context rather than as primary sources. This final version of the review has incorporated feedback from three independent expert reviewers.

The key question we seek to answer in this review is: **can regenerative agriculture (under any definition) provide solutions to the 'wicked' problems of modern agriculture, particularly in Aotearoa?**

It will cover:

- the specific externalities which have not been addressed by agricultural development to date
- the development in response of 'alternative' agricultures
- the role of practitioner-led movements in agriculture
- the history of the term 'regenerative agriculture'
- the development of its practices in the historical context
- the specific practices which fall under the umbrella of regenerative agriculture
- their potential to regenerate soils, waters, ecosystems, and communities
- the history of agriculture in Aotearoa New Zealand
- some conclusions on the potential for regenerative agriculture in Aotearoa.

---

1) Wicked problems are problems which, among other qualities, do not have true or false solutions or obvious stopping points [29]. Many problems in modern agriculture are wicked problems, for example soil degradation [30].

We need to talk about agriculture

The externalities of modern agriculture

There is little debate that modern intensive agricultural practices have significant and cumulative effects on the environment, which are becoming more apparent with time. When we speak of 'intensive' agriculture in this review, we mean agriculture which relies substantially on inputs external to the ecosystem of the farm itself, including irrigation, mineral fertilisers, pesticides, and mechanical tillage [1] (also known as 'conventional' or 'industrial' agriculture) [31]. Yield increases across the twentieth century can be primarily attributed to these factors, alongside improved crop and livestock breeding [1].
However, they also have negative effects both on and off the farm. Terrestrial agriculture is ultimately dependent on soils, which rather than being a substrate upon which agriculture is performed, represent a complex and biologically rich habitat that develops slowly - more slowly than current rates of loss [32]. Global soil loss due to erosion is estimated at 43 Pg per year [33], and remaining agricultural soils are degraded through loss of nutrients, oversupply of nutrients, loss of soil physical structure, and loss of soil biodiversity [34]–[37] - although the complexity of soil biodiversity globally is such that it is difficult to say we even understand the extent or importance of what is being lost [32], [37]–[39]. Clearing of non-agricultural habitats for agricultural use is also a major driver of biodiversity loss in a range of habitats, but particularly in the forested tropics [40]. 40% of known insect species are at risk of extinction with agricultural intensification as the primary driver [41], affecting all ecosystems [42].

Agriculture also relies on provision of adequate water, and returns waste to water. Use of fertilisers - particularly synthetic nitrogen fertilisers, as humans have doubled the amount of nitrogen entering the nitrogen cycle each year from the atmosphere [43] - has led to significant nutrient pollution, from both nitrogen and phosphate, in rivers and oceans worldwide [44]. Meanwhile, mining of phosphate from seabird guano deposits has severely damaged island ecosystems and displaced local peoples [45]. Irrigation to increase the productive capacity of soils beyond that which can be supported by rainfall has led to the depletion and in some areas salinisation of aquifers [46]. Even increases in efficiency can paradoxically lead to faster water use rather than less [47].

Intensification and industrialisation of agriculture has also led to a reduction in agricultural biodiversity - that is, the diversity of the animals and plants that are deliberately raised and grown [48]–[50], as well as soil biodiversity and insect biodiversity in these simplified systems [32], [51]. Intensive agriculture requires simplified systems and monocultures [1], [52], which reduces system resilience [53]. Many breeding programmes are targeted at developing breeds and strains which are well-adapted to high-input agriculture [54]. They have also tended to focus on above-ground production and ignored the potential impacts of differing root structures and soil-plant interactions, which can be highly important for soil structure [54], [55]. There are also some breeding programmes targeting resilience to environmental factors such as climate change [56] as well as consumer preferences [57].

Agriculture is also responsible for approximately 11% of global greenhouse gas emissions, plus emissions from land use change [58], and is the major source of emissions for some nations (such as Aotearoa) [59]. The most significant agricultural contributors are the manufacture and use of mineral nitrogen fertilisers which release nitrous dioxide (particularly in conjunction with rainfall events and irrigation), the farming of methane-producing ruminants and management of animal excrement, use of lime for soil amendment, and carbon loss from ecosystems as they are altered for agricultural use (including tree loss and soil cultivation) [60]–[63].

Finally, modern agriculture has significant social costs. Globally, most farmers are women, but this is highly skewed towards subsistence farmers in the Global South, while globally farm ownership and decision-making is heavily male-dominated, with commensurate impacts on social power and equity [64]. Despite the importance of the food system, agricultural labour in the Global North - as opposed to farming-as-land-ownership - is poorly paid and often exploitative, relying heavily on temporary migrant workers [65], [66]. Most importantly, intensive agriculture, despite its overwhelming focus on productivity, has failed to actually address global hunger: it produces more than enough food to meet global demand [2], but a third of the world experiences food insecurity and approximately ten percent of people are undernourished [67], despite intensive agriculture's production being used to justify its environmental impacts [68]. Crop yields do not predict hunger, and yield intensification does not reduce land use [31]. Therefore, a production-only focus for agriculture will not address hunger but will continue to damage the environments which are needed for food production to continue.

---

2) One Pg = one Gt (gigatonne); unit is given as per the referenced paper.

‘Alternative’ agricultures

So-called ‘alternative’ agricultures began to develop more or less in parallel with the industrialisation and intensification of ‘intensive’ agriculture. They are all responses, in various ways, to the problems laid out in the previous section. This section identifies the four most common and most closely relevant to the development of regenerative agriculture.

Organic agriculture is the oldest and most codified and ‘de-radicalised’, defined currently by what it excludes rather than what it includes: chemical pesticides and chemical fertilisers, antibiotics, and genetically modified (GM) organisms [69]. It does not generally place restrictions around other practices (e.g. irrigation, tillage) - in fact, maintaining organic practices with monocultures generally requires technological solutions [70]. There are a number of programmes of certification for organic farmers which have strict requirements around documentation and international cross-recognition [71]. Organic food has a small but significant market share and organic production accounted for approximately 1% of all agricultural land use worldwide in 2011 [72], rising to 1.4% in 2019 [73]. It has lower environmental impacts per unit of land area, although not necessarily per unit of production, but commonly improves biodiversity [74].

Conservation agriculture developed in the wake of the human-induced North American Dust Bowl erosion of the 1930s [72], [75] and is closely focused on retaining soil in arable and horticultural contexts. The three principles of conservation agriculture are minimising soil disturbance, maintaining plant cover at all times, and maximising crop diversity [76]. It does not prescribe or restrict inputs and has been criticised as limited on this basis [77]. It is often linked with the more general practice of ‘no till’ (i.e. planting only using direct drilling), but technically speaking this is only one aspect of the wider practice. Conservation agriculture is by some metrics extremely widely practised, usually in an industrial context with the use of herbicides to kill weeds and (in countries where environmental release of GM organisms is legal) GM crop strains [77] .

Agroecology is somewhat uniquely defined as a field of study, a social movement, and a political movement [10], [78], [79], all working alongside each other with the goal of achieving just transitions in agricultural practice [80]. It is “based on bottom-up and territorial processes, helping to deliver contextualised solutions to local problems” [8]. The core concept of agroecology is understanding agricultural systems as ecosystems, integrating ecology with agricultural sciences [81] to reduce reliance on external inputs and promote social and ecological resilience [53]. **Permaculture** is generally considered to be a form of agroecology [52] which has developed from a practitioner level somewhat separated from formal research [82]. It claims much more explicit derivation from Indigenous agricultural practices [83].

Holistic management/grazing management is a catch-all term for a set of practices also known as cell grazing, rotational grazing, management-intensive grazing, mob grazing, Technograzing, adaptive multi-paddock grazing, and holistic planned grazing, among other terms [84]–[91]. It refers to intensively managing grazing of ruminant livestock, with rotations determined by ecological response, to create a grassland ecosystem where ecosystem services negate the need for intensive inputs [85]. There is some degree of confusion in the literature as to how this differs from conventional rotational grazing [96],[97]. It is strongly practitioner-led and originally developed by dryland ranchers in natural grassland ecosystems in the Interior Plains of North America and southern Africa [98], [99].

---

3) ‘Chemical’ is not a scientific or particularly useful term, but in this context can be taken to mean products which are either manufactured or substantially purified by human activity.

What unites alternative agricultures

Agricultural knowledge and innovation systems have been thought of from an academic perspective as moving from centralised diffusion of specialised research to trans-disciplinary, holistic development of knowledge with practitioners/farmers as co-designers [100]. This represents general trends rather than a strict rule across all locations and systems (see this discussion of innovation in New Zealand deer farms [101]). Changes in knowledge systems as a whole are needed in order to achieve changes in practices at sufficient scale to address the current externalities of agriculture [102]. Alternative agricultural movements have by and large been founded and led by practitioners (used in this document to encompass advisors as well as farmers) rather than researchers, often as a response to the centralised model of innovation and to perceived and real failures to take values other than productivity into account [21]. This leads to observable factionalisation in the scientific literature [98].

Agroecology is notable in having explicitly identified practitioner-led and researcher-led work as different parts of the same field, especially as implementing ecosystem-based agriculture requires adaptive management from farmers [103]. This has caused it to come into conflict with narratives of technological progression [104]. Where farmers cannot form local groups, they can now use the internet to connect with like-minded groups [105], [106], which makes practitioner-led movements even more feasible than previously. Detailed literature can also be distributed for self-education [107]. Alternative agricultures therefore can also be viewed as expressing a shared desire for practitioners to lead development of their field and for innovation to be closely linked to frontline work [20]. Farmer decision-making is centred as a precondition of successful implementation [48]. (It should be noted that conventional agricultural extension programmes have also identified the need for this approach in order to achieve successful practice change [106].)

What else do the major alternative agriculture systems have in common? Broadly speaking, it is:

- The intention to internalise and account for various externalities of agriculture (e.g. pesticide use (organics), soil erosion (conservation agriculture and holistic grazing), social inequity (agroecology))
- The prioritisation of biodiversity as an integral part of agricultural systems (all except, to some degree, conservation agriculture)
- Concern for food security and human access to high-quality food - prioritised not through the lens of productivity but the lens of access to culturally appropriate local food [64], [108] (primarily agroecology, sometimes organic agriculture)

These are all values statements, but research can address the question of how practices align with and achieve the goals set by these values [17]. In addition, the questions of what research we choose to do, what purpose we do it for, and who we involve in it are also questions that research must address in order to provide context for its outcomes and the application of new knowledge by farmers. The most common criticism of alternative agricultures is that they neglect yield, but reviews have shown that organic and conservation agriculture can under many circumstances match conventional yields, when limiting factors and local conditions are adequately understood [72], [109]–[111].

Regenerative agriculture shares all of the key concerns of other alternative agricultures outlined above. In the next section, we will discuss what separates regenerative agriculture from the main existing alternative agricultures and how the term has developed.

---

4) ‘Ecosystem services’ are direct and indirect services provided to humans by nature, which can be divided into ‘provisioning’ (direct provision of goods, such as food and fiber) and ‘non-provisioning’ (social, cultural, and regulating) services [92]. Examples include retention of floodwaters by wetlands, breakdown of dung by dung beetles and other insects, and shelter for stock by riparian tree plantings [93]–[95].

What’s special about regenerative agriculture?

Regenerative agriculture as a term is still poorly defined [17], [19], [112]. Unlike organic agriculture, it has no legally mandated or internationally recognised certification processes for producers, although independent research organisations are developing their own certifications for the North American market [85], [113]. Unlike conservation agriculture, it does not have a single universally accepted set of core principles [14]. One recent review recommended that all papers that address it should provide their own definition of the term[19]. Other work has noted differences between its use in an academic context (which is still limited to a small body of work) and in the much more extensive grey literature [112]. A 2019 study found 23 uses of the term in academic papers, compared to 42,000 references in the grey literature [18]. Use of the term has increased significantly in both the academic and lay spheres since approximately 2015 [112], [20], [69], [19], [5], quadrupling in academic papers between 2017 and 2019 [19]. In this section we cover the history of the term and the regional and social contexts in which it arose.

History of the term

The precise emergence of the term ‘regenerative agriculture’ in the academic literature is hard to pin down. The first locatable academic paper which uses the term, from 1986 [114], cites a 1979 article which has not to date been recovered [17], [20]. In this paper, it is framed as a matter of increasing efficient use of farm resources rather than relying on ‘petroleum-based’ external inputs - in current parlance, circularising the farm system/economy. External to the academic literature, the popularisation of the term and sometimes the development is generally attributed to Robert Rodale, founder of the Rodale Institute [115], which has promoted regenerative agriculture since the early 1980s. He describes it as “encouraging nature to release the most benefits for human use with the least possible effort”. In non-academic contexts, it is widely linked with ‘soil health’ and - in the last decade - practices which increase the amount of carbon stored in soils [12], [13], [15], [116], [117]. A 2007 paper [118] advocates for ‘regenerative, semi-closed’ agricultural systems (but does not cite any of the 1980s papers using the term), and frames it in the context of the circular economy, [119], [120], where ‘regenerative/regeneration’ is considered to represent an alternative to ‘sustainability’ - the goal of improving systems rather than preventing them from degrading further [121]. However, regenerative agriculture is still sometimes described as a ‘[working] towards a sustainable food system’ [122]. It is also often described as being made unique in forefronting climate change mitigation through soil carbon sequestration as a key outcome [12]–[15], [69], [112], although some literature from the last five years also ascribes this outcome to agroecology [52].

Early use of the term ‘regenerative agriculture’ was, and in the academic literature still is, strongly linked with the main farming types in the United States and Australia [17] - that is, large-scale arable crop production [123], [124] and pastoral farming, primarily of cattle [116], [125]–[127]. The spread of the term to encompass other types of farming such as dairy farming [90], [97], tree crops [128], [129], and horticulture [130], has been more recent. Newton et al. found that over time it was linked with or described as cognate to “agroecological farming” “alternative agriculture,” “biodynamic agriculture,” “carbon farming,” “nature inclusive farming,” “conservation agriculture,” “green agriculture,” “organic regenerative agriculture,” and “sustainable agriculture””[19]. Of these, only ‘conservation agriculture’, ‘organic agriculture’, and ‘agroecology’ have widely accepted definitions [78], [131], [7].

---

5) Generally speaking alternative agricultures do not tend to distinguish between native and invasive/introduced biodiversity, which is a very important distinction outside the Old World. Is a farm in Aotearoa with rabbits more biodiverse than one without? Is that an optimal outcome?

The consistent themes in definitions of regenerative agriculture centre around:

- Restoring 'soil health' and increasing soil organic carbon through low levels of disturbance, maintaining continuous plant cover, and supporting soil ecology [13], [15], [18], [113], [122]–[124], [132], [133], [21], [17];
- Increasing agricultural and non-agricultural ecosystem diversity on farms, with the goal of replacing inputs with ecosystem services where possible [124], [132], [21], [17];
- Reducing external inputs in general, including pesticides, chemical/inorganic fertilisers, imported feed, and sometimes fuel/external electricity (although unlike organic agriculture, regenerative agriculture has no universal prohibitions on specific inputs) [12], [13], [15], [21], [117], [118], [134];
- Restoring and/or altering water cycles through improvements to soil infiltration and water holding capacity, as well as landscape-level movement of water, removing or reducing reliance on irrigation [18], [20];
- Improving farmers' socio-economic wellbeing and connection with their land [20], [113], [117], [122].

Not all definitions encompass all these themes, as can be seen from the number of citations for each. The most consistent and narrow definition of regenerative agriculture focuses only on soil and soil quality in connection to carbon sequestration, but this limitation does not extend to the wide variety of practices which have been described as fitting under the umbrella of regenerative agriculture. Few if any are unique to it [5]. These include the consistent use of cover crops [13], [14], [128], intensive grazing management (holistic/cell/adaptive/rotational grazing) [88], [97], various forms of agroforestry including silvopasture and intercropping [18], [132], integrating livestock and cropping systems [13], [14], [123], keyline irrigation/landscape management [112], [135], reduced tillage [13], [14], [128], crop and pasture diversity [14], circularisation of farm inputs [12], [118], and reduced or eliminated use of synthetic fertilisers and pesticides [12], [124]. All of these are underpinned by a strong emphasis (in both the scientific and grey literature) on practitioners engaging in systems thinking and understanding the root causes of negative outcomes [20], [136], [137], with this often being considered more important than the specific practices they choose to implement [123], [132].

In this, regenerative agriculture is strongly aligned with agroecology, which takes a similarly broad approach with a highest-level focus on the development of agroecosystems, as well as an explicit embrace of social justice and the need for societal and political reform as part of agricultural practice reform [8], [80], [138]. Regenerative agriculture has been described as a part of agroecology [5], [81], as equivalent to it [139], as a mixture of conservation agriculture, organic agriculture, and holistic grazing management [14], and as an ideology rather than an area of science [23]. It is explicitly different from organic agriculture in its increased flexibility [122].

The description of regenerative agriculture as an 'ideology' is not entirely rejected by less hostile reviews which describe it in more positive terms as a set of values [17], [20]. Like agroecology, it extends beyond analysis of agricultural productivity or systems to assert that agriculture needs to account for and value externalities both environmental and social. It is focused on outcomes rather than individual processes [20]. Given that agroecology has a rich body of scientific inquiry and literature associated with it, as well as policy implementation [78], this does not appear to be a barrier to the scientific analysis of regenerative agriculture - rather, an indication that it is important for studies to set out in detail how the broader principles of the movement are being applied in any given case.

Regenerative agriculture in context

To understand the current status of regenerative agriculture, it is also necessary to understand the context from which it has emerged. Despite its close similarities to agroecology in terms of approach and practices, the regenerative agricultural movement has been largely distinct from the agroecological movement. The agroecological movement has been most widely taken up in Europe and South America, and is closely linked with Indigenous farmers and movements in the latter location [10], [78]. Papers reviewing regenerative agriculture generally do not consider the extensive body of literature on agroecology, or related fields such as landscape ecology, except when those papers explicitly mention regenerative agriculture - see for example Newton et al. [19] (usually as a synonym for agroecology, for example Callicott [140]). Agroecology does not reciprocally recognise regenerative agriculture, either; a review of the importance of livestock in agroecological systems does not mention any form of holistic grazing [48], and a 2020 review acknowledges only that agroecological practices 'can be called regenerative' [138].

The key practitioner proponents of the practice most closely associated with regenerative agriculture (as opposed to other alternative agricultural systems such as grazing management to improve water cycling and soil fertility) were based in Australia, the United States of America, and Zimbabwe [85], [112], [135], [141], [142] - areas dominated by dryland pastoral farming [17]. Even considering the increased presence of the term in the last decade, a recent Francophone review noted that almost all the primary sources came from the English literature, and the most-cited practitioners were all white Anglophone/Anglosphere farmers [112]. This is highly relevant because agriculture in the settler-colonial Anglosphere is dominated by systems which imported European farming practices and agro-ecosystems onto continents and islands where they had not previously existed. In the most extreme example, Aotearoa's current dominant land-use (pastoral agriculture of large ruminant mammals) has been described as 'inevitable' [143], when ruminants - and indeed land mammals - were entirely absent from the Aotearoa archipelago until approximately seven hundred years ago [144]. The dominance and increasing intensification of pastoral agriculture is not an inevitability of our climate or geography, but a specific choice made mostly by European settlers.

The development of the settler-colonial states of the Americas and the Pacific occurred as a result of the dispossession of Indigenous peoples in these areas, opening up large areas of land to be farmed using European agricultural modes, crops, and livestock. Average farm sizes in the settler-colonial Anglosphere and much of Latin America are, as a result, significantly larger than farms in Europe, Asia, or Africa [145]. Compensation payments to slave-holders when slavery was outlawed in the British Empire also funded the agglomeration of agricultural estates in Europe at the expense of smallholders, demonstrating the global effects of these agricultural systems [146]. The development of large farm estates in the settler-colonial world was supported by the development of chattel slavery as a primary mode of large-scale agricultural production in the Americas [147] and forced labour (not legally but debatably a form of slavery) in Australia and the Pacific [148]. While a number of agricultural crops (particularly maize, potatoes, and cassava) from the Americas have become part of the global intensive agricultural package subsequent to European colonisation of the Americas [149], the techniques used to farm them on commercial scales are generally not those of the Indigenous cultures that domesticated them. Rather European plough-based agriculture is used [150], although traditional methods are still applied at local levels [151]. The dominant commercial mode of farming in the countries where regenerative agriculture has developed has, fundamentally, been the transfer of European agricultural practices and societies to new ecosystems [152].

The Indigenous agricultures marginalised in these areas are often mischaracterised because they do not necessarily fit into the progressive model attached to Western agricultural systems, which assumes that societies move from hunting and gathering to settled agriculture, including the plough, as they become more sophisticated [153]. Indigenous modes of life in the Americas, Australasia, and the wider Pacific include a mixture of deliberate planting and fishing, hunting, and gathering [151] including extensive use in tropical and sub-tropical zones of what are now known as 'food forests' [154], rather than conforming to Western/European understandings of 'wild land' versus 'settled land' [155]. European understanding of Indigenous systems in the Americas was significantly limited by the deaths of ~90% of the Indigenous population following the beginning of colonisation [156], such that extensive settled agricultural systems such as the terra preta soils in the Amazon have only recently been re-discovered/acknowledged [157]–[159]. However, Europeans often openly acknowledged at the time of settlement that European-style agriculture in colonial settlements was an experimental process that could not be made successful by replicating European practices, and that Indigenous communities were crucial sources of knowledge [160].

The field of agroecology has done a significant amount of work in acknowledging Indigenous practices as sources of knowledge for implementing agroecological principles. Indigenous knowledge can allow the recognition of alternatives rather than trying to overcome the constraints of imposing European agro-ecosystems onto existing ecosystems [81]. However, it is important not to subsume Indigenous knowledge into Western knowledge systems by deeming Indigenous practices as merely 'another kind' of agroecology [83]. Regenerative agriculture has been identified by some Indigenous groups as in alignment with their principles [161], but the same danger applies, with surface levels of alignment being cherry-picked to gain credibility for the regenerative movement without real engagement with or participation by Indigenous peoples. Moreover, the most popular principles of regenerative agriculture, which focus on soils, do not necessarily embrace social elements in the same way agroecology does, and it is these social elements which have caused agroecology as a field to be identified as key to food sovereignty for Indigenous peoples [162]. Regenerative agriculture, broadly speaking, has yet to do the same sort of work, because it comes from settler farmers - sociology has already identified it as a method of reclaiming social licence for this group [28]. If we accept the foundation of regenerative agriculture as a push to 'regenerate' land to a productive agricultural condition, and to 'reconnect' farmers (as landowners, not agricultural labourers) to their land, we must take into account what the original condition of that land was, and who the original owners were. 'Regenerative' agriculture cannot be a return to the past, because the specific past sometimes implied does not exist in the places where it has emerged. There has never been a time when European modes of agriculture were practised in a sustainable or local ecosystem-appropriate manner in settler-colonial states; colonisation is and always has been a process of appropriation, destruction, and attempted assimilation [163]. In particular, the 'reconnection' of farmers to land should potentially be re-contextualised as addressing the unacknowledged trauma of colonial settlement, which cut settlers off from their ancestral lands and societies, as described in Imagining Decolonisation [164].

What are we regenerating?

In this context - of regenerative agriculture as a set of practices emerging from settler-colonial states - it can most appropriately be framed as regeneration of agriculture *itself*, by internalising its external impacts and identifying sets of practices which restore and sustain agricultural systems. All of the core principles of regenerative agriculture to date ultimately revolve around restoring ecosystem services as appropriate for local landscapes, with the added urgency, in the twenty-first century, of mitigating and offsetting carbon emissions. The specific outcomes targeted by researchers and practitioners of regenerative agriculture are **soil ecosystem function and carbon sequestration; water quality and availability; agroecosystem biodiversity;** and **farmer understanding and wellbeing**. Regenerative agriculture is *not* the rebuilding of something old, even as it includes practices of long standing [112]. It is the latest development of a century of responses to intensifying, industrialising, settler-led agriculture, framed by the current climate crisis.

Regenerative practices

This section discusses the literature around specific agricultural practices linked to the identified regenerative outcomes, all of which have been included by some practitioners and or/academics under the umbrella of regenerative agriculture. It is important to note at the outset that this discussion does not exclude economic profitability or productivity as metrics for agricultural success; instead, it is intended to *also* encompass environmental outcomes. Nonetheless, environmental benefits often lead to significant economic returns [165], [166]. In addition, we acknowledge that not all practices are equally relevant to all areas of farming; for example, pasture and grazing management is obviously specific to pastoral livestock farming, and tillage is more relevant to horticulture and arable cropping. We do not discuss some practices specific to non-pastoral livestock farming (colloquially called ‘factory farming’) as they are not considered to be regenerative by any sources.

Regenerating soils and climate

Understanding and improving soil quality or health is considered by many practitioners and researchers to be the core aim of regenerative agriculture [22], [122], and is central to both the goals of sequestering carbon [13] and addressing soil degradation [37]. These goals are directly linked because there is a strong relationship between soil organic matter content (which holds the bulk of soil carbon) and other aspects of soil quality, such as soil physical condition [167] and agricultural yield/fertility [168], as well as water infiltration and holding capacity [169]. Most of the core regenerative agricultural practices - such as reduced tillage, reduced fertiliser use, increased pasture diversity, grazing management, and use of cover crops - have been shown to have some direct relationship with soil quality. Healthy soils underpin all the United Nations' Sustainable Development Goals [36].

But what is soil quality? Unlike air quality or water quality, which have well-defined sets of indicators [170], [171] (although contention sometimes remains about appropriate levels for those indicators, such as nitrate in freshwater [172]), there is no widely agreed set of indicators for soil quality or soil health [173], or even agreement on whether those terms are appropriate to use [174]. In general, scientists prefer the term 'soil quality' and practitioners 'soil health' [37]. It generally goes unstated that 'soil quality' assessments are fundamentally assessments of soils' capability to act as **agricultural** soils, as soil can be unsuited for agriculture but perfectly 'healthy' as part of a natural ecosystem [175]. No agricultural use of soils is 'natural' and there is no set of agricultural practices that truly replicates processes that would generate and affect soils absent human involvement. Therefore, it has been suggested that soil health should be considered as a useful metaphor for soil's "capacity to promote the pertinent functions of the *land* in which it is embedded" [176] but also that it is useless as a concept because it cannot be directly quantified [175]. 'Soil quality' is then, perhaps, a measure of the health of an agro-ecosystem - that is, a given soil's capacity to operate as part of an agro-ecosystem without transferring impacts externally, and to retain or improve that capacity.

Some general sets of indicators have been developed by various national bodies, principally centering around soil organic matter/carbon, soil physical structure and interaction with water, and availability of key nutrients [177]. Soil carbon, soil structure, soil water dynamics, and microbial biomass are the indicators measured by the Soil Carbon Initiative [178]. There are a number of physical tests of soil structure which have been designed for or are practical for practitioner use, such as the Visual Soil Assessment [179] and simple water infiltration tests [180], as well as laboratory tests such as macroporosity which can be linked to pasture growth [181], [182]. Debate around chemical indicators (i.e. major nutrients) has focused on the difference between raw concentration and availability to plants, and also the effect of micronutrients such as magnesium and calcium on major nutrient availability and plant growth. This has led to the development of alternative testing methods measuring major nutrient availability under specific conditions. This includes measurements of organic extractants [183], [184], which require calibration in new soils and generally lead to recommendations of lower fertiliser use [184] (an economic benefit to the farmer). There is wide consensus that the soil ecosystem is linked to soil ecosystem services and that metrics of biological diversity are part of the measure of soil quality [177], [185], [51], but there is even less consensus on appropriate biological metrics than on physical and chemical metrics [32], [38], [39]. There is also a considerable divide between practitioners and soil scientists in some areas [186], [187], primarily about the generalisability of specific indicators of soil quality, or the contribution of specific practices. For example, the ratio of fungi to bacteria is frequently promoted as a key metric of soil health [123], but this is not strongly supported by the existing literature, particularly in comparison to analysis of total microbial biomass and/or fungal biomass [188], [189], and in light of the extreme complexity of soil microbial communities [190]. Many indicators are localised so it is hard to prescribe metrics at a global scale [37]. For example, diversity indicators for specific groups of soil invertebrates, such as community structure, can be useful but require a high level of skill and knowledge to accurately use [177].

The most accepted and perhaps important general chemical metric is soil organic matter/carbon [37], as it affects soil structure [191], [192] and is strongly linked to agricultural yield [168] and water cycle regulation [169]. On the other hand, perhaps the most controversial aspect of regenerative agriculture claims is whether regenerative agricultural practices can reliably increase soil carbon as part of climate change mitigation [193]–[195]. There is extensive debate about whether increases are even possible [196], [197], whether they are possible to the extent claimed [69], whether measurement practices are accurately detecting them [198]–[201], and how long carbon can even be sequestered for in actively farmed soils [202]. Perhaps the only un-debated aspect is that soil contains carbon.

Small increases in soil carbon can still have large beneficial impacts, and the general weight of evidence is that agricultural practices - including organic matter addition, nitrogen fertilisation (in some cases), intercropping, perennial crops, and possibly reducing tillage - can increase soil carbon over time [203], [204], with the main barriers being around practice adoption and effective combination of practices [204]. Equally important is limiting and reducing carbon *loss,* and other greenhouse gas emissions, from soils [203], [205]. This can be most effectively done by lessening erosion [99] and reducing nitrogen overloading [206], but is also closely linked with soil microbial activity [51], [205]. Addition of biochar to soils is another method of carbon sequestration in soils which can also improve retention of nutrients [207], [208].

Another key question around soil quality is around the roles of disturbance and soil microbial and invertebrate biodiversity (decreasing the former and increasing the others being two of the main consistent regenerative agriculture principles) and functional ecosystem interactions, such as the role of plant secondary metabolites [54]. The underlying argument here is that lowered disturbance allows the development of a resilient, high-biomass ecosystem [209], with biodiversity being less important as a measure in itself and more important as a provider of functional resilience to disturbance [39]. In particular this seems highly likely to be true for microbial communities, which have complex activity patterns where 95% of total biomass can be inactive at any given time [38], and which may contribute over 50% of soil organic carbon as necromass [210]. Soil biodiversity has been shown to decrease with intensive agriculture [51], but there is insufficient knowledge on interactions at appropriate spatial scales to directly recommend policy [32]. Introducing novel agricultural plant species in some locations has also involved introducing symbiotic microorganisms [211], demonstrating the complex relationships between soil microbial diversity and agriculture. On the other hand, the possibility that the rise of “kauri dieback” disease in Aotearoa may be due to environmental changes to the relationship between an extant soil microorganism and a native tree species [212] demonstrates the importance of factors and relationships within the soil/plant ecosystem which are not yet known or understood.

The key practices that have been linked to soil quality, including soil carbon, are **tillage, fertiliser type and use**, **pasture and crop diversity**, **cover crops**, **grazing management**, **irrigation,** and **pesticide use**.

Reduced tillage is the central tenet of conservation agriculture [7] and its impacts on soil carbon, soil structure, water use, and erosion have been extensively studied [76], [199], [209], [213]–[221]. It is highly effective in dry climates (when combined with soil covers and crop rotation) in increasing topsoil organic matter and water holding capacity, and reducing erosion and runoff [76], [77]. It also increases total soil biomass [188]. However, the effectiveness of different degrees of tillage in improving soil structure depends on soil type and moisture levels [222]. Reducing tillage does not necessarily increase pest prevalence, perhaps because tillage also reduces predator numbers [223], but disease control depends heavily on its integration with other practices such as crop rotation [222] and cause and effect is not well understood [76]. The evidence is equivocal as to the effectiveness of zero tillage in isolation for carbon sequestration. As a practice zero tillage is only beneficial in certain situations [224], [225].

Fertiliser type and use has a significant impact on soil quality. Persistent large-scale use of synthetic NPKS fertilisers can acidify soil and disrupt ecosystem services [226], [227]. Manufacture and use of nitrogen fertiliser is a significant contributor to agricultural greenhouse gas emissions [62], [228], [229]. However, lack of nutrient addition can also cause soil degradation over extended periods of agricultural production [34], [230], [231], and carbon cannot be sequestered without additional nitrogen [196]. Regenerative agriculture focuses on circularising farm nutrient cycling to the greatest extent possible through use of organic amendments, crop-livestock integration, and crop/pasture diversity, in particular through promoting natural nitrogen fixation. The goal is to avoid nitrogen excess, which leads to nitrogen leaching and increased soil greenhouse gas emissions [232]. As mulches, organic amendments to soil can also reduce water transpiration and erosion [233] and can help sequester carbon and store nitrogen [202], [233]–[235]. Biochar as an amendment can sequester carbon and control nutrient release[208], [236], [237]. Live microbial cultures are popular as amendments among some practitioners, but there is a lack of data on their efficacy outside of companies producing them [37].

Pasture and crop diversity includes intercropping, crop rotation, and diverse perennial crops and pastures. It increases soil biodiversity [238] and therefore ecosystem services [51]. Appropriate use of nitrogen-fixing annual [43], [239] and perennial [230] crops, including in rotation, can provide this major nutrient, and plant functional diversity can alter availability of other nutrients [54]. It can also change abundances of pests and diseases [240]–[242].

Cover crops and mulches, used as part of rotations, provide soil cover. They reduce water and wind erosion [43] and, if leguminous cover crops are used as green mulches, can add carbon and nitrogen to soil [243], with comparable yields to conventional systems using fertiliser [43]. They are also linked to increases in soil biodiversity [189] and in some cases can significantly reduce nitrogen leaching over winter [244]–[246]. There is a considerable body of evidence that their use whenever possible is preferable to leaving soils fallow [43], particularly to reduce soil erosion [191].

Grazing management - specifically intensive management of pastoral animals on perennial pastures, not merely rotational grazing to a set timeline [117] - affects pasture growth and therefore water cycling, pasture yield, erosion, nutrient, and biodiversity, which all affect soil quality, soil biological activity, and carbon sequestration [62], [202], [247]–[249], as well as greenhouse gas emissions from ruminants [250], [251]. There is considerable evidence for the benefits of intensive grazing management in dryland pasture in terms of soil quality and ecosystem services including water infiltration [91], [252], water quality [253], [254], pasture composition [255] and potentially increasing carbon and nitrogen stocks [96], [256]. It is important for grazing management studies to address real farm practices and not confound the effects of different management aspects [141], [257]. In particular, trials should not assume that continuous grazing (or timed rotation grazing) leads to spatially homogeneous grazing patterns [89]. Intensive grazing of winter and summer crops (rather than pastures) in wet climates can supplement pasture with feed produced on-farm rather than brought-in feed, but can also lead to significant disturbance of soils and bare soil, and subsequent sediment and nutrient run-off and soil compaction, depending upon how crop grazing is managed [258]–[260].

Irrigation can decrease soil carbon [236] and in some locations salinise soils [261]. Requirements for irrigation can be effectively reduced, to the limits of local evapotranspiration, by management of soil organic matter and structure. High organic matter and good soil structure increase infiltration of natural rainfall and water holding capacity [169], [191]. Warming climates are expected to increase demand for irrigation [262].

Pesticide use affects soil by killing and altering the activity, biomass, reproduction, and other activities of soil invertebrates [264], which can impact the important ecosystem services they provide [94]. Reducing pesticide use has been described as a ‘no-regret’ solution to the current invertebrate biodiversity crisis [265].

Because soil is a complex ecosystem, **no single one of these practices is an effective guarantor of soil quality**, however that is measured. Instead, appropriate packages of practices must be developed for local soils and climatic conditions [77].

---

6) We use ‘pesticides’ here as a generic term to include herbicides, fungicides, and insecticides - the main agricultural pesticides which are broadly applied [263].

Regenerating waters

In comparison to soil, there is a degree of consensus on what constitutes water quality and what causes it to degrade in agricultural contexts, though there is debate over appropriate limits for different catchments [266]. Broadly speaking, water (encompassing both freshwater and groundwater), while varying depending on the environment that it is found in, is principally degraded by run-off of sediment, excess nutrients, and pathogen-carrying fecal matter [44], [267], [268]. Sediment blocks photosynthesis and affects flow, nutrients promote algal overgrowth (lowering oxygen levels), and the presence of pathogens makes water non-potable and/or dangerous to interact directly with. The effect of agricultural pesticides on freshwater ecosystems depends on mobilisation and degradation of pesticides in soils and terrestrial ecosystems [269] but is globally significant [263]. The location of water matters as well as the quality: too much or too little water at the wrong time or place are both damaging to agro-ecosystems. Both droughts and floods contribute to soil loss and soil degradation, so the condition of soils and waters is intimately linked [225]. Choices around irrigation use also impact soil health [236], [270]. Landscape-scale alteration of water cycles also strongly impacts flooding risk and erosive capacity of rivers [268], [271], [272].

Regenerative agricultural practices focus on water largely in terms of managing the water cycle to ensure that soils store water year-round for pasture or crops, minimising need for irrigation beyond rainfall as much as possible. Irrigation in and of itself is not necessarily a non-regenerative practice, but draining and contamination of aquifers used to support agricultural production [273], [274] is clearly not regenerative in a systems sense. It can be regarded as another external input, as water stored in aquifers would not naturally return to surface water cycles in the quantities and over the timescales enabled by irrigation. Water used for agriculture is largely lost as water vapour [44]. Long-term use of irrigation has widespread ecosystem effects such as year-round low river levels and loss of water for trees in non-agricultural ecosystems [268], [275], [276]. Irrigation can also take place using stored rainfall rather than drawing on aquifers [277]. This could have positive effects (recharging aquifers) or negative (promoting leaching of nutrients) depending on how it is used.

The regenerative agricultural practices that most closely concern water quality are **tillage, pesticide use, fertiliser use, grazing management**, and **rewilding/ecosystem restoration**.

Reducing tillage in some soils leads to higher soil organic matter [76], [77] and improved soil structure [215], which improves infiltration and soil water holding capacity [76], [191]. Tillage is also a major source of soil erosion [278], which can end up in waterways. However, the effect of reduced tillage is highly dependent on soil type and moisture [222], on the type of tillage and measurement used [200], [216], [279], and also on which other practices it accompanies, such as large-scale pesticide use.

Pesticide use can result in diffuse contamination of freshwater depending on rates of application, mobilisation, and degradation. All pesticides (insecticides, fungicides, and herbicides) have significant and well-documented effects on freshwater ecosystems [41], [261], [280] which lead to direct impacts on ecosystem services such as decomposition [281]. Unlike organics, regenerative agriculture practitioners do not have a consensus on eliminating pesticide use altogether, but techniques such as integrated pest management can support reduced use [282]. Practices which support increased insect biodiversity can also support increased predator control of pests [223].

Fertiliser use is perhaps the key agricultural practice impacting water quality, for two reasons. Firstly, excess nutrients which are not taken up by plant growth or adsorbed to soils are mobilised into groundwater and waterways [283]. They can also be mobilised regardless of adsorption if soil loss into waterways then occurs. This applies to both inorganic fertilisers and organic nutrient sources such as effluent, manure, and composts, depending on rate, timing, and method of application. Secondly, when fertilisers are being used to support pasture growth for livestock beyond the natural carrying capacity of a piece of land, excess N in pasture becomes excess N in livestock urine and excreta, which is also ultimately mobilised into water if it is beyond the uptake capacity of the pasture ecosystem [206], [284], [285]. Nutrient pollution (eutrophication) is one of the most serious forms of agricultural pollution of water [44] and has been described as “both socially and environmentally unacceptable” [286]. It is important to consider both nitrogen and phosphorus as excess nutrients to understand true environmental impacts [287]. Most regenerative agriculture practitioners seek to minimise if not eliminate use of inorganic/chemical fertilisers, usually going well beyond regulated minimisation [266]. However, claims in some grey literature sources about the ability of different plants to release nutrients from soils [137] do not necessarily reflect soil capacity to maintain long-term nutrient balance.

Grazing management impacts water quality when it affects soil compaction [167] and soil cover [259]. Compacted soil leads to higher levels of runoff rather than infiltration and bare soil is more easily eroded, again leading to higher levels of sediment runoff (and other contaminants if attached to sediment). Intensive grazing management can improve water infiltration in dryland pasture [253], [254]. Use of winter crops as part of grazing can lead to runoff if bare soils are left, particularly in wet climates.

Finally, **'rewilding'** [288] or return of agricultural land to self-sustaining non-agricultural ecosystems can play a key role in water quality, as wetlands and riparian boundaries provide ecosystem services including improving water quality through multiple effects and on multiple axes [283], [289], [290], as well as providing capacity to handle temporary periods of increased water flow [93], [291], reducing erosion [166], and sequestering carbon [62], [292]. This does not necessarily mean returning ecosystems to their 'original' state, as this may not be possible [288].

Regenerating ecosystems

“Increasing diversity” is one of the generally-agreed tenets of regenerative agriculture. This can be interpreted in multiple ways: as increasing the diversity of agro-ecosystems as a whole, increasing the diversity of the ecosystems in which agro-ecosystems operate, and increasing the diversity within different productivity streams of agro-ecosystems, by taking up practices such as intercropping, diverse pastures, or agroforestry. Specialisation of agricultural systems - reducing the number of types of farming practised per farm, often to monoculture, as well as the number of breeds/strains of individual animal species and crops used has increased substantially. It has been favoured by the low monetary cost of inputs (i.e. fertilisers and pesticides) and discounting of their non-monetary costs [293] as well as the increased complexity and scale of external systems with which farmers are interacting [294]. As a specific example, when fertiliser is cheap and mechanised tillage is used, it is easier to only farm wheat at a large scale than to have an integrated crop/livestock system to maintain soil fertility. Increasing diversity is a specific goal of regenerative agriculture [129] which aligns it most closely with agroecology, which ultimately seeks to, wherever possible, replace inputs with ecosystem services [92], [103], [147] through integrating ecology and knowledge of ecological systems with agricultural science and practices [81], [295]. Regenerative agriculture as a movement has been criticised for not paying enough attention to diversity-increasing agroecological practices such as integrated pest management, intercropping, and strip cropping [5]. However, other sources consider these to already be included in the corpus of regenerative practices [18], [139], reflecting the variety of definitions of ‘regenerative agriculture’. Integrated and diversified farming systems have been shown to improve ecosystem services [293], [296], [297], although it is still extremely difficult to draw direct links between soil biodiversity and specific ecosystem services [39]. This is due to the complexity of interactions between environmental conditions and ecosystems, as well as temporal effects. One common argument is that it is necessary to increase agricultural production to save land for biodiversity [298], but this ignores the opportunities of ecosystem services provided by integrated biodiversity [95]. Identifying indicators for ecosystem services requires a local lens involving farmers, and interpretation is as important as parameter selection [299]. Ecosystem services can also have tradeoffs between each other, which should not be overlooked [92]. Most importantly, using single practices within otherwise intensive systems does not equate to a diverse, ecologically-oriented system [295].

Diversifying agro-ecosystems can be more difficult to integrate with conservation approaches outside the Old World, as most agriculturally important species are exotic and can be damaging. Taking Aotearoa as an example, deer are both farmed and, through prior introductions for sport, established as a significant mammalian pest. Farm escapes have helped establish new pest populations [300]. In Europe, 50% of species depend on agricultural habitats [227] whereas, as an example, native plant species in Aotearoa are generally adapted to low-N, low-pH soils [301], [302]. Native fish, bird, and some invertebrate species mostly prefer forest ecosystems and are not routinely present in actively farmed agricultural habitats , though this is an under-studied area [302]–[304]. Re-wilding native ecosystems in areas such as wetlands, riparian banks, and re-forested erosion-prone slopes can still provide important habitat, but this requires a more deliberately patchwork approach to land use [305]–[307]. This contrasts with native agroforestry systems in use in Africa [230] and Europe [308], where there is significant potential to integrate native species into agricultural practice.

The specific practices which are most closely aligned to increasing biodiversity in agricultural systems are **pesticide reduction**, **agroforestry**, **integrated systems**, and **diverse crops and pastures**.

Pesticide reduction has been a central tenet of alternative agricultures for over half a century, most widely popularised by Rachel Carson’s book *Silent Spring* [309]. This includes reduction in use of herbicides, insecticides, and fungicides. Pesticides significantly reduce the biodiversity of soil organisms [264] and can penetrate groundwater as well as freshwater ecosystems [310]. Insecticides and fungicides have more impact than herbicides on soil organisms [311], and herbicides can negatively impact desirable species even when used selectively [312]. Some pesticides considered acceptable by organic systems can still cause build-up of undesirable compounds in soils (e.g. copper) [313]. Use of drenches prevents the introduction or re-introduction of dung beetle species providing ecosystem services such as reduced sediment runoff and reduced greenhouse gas emissions [94], [314]–[317]. Control of pests through understanding of agroecosystems and drivers of pest/pathogen populations is known as **integrated pest management**. This represents a shift to a system or landscape-level approach to management, although it does not *necessarily* have pesticide reduction as a goal [282]. One study found that insect pests were significantly lower on regenerative farms using a variety of practices including reduced or no pesticides, but not formal integrated pest management [124]. High-input practices in general reduce soil biodiversity [191], [318].

Diverse pastures refers to deliberately cultivating multispecies grasslands in place of monospecies or two-species pastures (such as the ryegrass-clover pasture system used in some pastoral farms in Aotearoa). This more closely mimics natural grasslands [319] and offers the opportunity to take advantage of ecosystem services provided by different plant functional groups, including the effects of phytochemical release in soils [54] and other plant-soil interactions, including nutrient release [320]. There is some evidence that managing ruminant grazing diets through plant choice can impact greenhouse gas emissions, particularly nitrous oxide from urinary nitrogen [320]–[322], as well as mitigating nitrate leaching [323]–[326]. There is evidence they can have higher nutritive value [327], though maintaining them also requires higher levels of management [328]. Diverse pastures have also been shown to be more resilient to climatic conditions [329], [330], potentially addressing issues of persistence and resilience in low-diversity pastures [331]–[334] and mitigating drought risk [335]. Grazing management can also interact with multispecies pastures to promote high-forage value species [255], [336]. Unfortunately, much of the existing research that has been done on diverse pastures has focused on combining relatively low numbers of species (seven or fewer) in order to iteratively test combinations [329], [337], with few exceptions [90]. Significant knowledge gaps remain over the most appropriate mixes of species for different location and purposes, such as antihelminthic properties or improving soil structure and leaching [326], [338]. In the context of Aotearoa, there is some existing work on the properties of individual species which can be taken into account [339].

Crop diversification including crop rotation, intercropping, use of cover crops, and strip cropping is protective against pests [1], [189], [340] and can reduce nitrogen fertilisation requirements [230], [239], [341]. Diversification is also an important factor in retaining yield [31], [111], reducing risk to farmers [342], and improving nutrient management [241].

Agroforestry encompasses a variety of regenerative practices [154] all of which focus on incorporating tree species into agriculture. This can take the form of intercropping (planting trees between crops) [230], silvopasture (trees in grazed lands) [343], and riparian buffer planting [95], [344]. Trees provide a wide variety of ecosystem services in different contexts including erosion and drought control [343]; native biodiversity support; shade, shelter, and forage for livestock [95]; shelter for crops; carbon sequestration [62]; and mitigation of sediment and nutrient run-off into waterways [165], [292]. In general, inclusion of non-productive vegetation in agro-ecosystems improves ecosystem services [345]. There is considerable overlap between agroforestry and the general principle of **integrating systems**.

Integrating systems refers to connecting different agricultural production systems on a single farm or piece of land. The most significant form is the integration of crop and livestock systems, directly recycling animal waste into fertiliser for crops and crop waste into animal feed. Crop-livestock integration has been extensively studied globally and has generally been shown to have positive impacts on yield, biodiversity, soil quality, and the farm environment [53], [102], [110], [341], [346] but is not always implemented in a holistic way [347]. Another important practice is intercropping and strip cropping of non-tree crops, which can promote 'win-win' gains in ecosystem services and yields [297]. Coppicing of trees can also be integrated with livestock production, with trees coppiced for feed and used for nutrient management [348], [349]. Different forms of livestock production can also be integrated with each other [350]. In one modelled case (beef and dairy) integration reduced total greenhouse gas emissions and potentially improved social licence [351]. One analysis found existing integrated crop-livestock systems required greater managerial intensity, knowledge, and capital but reduced disease and weed abundance [352]. In general, diversification practices within agricultural systems have been identified as crucial to making up yield gaps between organic/low-input and intensive agricultural systems [31], [72], [111], [353], [354]. Support and/or introduction (where not present) of non-crop/livestock species such as dung beetles into agroecosystems has also been successful [94], [315]. However, the patchy history of species introductions [355] highlights the potential for unintended consequences, and from an Indigenous perspective they bring yet another layer of exotic introduction [356].

Regenerating communities

Improving agricultural livelihoods has been identified as one of the major transformations required for agriculture at the global scale [64], [357]. Studies of farmers who take up regenerative practices show that community and wellbeing are both one of the biggest attractions of regenerative agriculture [358] and one of the most significant barriers to entry - in that farmers can feel pressure from their communities to stick to conventional practices [21], and are sometimes reluctant to self-identify as regenerative farmers due to stigma [358]. They can connect with other 'alternative' agricultural practitioners on the internet [105]. Peer-to-peer learning opportunities have been identified as crucial to regenerative transitions [117]. (It is worth noting that the academic literature is probably not keeping up with the pace of change in community expectations; farmers in Aotearoa are increasingly connected and self-organising using the internet [359].)

Few agricultural sustainability frameworks measure farmer wellbeing, but one study in Australia of self-identified regenerative graziers suggested regenerative practices were associated with higher eudaimonic wellbeing (experiencing meaning and purpose) and perception of community connectedness [126]. Outside views of regenerative agricultural practices vary. One study of holistic grazing in the North American Great Plains found that non-regenerative as well as regenerative farmers perceived regenerative practices to have benefits [360]. However, a study of farmers who had not planted riparian banks in Taranaki, Aotearoa found that they perceived them as having no positive benefits, whereas farmers who had chosen to plant riparian zones perceived multiple benefits [361]. To achieve landscape-scale transformation, collaboration and a common vision across multiple farms is needed [305].

No specific set of regenerative practices is directly targeted at improving community and wellbeing, though Māori frameworks understand culturally regenerative practices as directly linked to the wellbeing of iwi, hapū, and whānau [362]. Some regenerative farm advisors regard a paradigm shift towards planning and decision-making on a systems level [363] as a key aspect of regenerative practices, though this does not imply its absence in non-regenerative systems [364]. One study suggests committing to regenerative practices changes the relationship farmers have with land, strengthening the value placed on non-monetary outcomes including biodiversity [365]. This differs markedly from some existing models for farmers, which often represent agroecosystems using mechanistic models of abiotic resource flows [103]. Economic considerations (productivity and financial stability) are still highly important to regenerative farmers, and improved economic indicators can also be a motivator to transition [117].

The major gap in discussions of community and wellbeing for regenerative practices is around farm *workers* as a whole. The studies cited above all focus on farmers as land and/or business-owners. This ultimately ties into the settler-colonial conception of the yeoman farmer, master of his own land [28]. Agricultural labour in much of the Global North is heavily reliant on temporary, often migrant labour [66]. If regenerative agriculture is to live up to its own standards, it should address wellbeing and connection for workers as well as land-owners. This approach is seen in the Rodale Institute's Regenerative Organic Standard [113], but needs to be addressed from a research perspective as well.

Regeneration in Aotearoa

It is uncontroversial to say that there is essentially no academic literature on regenerative agricultural practices *per se* in Aotearoa New Zealand, with all the major works available having been published in the last two years and being reviews or discussions of the system, rather than active research [17], [20], [23], [24], [28]. However, it has received extensive coverage in the media and from activist groups [25]–[27], [139], [366], and a number of industry bodies have announced research projects to assess its suitability [367]–[370]. Over the last two years, it has particularly been promoted by the farmer group Quorum Sense and been covered multiple times on the popular farming show *Country Calendar*. In this section, we will discuss the history of agriculture in Aotearoa, what place regenerative agricultural principles and practices might have, and what the future could look like.

Agriculture in Aotearoa

The commonly understood history of agriculture in Aotearoa starts with the agricultural practices brought by Māori when the first waka arrived approximately seven hundred years ago. Māori agriculture was horticultural and relied on a ‘package’ of tropical plants, some of which did not survive in Aotearoa’s temperate climate [371], [372]. Kūmara (*Ipomoea batatas)*, originally from South America, was the most important. Early European visitors to Aotearoa were impressed by the lack of weeds in Māori gardens [373] and their horticultural knowledge, which allowed kūmara to be cultivated as far south as Ōtepoti | Dunedin [374]. European crops were widely taken up once introduced, particularly potatoes [371], and early nineteenth century Māori farmers, primarily based in the Waikato and Bay of Plenty, were net exporters of food - both to Pākehā (white European) settlers and overseas [375]. However, following the signing of Te Tiriti o Waitangi, Māori land was rapidly expropriated by Pākehā settler-colonists through land deals and military action, deforested, and turned to pastoral agriculture [45], [376], supported by refrigerated shipping beginning in 1882 [377], which made it possible for European settler-farmers in Aotearoa to sell meat and dairy products to European markets. In the early twenty-first century, over half of Aotearoa’s total landmass is still used for pastoral agriculture [378], primarily sheep, beef and deer farming (in terms of land usage), followed by dairy cattle. Aotearoa thus experienced an unusually rapid transition from a managed forest ecosystem to pastoral agriculture. Rather than specialty products, with some exceptions such as mānuka honey and wine, Aotearoa has a demand-driven, commodity-based agricultural system [379] that primarily exports bulk goods such as milk powder [45]. This export-driven market disconnects production from local ecological feedback [376]. The intensification of ‘agro-industry’ in Aotearoa has been described as “inescapable, relentless and embedded within New Zealand's social-ecological institutions affecting agro-ecosystems” [143], prioritising (to a limited extent) the protection of soils and waters over native biodiversity [380]. However, agricultural impacts on soils and waters are still significant and ongoing [381], [382]. Alternative agricultures have made very little headway in Aotearoa [383], aside from organic production, which commands price premiums [384], [385] while still allowing for conventional specialised production [70]. Some forms of organic agriculture have been described as more compatible with Māori world-views about agriculture [386]. However, as of 2019 only 0.8% of land in Aotearoa was in organic production - just over half the global average [73]. There have been calls for landscape ecology [305], [306] to focus on creating sustainable landscapes in Aotearoa, and the field of agroecology is regarded as a potential tool for returning Māori worldviews to agriculture [387]–[389].

The dairy industry is a particular focus for criticism as the most profitable [390], but also most industrialised and intensified, form of agriculture in Aotearoa [45], [391]. Increased fertiliser and imported feed use directly reduces the environmental efficiency of dairy production [392]. The most significant environmental impacts have been on water quality [267], [286], [381], [393], which is directly incompatible with the importance of water as a source of identity and integral part of human relationships in te ao Māori [394]. Agriculture also accounts for nearly half of all greenhouse gas emissions in Aotearoa , principally due to dairy, sheep, and beef farming [59]. On the other hand, because of the extensive amount of landmass they take up, sheep and beef farms host nearly a quarter of remaining native vegetation and sequester approximately ⅓ of their carbon emissions [395], [396]. The agricultural economy is highly siloed, which reduces opportunities for integrated/circular approaches [379]. Proven practices such as deferred grazing and agroforestry are not taken up due to a focus on incrementally improving existing systems [336]. There is a strong existing body of farm systems research within specific industries, e.g. hill country pastoral farming [364].

Finally, in terms of social impacts, the agricultural industry in Aotearoa is heavily reliant on seasonal migrant labour from the Pacific region in specific sub-areas (horticulture, viticulture, and increasingly dairy farming), which can lead to exploitative practices, particularly when workers are also housed on-site [397], [398]. In terms of ownership versus labour, farmers-as-owners in Aotearoa are overwhelmingly male, Pākehā, and older [399], [400]. This represents a significant demographic divide between the wider population and those in control of and making decisions about land management practices.

Regenerative agriculture in Aotearoa

In considering the potential utility of regenerative agriculture in Aotearoa, the crucial point is that agriculture in Aotearoa has simply, despite its rapid transition to a highly productive export-driven system, had much less time for the impacts of industrial agriculture to be felt. As in other settler-colonial countries, agricultural production is rarely understood in the modern era as the product of the sweeping and deliberate transformation of local ecosystems that early European settlers knew themselves to be undertaking [307], [376]. However, the geography of Aotearoa and the early focus of European settlers on products that could be exported to European markets (meat, wool, and butter), combined with the technological innovation that made that possible, meant that intensive arable production and its associated impacts have never been significant here. Aotearoa's soils are relatively carbon-rich [236], [401]–[403] but often naturally low in nitrogen, phosphorus, and trace elements [382], [404], to the extent that seabird colonies represented a major source of nutrient transfer [405]. Historically, even post-Māori arrival, the dominant ecosystem was forested and had no mammalian herbivores [144], [406]. Therefore, the internationally widespread view of regenerative agriculture, which is narrowly focused on soil quality/carbon sequestration in the context of natural grasslands with native mammalian herbivores, is not particularly useful here. It is not possible to 'regenerate' an ecosystem that never naturally existed.

However, as established, this is one particularly narrow conception of what regenerative agriculture is. The unifying principles of regenerative agriculture, as earlier defined, center around creating agro-ecosystems that rely primarily on ecosystem services for productivity and can remediate the impacts of intensive agriculture. If we instead ask what the externalities of agriculture are in Aotearoa that could potentially be mediated by regenerative practices, the key problems are:

Biodiversity - the majority of Aotearoa's pre-human forests and wetlands have been cleared and repurposed as agricultural land [382], [406], [407], and there is a significant bias towards steep landscapes unsuited for agriculture in what remains, which does not represent lowland ecosystems [406]. All major terrestrial faunal groups are experiencing significant threats [408]. Indigenous biodiversity on farms is valued chiefly in terms of Western-style conservation ('land sparing') rather than for any ecosystem services it may provide [404], [409]. Some ecosystems are essentially changed beyond recovery to their original state [410].

The water cycle - agriculture in some areas of Aotearoa relies heavily on irrigation from rivers and aquifers, particularly in the relatively drier areas of Canterbury | Waitaha and the Hawke's Bay | Te Matau-a-Māui. This has contributed to significant drops in aquifer levels [274] and nitrate contamination, particularly in areas of intensive dairy farming [411]. Conversion of wetlands to agricultural production has resulted in ongoing carbon emissions [412] and increased flooding risks [93]. Freshwater is significantly contaminated nationally [381] and the majority of contamination from farms enters the freshwater system through streams that fall below the current limits for regulatory remedial action [413]. Some lowland stream ecosystems are so badly damaged by agriculture all sensitive taxa have been lost [414] and only intensive management can remediate them [415]. Additionally, retention times in the water cycle means that even immediate action may not be reflected in contamination levels for some time [381]

Erosion - The majority of pastoral land in Aotearoa is in hill country and its geological history and climate means that it is highly prone to erosion [416], exacerbated by massive deforestation [406] - 96 million tonnes of soil are lost per year [166]. Erosion means not only the loss of soil and in some circumstances net loss of the carbon stored within it [417], [418], but can lead to contamination of waterways and damage to remaining land.

Soil compaction - with a temperate and relatively wet climate, many soils in Aotearoa are prone to and experiencing compaction from machinery and livestock under intensive agriculture [167], [382]. This is damaging to soil quality and the ability of water to move through soils, resulting in higher runoff and lower water storage [419]. This also increases vulnerability to drought.

Nutrient balance - while unmanaged ecosystems in Aotearoa generally have low nutrient contents where inputs from ocean ecosystems are not involved, some agricultural areas have high levels of nutrient run-off [420], [421] and ongoing nitrogen saturation of soils [422], although there have been limited studies on the direct effects of specific agricultural practices on freshwater ecosystems (e.g. fertiliser use, winter cropping, effluent treatment) [423]. Modeling of nitrogen and phosphorus transport has primarily been conducted using a commercial software tool (Overseer), which in a recent external review was described as not fit for the purposes it is being applied for [286]. In areas of intensive dairy farming soils now have an excess rather than a deficiency of phosphorus, after less than half a century of intensive farming practices [419], and may be losing carbon [422], [424].

Regenerative agriculture therefore has a role to play in Aotearoa in the context of regenerating water cycles, addressing the specific local issues with our soils, and finding, insomuch as it is possible, ways to integrate native biodiversity and ecosystems with agroecosystems. Work to align agricultural practices with tikanga Māori (Māori principles) and mātauranga Māori (Māori knowledge) has been assessed in the context of agroecology [162], [386]–[388] though not yet, in the academic literature at least, strictly in the context of regeneration and regenerative agriculture. Commercial and community Māori enterprises focusing on regenerative agriculture are developing rapidly [368], [425].

Rejection of regenerative agriculture in the context of Aotearoa has focused on two specific (though contradictory) objections: that regenerative agricultural practices have not been tested properly in Aotearoa so cannot be recommended [23], and that they are already in practice in Aotearoa and therefore minor improvements to existing practices are preferred to further significant change [23], [24]. Practice changes (whether they are labelled 'regenerative' or not) that lead to reduced or static production are criticised on the grounds that this will only increase production in other, less environmentally-minded countries [426]. Dairy production in Aotearoa has been described as the least carbon-intensive in the world, although in fact it is within standard error of the carbon footprint of a number of other countries [427] and as of 2015 only 32% of dairy farms operated with eco-efficient low-input systems [392], [428].

Understanding regenerative agriculture as a set of practices appropriate to achieve remediation along with ensuring future production, it is clear there is plenty of work to be done in Aotearoa, and specific targets to be set for regeneration and testing of practices to identify both trade-offs [429] and win-win scenarios. It is imperative to identify the practices that work in a local context [19], as agroecologists so often emphasise [53]. For example, there is evidence that one-off full-inversion tillage can store carbon in some Aotearoa soils [236], [430] even though there is significant evidence that in many soils tillage causes net loss of carbon [216], [217], [431]. A standardised measurement programme for soil carbon stocks has yet to be developed, but is crucial to monitoring changes and response to agricultural practice changes [432]. For another, the high level of endemism among native species in Aotearoa [408] means that work to better integrate native and agro-ecosystems cannot be generalised from other ecosystems [20]. Understanding interactions between native plantings and ecosystem services from invertebrates, for example, is at an early stage [433]. Lupins, which are already being taken up as a nitrogen-fixing pasture component in high country farms in the South Island | Te Waipounamu [434] - diversifying pastures - are damaging to downstream freshwater ecosystems [435]. Local research on the constraints of implementing practices (such as establishing diverse pastures [436], [437]) is vital - and therefore needs to be carried out where it is lacking. Inaction only supports the status quo [307].

Secondly, as long as significant impacts such as those listed above remain, it is meaningless to claim that the current system of agricultural practices is truly regenerative in our context, even if they are an improvement on some overseas practices (for example, established use of ryegrass/clover pasture rather than monoculture ryegrass) [438]. Additionally, individual practices cannot adequately address detrimental outcomes on their own [95]. For some areas of agriculture, the cost of unaccounted-for externalities (including globally, such as the impacts of palm kernel production) is estimated to outweigh actual revenue [391]. Where significant impacts are being caused by specific current practices (e.g. fertiliser and imported feed use [382], [392], [381]) there is an urgent need to trial different approaches, rather than focus on small changes. Evidence for the regenerative impact of a number of practices (e.g. diversifying pastures, agroforestry in hill country, deferred grazing, riparian planting) already exists [95], [165], [326], [336], [409], [439] - the question is how best to motivate their adoption. Existing surveys of regenerative and non-regenerative practitioners can provide guidance here [117], [360], [361], as well as other existing guidance on agricultural extension programmes [106].

Productivity/profitability can and should be assessed as part of a suite of outcomes [110], [134], [440], [441], but care must be taken to disambiguate system profits from capital gains on land value, which do not necessarily reflect the sustainability of agricultural practices [442]. This is particularly important for ruminant livestock agriculture, as greenhouse gas emissions are in part a result of direct inefficiencies in production, representing carbon and nitrogen lost from the production system [232], [443]. Existing studies show that lower-input farm systems are often more profitable at low prices (or high input costs) and therefore more resilient [444], [445]. Resilience - both environmental and economic - is highly important in the face of the predicted impacts of climate change on Aotearoa [446].

Finally, there is significant evidence that sets of practices included in regenerative agriculture (e.g. the three core practices of conservation agriculture [225]) must be practised as a whole to have worthwhile impact; their effects are compounding. This requires systemic changes and testing, rather than trialing individual practices one by one [70], [123], [128], [295]. Economic analysis also suggests addressing multiple externalities at once (nitrogen leaching and carbon emissions) is better for farmers, even excluding analysis of all environmental benefits [447]. Regenerative agriculture as a movement towards a semi-circular agricultural economy (a concept also increasingly discussed in non-academic organic agricultural circles) requires integration of different agricultural areas, rather than continued (over)simplification [118], [448]. To address the need for integrated practices and analysis, we can look to approaches such as life cycle analysis [134], [248], [287], [449], which allows examination of multiple outcomes on a farm system level, and landscape ecology, which allows collaborative design on a landscape scale [306].

The future of regenerative farming

Defining regenerative agriculture as a set of practices that improves system performance now and in the future, while acknowledging the full set of agricultural outcomes, we find that the practices most closely associated with it are sound and the vast majority are already being implemented to some degree. These include holistic grazing, diverse pastures, livestock/crop integration, silvopasture, crop rotation, reduced tillage, and others. There is significantly more agreement about the principles of regenerative agriculture than the practices, probably due in part to variation between locations and farming systems. However, there is a lack of economic and productivity data (and data on social wellbeing, which is linked [126]) for regenerative (versus organic or conservation agriculture) systems, in part due to the difficulty in comparing diverse sets of practices across different agricultural contexts [31]. In general, 'regenerative agriculture' as a term is having a moment in the sun, being taken up by large commercial operations [403]. It attracts significant hostility in part because when meaningfully applied, it is a radical reconceptualisation of how the success of agricultural practices should be measured [161], building on the foundations laid by and ongoing work of other alternative agricultures. In many contexts, it demands not just minor adjustments to existing practices but entirely new approaches. Technological solutions are not inherently excluded by regenerative agriculture (or indeed other systems such as agroecology [6], [70]) but technological solutions are often preferred because they are more amenable to the 'tinkering around the edges' approach of intensive agriculture [104]. They can also be prohibitively expensive for farmers to take up. They have been described in the Aotearoa context as the 'main opportunit[y] to reduce farm emissions' [454]. While solutions such as improving animal traits through breeding can provide significant gains, for example in reducing nitrogen emissions, [455], [456], they must be tested alongside practice changes to ensure the gains are present in regenerative as well as intensive conditions. Adoption of a single-practice mindset puts regenerative agricultural practices in danger of greenwashing and adoption into industrial systems in the same way that organic practices and some aspects of agroecology have been [70], particularly as financial institutions incorporate practices into metrics for sustainable investment [457]–[459].

The question posed at the start of this literature review was "**can regenerative agriculture (under any definition) provide solutions to the 'wicked' problems of modern agriculture, particularly in Aotearoa?**". Having defined regenerative agriculture as any set of practices that lead to low-impact, integrated agro-ecosystems - based on outcomes - this is in fact not the most useful question. A more useful question is "**in Aotearoa, which sets of agricultural practices are regenerative?**" - meaning, which sets of practices move us closer to the most closed possible agro-ecosystem with the lowest environmental impacts on a system level?

The same question can be asked in any country's context. Western science is well-placed to help answer this question as it relates both to aspects of individual practices, where appropriate, as well as the outcomes of system-level changes. There is also a clear meeting place in this framing for regenerative agriculture and mātauranga Māori, with the latter being especially aligned with landscape-scale management as kaitiakitanga and care for Papatuānuku. Agricultural practices and systems can be assessed by mana whenua for their alignment with ao Māori principles, as a key component of their identification as regenerative. In fact, nobody can seriously claim 'regeneration' in Aotearoa if it does not align with the values of mana whenua, as the original agricultural practitioners on these islands.

Ultimately, what we call improvements in agricultural practices is much less important than *whether* they improve. Defenders of current agricultural practices in Aotearoa call them 'contextually optimal' [24]. In the context of nearly two hundred years of settler-colonial imposition of European ecosystems and practices onto an archipelago in Te Moana-Nui-a-Kiwa [460], with increasingly troubling environmental outcomes, this seems like a dangerous sort of arrogance: whose context are we actually acknowledging? Fortunately, the rich body of literature on alternative agricultural practices and systems assessments gives us the tools that permit us to do better - to, hopefully, regenerate.

Bibliography

[1] P. A. Matson, W. Parton, A. Power, and M. J. Swift, ‘Agricultural Intensification and Ecosystem Properties’, *Science*, vol. 277, pp. 504–9, Jul. 1997, doi: 10.1126/science.277.5325.504.

[2] C. Hiç, P. Pradhan, D. Rybski, and J. P. Kropp, ‘Food Surplus and Its Climate Burdens’, *Environ. Sci. Technol.*, vol. 50, no. 8, pp. 4269–4277, Apr. 2016, doi: 10.1021/acs.est.5b05088.

[3] P. L. Pingali, ‘Green Revolution: Impacts, limits, and the path ahead’, *Proc. Natl. Acad. Sci.*, vol. 109, no. 31, pp. 12302–12308, Jul. 2012, doi: 10.1073/pnas.0912953109.

[4] J. Pretty *et al.*, ‘Policy Challenges and Priorities for Internalizing the Externalities of Modern Agriculture’, *J. Environ. Plan. Manag.*, vol. 44, no. 2, pp. 263–283, Mar. 2001, doi: 10.1080/09640560123782.

[5] K. E. Giller, R. Hijbeek, J. A. Andersson, and J. Sumberg, ‘Regenerative Agriculture: An agronomic perspective’, *Outlook Agric.*, vol. 50, no. 1, pp. 13–25, Mar. 2021, doi: 10.1177/0030727021998063.

[6] P. Migliorini *et al.*, ‘Controversial topics in agroecology: A European perspective’, *Int. J. Agric. Nat. Resour.*, vol. 47, no. 3, Art. no. 3, Dec. 2020, doi: 10.7764/ijanr.v47i3.2265.

[7] P. R. Hobbs, K. Sayre, and R. Gupta, ‘The role of conservation agriculture in sustainable agriculture’, *Philos. Trans. R. Soc. B Biol. Sci.*, vol. 363, no. 1491, pp. 543–555, Feb. 2008, doi: 10.1098/rstb.2007.2169.

[8] Food and Agriculture Organization of the United Nations, ‘The Ten Elements of Agroecology’. Food and Agriculture Organization of the United Nations, 2011. Accessed: Jun. 14, 2021. [Online]. Available: http://www.fao.org/3/i9037en/i9037en.pdf

[9] C. I. Nicholls and M. A. Altieri, ‘Pathways for the amplification of agroecology’, *Agroecol. Sustain. Food Syst.*, vol. 42, no. 10, pp. 1170–1193, Nov. 2018, doi: 10.1080/21683565.2018.1499578.

[10] C. R. Anderson, J. Bruil, M. J. Chappell, C. Kiss, and M. P. Pimbert, ‘From Transition to Domains of Transformation: Getting to Sustainable and Just Food Systems through Agroecology’, *Sustainability*, vol. 11, no. 5272, Art. no. 19, Jan. 2019, doi: 10.3390/su11195272.

[11] S. Bellon and G. Ollivier, ‘Institutionalizing Agroecology in France: Social Circulation Changes the Meaning of an Idea’, *Sustainability*, vol. 10, no. 1380, Art. no. 5, May 2018, doi: 10.3390/su10051380.

[12] ‘Regenerative Annual Cropping @ProjectDrawdown #ClimateSolutions’, *Project Drawdown*, Feb. 06, 2020. https://www.drawdown.org/solutions/regenerative-annual-cropping (accessed Jun. 02, 2021).

[13] R. Lal, ‘Regenerative agriculture for food and climate’, *J. Soil Water Conserv.*, vol. 75, no. 5, pp. 123A-124A, Sep. 2020, doi: 10.2489/jswc.2020.0620A.

[14] A. McGuire, ‘Regenerative Agriculture: Solid Principles, Extraordinary Claims | CSANR | Washington State University’, *Center For Sustaining Agriculture And Natural Resources*, Apr. 04, 2018. https://csanr.wsu.edu/regen-ag-solid-principles-extraordinary-claims/ (accessed Jun. 02, 2021).

[15] N. Teal, ‘Regenerative Agriculture can play a key role in combating climate change’, *Medium*, May 29, 2021. https://medium.com/oneearth/regenerative-agriculture-can-play-a-key-role-in-combating-climate-change-cbaacef65d36 (accessed Jun. 08, 2021).

[16] G. J. Kenne and R. W. Kloot, ‘The Carbon Sequestration Potential of Regenerative Farming Practices in South Carolina, USA’, *Am. J. Clim. Change*, vol. 08, no. 02, Art. no. 02, Apr. 2019, doi: 10.4236/ajcc.2019.82009.

[17] C. N. Merfield, ‘An Analysis and Overview of Regenerative Agriculture’, The BHU Future Farming Centre, Lincoln, NZ, 2–2019, 2019.

[18] P. J. Burgess, J. Harris, A. R. Graves, and L. K. Deeks, ‘Regenerative Agriculture: Identifying the impact; enabling the potential’, Cranfield University, Bedfordshire, UK, 2019.

[19] P. Newton, N. Civita, L. Frankel-Goldwater, K. Bartel, and C. Johns, ‘What Is Regenerative Agriculture? A Review of Scholar and Practitioner Definitions Based on Processes and Outcomes’, *Front. Sustain. Food Syst.*, vol. 4, no. 577723, 2020, doi: 10.3389/fsufs.2020.577723.

[20] G. Grelet *et al.*, ‘Regenerative agriculture in Aotearoa New Zealand – research pathways to build science-based evidence and national narratives’, Manaaki Whenua – Landcare Research, Lincoln, N.Z., 2021. [Online]. Available: https://www.landcareresearch.co.nz/publications/regenag/regenerative-agriculture-white-paper-sets-out-pressing-research-priorities/

[21] J. O’Connor, ‘Barriers For Farmers & Ranchers To Adopt Regenerative Ag Practices In The US’, Guidelight Strategies, Aug. 2020. Accessed: Jun. 09, 2021. [Online]. Available: https://forainitiative.org/wp-content/uploads/Barriers-to-Adopt-Regnerative-Agriculture-Interactive.pdf

[22] N. Masters, *For the love of soil: strategies to regenerate our food production systems.* New Zealand: Printable Reality, 2019.

[23] J. Hickford, ‘Special Issue on Regenerative Agriculture’, *AgScience*, no. 57, Dec. 2020.

[24] J. S. Rowarth, A. H. C. Roberts, W. King, and M. J. Manning, ‘New-generative agriculture – based on science, informed by research and honed by New Zealand farmers’, *J. N. Z. Grassl.*, vol. 82, pp. 221–229, 2020.

[25] J. Rowarth, ‘Dr Jacqueline Rowarth: Is regenerative agriculture really the way forward?’, *NZ Herald*, Auckland, New Zealand, May 11, 2020. Accessed: May 05, 2021. [Online]. Available: https://www.nzherald.co.nz/the-country/news/dr-jacqueline-rowarth-is-regenerative-agriculture-really-the-way-forward/W2S7AX5QZU64CJTFZYAWG4LPUA/

[26] A. Siegfried, ‘What is Regen Ag and why is it big for NZ?’, *Newsroom*, May 04, 2020. https://www.newsroom.co.nz/page/alina-siegfried-good-bad-opportunity (accessed Jul. 06, 2021).

[27] Pure Advantage, ‘Our Regenerative Future’, *Pure Advantage*. https://pureadvantage.org/campaigns/ourregenerativefuturecampaign/ (accessed Jul. 30, 2021).

[28] E. A. Burns, ‘Thinking sociologically about regenerative agriculture’, *N. Z. Sociol.*, Dec. 2020, Accessed: Jun. 14, 2021. [Online]. Available: https://search.informit.org/doi/abs/10.3316/INFORMIT.562268559313895

[29] H. W. J. Rittel and M. M. Webber, ‘Dilemmas in a General Theory of Planning’, *Policy Sci.*, vol. 4, pp. 155–169, 1973.

[30] J. Bouma and A. McBratney, ‘Framing soils as an actor when dealing with wicked environmental problems’, *Geoderma*, vol. 200–201, pp. 130–139, Jun. 2013, doi: 10.1016/j.geoderma.2013.02.011.

[31] L. C. Ponisio and P. R. Ehrlich, ‘Diversification, Yield and a New Agricultural Revolution: Problems and Prospects’, *Sustainability*, vol. 8, no. 11, Art. no. 11, Nov. 2016, doi: 10.3390/su8111118.

[32] M. Pulleman *et al.*, ‘Soil biodiversity, biological indicators and soil ecosystem services—an overview of European approaches’, *Curr. Opin. Environ. Sustain.*, vol. 4, no. 5, pp. 529–538, Nov. 2012, doi: 10.1016/j.cosust.2012.10.009.

[33] P. Borrelli *et al.*, ‘Land use and climate change impacts on global soil erosion by water (2015-2070)’, *Proc. Natl. Acad. Sci.*, vol. 117, no. 36, pp. 21994–22001, Sep. 2020, doi: 10.1073/pnas.2001403117.

[34] R. Lal, ‘Soils and food sufficiency. A review’, *Agron. Sustain. Dev.*, vol. 29, no. 1, pp. 113–133, Mar. 2009, doi: 10.1051/agro:2008044.

[35] K. N. Potter, H. A. Torbert, H. B. Johnson, and C. R. Tischler, ‘Carbon storage after long-term grass establishment on degraded soil’, *Soil Sci.*, vol. 164, no. 10, pp. 718–725, Oct. 1999, doi: 10.1097/00010694-199910000-00002.

[36] P. Smith *et al.*, ‘Soil-derived Nature’s Contributions to People and their contribution to the UN Sustainable Development Goals’, *Philos. Trans. R. Soc. B Biol. Sci.*, 2021.

[37] R. M. Lehman *et al.*, ‘Understanding and Enhancing Soil Biological Health: The Solution for Reversing Soil Degradation’, *Sustainability*, vol. 7, no. 1, Art. no. 1, 2015, doi: 10.3390/su7010988.

[38] N. Fierer, ‘Embracing the unknown: disentangling the complexities of the soil microbiome’, *Nat. Rev. Microbiol.*, vol. 15, no. 10, pp. 579–590, Oct. 2017, doi: 10.1038/nrmicro.2017.87.
[39] M. Ludwig, P. Wilmes, and S. Schrader, ‘Measuring soil sustainability via soil resilience’, *Sci. Total Environ.*, vol. 626, pp. 1484–1493, Jun. 2018, doi: 10.1016/j.scitotenv.2017.10.043.
[40] N. Dudley and S. Alexander, ‘Agriculture and biodiversity: a review’, *Biodiversity*, vol. 18, no. 2–3, pp. 45–49, Jul. 2017, doi: 10.1080/14888386.2017.1351892.
[41] F. Sánchez-Bayo and K. A. G. Wyckhuys, ‘Worldwide decline of the entomofauna: A review of its drivers’, *Biol. Conserv.*, vol. 232, pp. 8–27, Apr. 2019, doi: 10.1016/j.biocon.2019.01.020.
[42] J. A. Harvey *et al.*, ‘International scientists formulate a roadmap for insect conservation and recovery’, *Nat. Ecol. Evol.*, vol. 4, no. 2, pp. 174–176, Feb. 2020, doi: 10.1038/s41559-019-1079-8.
[43] C. Tonitto, M. B. David, and L. E. Drinkwater, ‘Replacing bare fallows with cover crops in fertilizer-intensive cropping systems: A meta-analysis of crop yield and N dynamics’, *Agric. Ecosyst. Environ.*, vol. 112, no. 1, pp. 58–72, Jan. 2006, doi: 10.1016/j.agee.2005.07.003.
[44] S. R. Carpenter, E. H. Stanley, and M. J. Vander Zanden, ‘State of the World’s Freshwater Ecosystems: Physical, Chemical, and Biological Changes’, *Annu. Rev. Environ. Resour.*, vol. 36, no. 1, pp. 75–99, 2011, doi: 10.1146/annurev-environ-021810-094524.
[45] M. A. Wynyard, ‘The Price of Milk: Primitive accumulation and the New Zealand Dairy Industry 1814-2014’, Doctor of Philosophy, University of Auckland, Auckland, New Zealand, 2016.
[46] A. Pulido-Bosch *et al.*, ‘Impacts of agricultural irrigation on groundwater salinity’, *Environ. Earth Sci.*, vol. 77, no. 5, p. 197, Mar. 2018, doi: 10.1007/s12665-018-7386-6.
[47] W. E. Dench and L. K. Morgan, ‘Unintended consequences to groundwater from improved irrigation efficiency: Lessons from the Hinds-Rangitata Plain, New Zealand’, *Agric. Water Manag.*, vol. 245, p. 106530, Feb. 2021, doi: 10.1016/j.agwat.2020.106530.
[48] B. Dumont, L. Fortun-Lamothe, M. Jouven, M. Thomas, and M. Tichit, ‘Prospects from agroecology and industrial ecology for animal production in the 21st century’, *Animal*, vol. 7, no. 6, pp. 1028–1043, Jun. 2013, doi: 10.1017/S1751731112002418.
[49] M. B. Hufford, J. C. Berny Mier y Teran, and P. Gepts, ‘Crop Biodiversity: An Unfinished Magnum Opus of Nature’, *Annu. Rev. Plant Biol.*, vol. 70, no. 1, pp. 727–751, Apr. 2019, doi: 10.1146/annurev-arplant-042817-040240.
[50] L. Pacicco, M. Bodesmo, R. Torricelli, and V. Negri, ‘A methodological approach to identify agro-biodiversity hotspots for priority in situ conservation of plant genetic resources’, *PLOS ONE*, vol. 13, no. 6, p. e0197709, Jun. 2018, doi: 10.1371/journal.pone.0197709.
[51] F. T. de Vries *et al.*, ‘Soil food web properties explain ecosystem services across European land use systems’, *Proc. Natl. Acad. Sci.*, vol. 110, no. 35, pp. 14296–14301, Aug. 2013, doi: 10.1073/pnas.1305198110.
[52] M. D. Hathaway, ‘Agroecology and permaculture: addressing key ecological problems by rethinking and redesigning agricultural systems’, *J. Environ. Stud. Sci.*, vol. 6, no. 2, pp. 239–250, Jun. 2016, doi: 10.1007/s13412-015-0254-8.
[53] C. Neely and A. Fynn, ‘Critical choices for crop and livestock production systems that enhance productivity and build ecosystem resilience’, Food and Agriculture Organization of the United Nations, Rome, Italy, TR-11, 2011.
[54] A. K. Clemensen, F. D. Provenza, J. R. Hendrickson, and M. A. Grusak, ‘Ecological Implications of Plant Secondary Metabolites - Phytochemical Diversity Can Enhance Agricultural Sustainability’, *Front. Sustain. Food Syst.*, vol. 4, p. 10, 2020.
[55] A. Romero-Ruiz, N. Linde, T. Keller, and D. Or, ‘A Review of Geophysical Methods for Soil Structure Characterization’, *Rev. Geophys.*, vol. 56, no. 4, pp. 672–697, 2018, doi: 10.1029/2018RG000611.
[56] S. J. Rowe *et al.*, ‘Selection for divergent methane yield in New Zealand sheep - a ten-year perspective’, *Proc. Assoc. Adv. Anim. Breed. Genet.*, vol. 23, pp. 306–309, 2019.
[57] V. Corrigan, D. Hedderley, G. Langford, and C. Zou, ‘Flavour analysis of New Zealand grown blackcurrants: an evaluation of expert selection methods’, *N. Z. J. Crop Hortic. Sci.*, vol. 42, no. 4, pp. 247–264, Oct. 2014, doi: 10.1080/01140671.2014.894920.
[58] O. Edenhofer, Ed., *Climate change 2014: mitigation of climate change: Working Group III contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. New York, NY: Cambridge University Press, 2014.
[59] Ministry for the Environment, ‘New Zealand’s Greenhouse Gas Inventory 1990–2019’, Ministry for the Environment, Wellington, New Zealand, ME 1559, 2021.
[60] D. Giltrap, A. Manderson, S. Saggar, and R. Davison, ‘Developing a farm-scale greenhouse gas calculator for sheep and beef farms’, in *Science and policy: nutrient management challenges for the next generation*, Palmerston North, N.Z.: Fertiliser and Lime Research Center, Massey University, 2017.
[61] K. R. Tate *et al.*, ‘Land-use change alters New Zealand’s terrestrial carbon budget: uncertainties associated with estimates of soil carbon change between 1990–2000’, *Tellus B Chem. Phys. Meteorol.*, vol. 55, no. 2, pp. 364–377, Jan. 2003, doi: 10.3402/tellusb.v55i2.16762.
[62] B. W. Griscom *et al.*, ‘Natural climate solutions’, *Proc. Natl. Acad. Sci.*, vol. 114, no. 44, pp. 11645–11650, Oct. 2017, doi: 10.1073/pnas.1710465114.
[63] C. A. M. de Klein, R. R. Sherlock, K. C. Cameron, and T. J. van der Weerden, ‘Nitrous oxide emissions from agricultural soils in New Zealand—A review of current knowledge and directions for future research’, *J. R. Soc. N. Z.*, vol. 31, no. 3, pp. 543–574, Sep. 2001, doi: 10.1080/03014223.2001.9517667.
[64] ‘Transforming Food and Agriculture to Achieve the SDGs’, Food and Agriculture Organization of the United Nations, Rome, Italy, 2018. Accessed: Oct. 15, 2020. [Online]. Available: http://www.fao.org/3/i9900en/i9900en.pdf
[65] S. Rotz *et al.*, ‘Automated pastures and the digital divide: How agricultural technologies are shaping labour and rural communities’, *J. Rural Stud.*, vol. 68, pp. 112–122, May 2019, doi: 10.1016/j.jrurstud.2019.01.023.
[66] S. Rosewarne, ‘The Making of Agricultural Industry’s Temporary Migrant Workforce: Beyond Exploitative Experiences?’, *J. Aust. Polit. Econ.*, vol. 84, pp. 5–12, 2019.
[67] *The Sustainable Development Goals Report 2021*. New York, NY, USA: United Nations, 2021. Accessed: Aug. 09, 2021. [Online]. Available: https://unstats.un.org/sdgs/report/2021/The-Sustainable-Development-Goals-Report-2021.pdf
[68] M. D. Anderson and M. Rivera-Ferre, ‘Food system narratives to end hunger: extractive versus regenerative’, *Curr. Opin. Environ. Sustain.*, vol. 49, pp. 18–25, Apr. 2021, doi: 10.1016/j.cosust.2020.12.002.
[69] C. Hermani, ‘Regenerative Agriculture and the Quest for Sustainability - Inquiry of an Emerging Concept (Master Thesis)’, Master of Science, Humboldt-Universität Zu Berlin, Berlin, Germany, 2020. Accessed: Jun. 09, 2021. [Online]. Available: http://rgdoi.net/10.13140/RG.2.2.36015.97447
[70] M. A. Altieri, C. I. Nicholls, and R. Montalba, ‘Technological Approaches to Sustainable Agriculture at a Crossroads: An Agroecological Perspective’, *Sustainability*, vol. 9, no. 3, Art. no. 3, Mar. 2017, doi: 10.3390/su9030349.
[71] AsureQuality, ‘International Organic Standards - Organic Certification - Certified Organic NZ’, *AsureQuality*. https://www.asurequality.com/services/certification/organic-certification/international-organic-standards/ (accessed Aug. 05, 2021).
[72] L. C. Ponisio, L. K. M’Gonigle, K. C. Mace, J. Palomino, P. de Valpine, and C. Kremen, ‘Diversification practices reduce organic to conventional yield gap’, *Proc. R. Soc. B Biol. Sci.*, vol. 282, no. 1799, p. 20141396, Jan. 2015, doi: 10.1098/rspb.2014.1396.
[73] H. Willer and J. Lernoud, Eds., *The World of Organic Agriculture: Statistics & Emerging Trends 2019*. Frick Bonn: FiBL IFOMA-Organics international, 2019.
[74] H. L. Tuomisto, I. D. Hodge, P. Riordan, and D. W. Macdonald, ‘Does organic farming reduce environmental impacts? – A meta-analysis of European research’, *J. Environ. Manage.*, vol. 112, pp. 309–320, Dec. 2012, doi: 10.1016/j.jenvman.2012.08.018.
[75] B. I. Cook, R. L. Miller, and R. Seager, ‘Amplification of the North American “Dust Bowl” drought through human-induced land degradation’, *Proc. Natl. Acad. Sci.*, vol. 106, no. 13, pp. 4997–5001, Mar. 2009, doi: 10.1073/pnas.0810200106.
[76] C. Palm, H. Blanco-Canqui, F. DeClerck, L. Gatere, and P. Grace, ‘Conservation agriculture and ecosystem services: An overview’, *Agric. Ecosyst. Environ.*, vol. 187, pp. 87–105, Apr. 2014, doi: 10.1016/j.agee.2013.10.010.

[77] K. E. Giller *et al.*, 'Beyond conservation agriculture', *Front. Plant Sci.*, vol. 6, 2015, doi: 10.3389/fpls.2015.00870.

[78] A. Wezel, S. Bellon, T. Doré, C. Francis, D. Vallod, and C. David, 'Agroecology as a science, a movement and a practice. A review', *Agron. Sustain. Dev.*, vol. 29, no. 4, pp. 503–515, Dec. 2009, doi: 10.1051/agro/2009004.

[79] A. M. Loconto and E. Fouilleux, 'Defining agroecology: Exploring the circulation of knowledge in FAO's Global Dialogue', *Int. J. Sociol. Agric. Food*, vol. 25, no. 2, Art. no. 2, Aug. 2019, doi: 10.48416/ijsaf.v25i2.27.

[80] E. Isgren and B. Ness, 'Agroecology to Promote Just Sustainability Transitions: Analysis of a Civil Society Network in the Rwenzori Region, Western Uganda', *Sustainability*, vol. 9, no. 8, Art. no. 8, Aug. 2017, doi: 10.3390/su9081357.

[81] C. A. Edwards, T. L. Grove, R. R. Harwood, and C. J. Pierce Colfer, 'The role of agroecology and integrated farming systems in agricultural sustainability', *Agric. Ecosyst. Environ.*, vol. 46, no. 1, pp. 99–121, Sep. 1993, doi: 10.1016/0167-8809(93)90017-J.

[82] R. S. Ferguson and S. T. Lovell, 'Permaculture for agroecology: design, movement, practice, and worldview. A review', *Agron. Sustain. Dev.*, vol. 34, no. 2, pp. 251–274, Apr. 2014, doi: 10.1007/s13593-013-0181-6.

[83] J. L. Caradonna and F. Apffel-Marglin, 'The regenerated chacra of the Kichwa-Lamistas: an alternative to permaculture?', *Altern. Int. J. Indig. Peoples*, vol. 14, no. 1, pp. 13–24, Mar. 2018, doi: 10.1177/1177180117740708.

[84] J. F. L. Charlton and J. H. Wier, 'TechnoGrazing^{TM} a new grazing concept', *Proc. N. Z. Grassl. Assoc.*, pp. 33–36, Jan. 2001, doi: 10.33584/jnzg.2001.63.2428.

[85] 'EOV: The Science-based label for Regenerative Food and Fiber', *Savory Institute*. https://savory.global/land-to-market/eov/ (accessed Oct. 15, 2020).

[86] R. Teague *et al.*, 'Benefits of Multi-Paddock Grazing Management on Rangelands: Limitations of Experimental Grazing Research and Knowledge Gaps', in *Grasslands: Ecology, Management, and Restoration*, Nova Science Publishers, Inc, 2008.

[87] T. F. Döbert *et al.*, 'Adaptive multi-paddock grazing improves water infiltration in Canadian grassland soils', *Geoderma*, vol. 401, p. 115314, Nov. 2021, doi: 10.1016/j.geoderma.2021.115314.

[88] H. Gosnell, K. Grimm, and B. E. Goldstein, 'A half century of Holistic Management: what does the evidence reveal?', *Agric. Hum. Values*, vol. 37, no. 3, pp. 849–867, Sep. 2020, doi: 10.1007/s10460-020-10016-w.

[89] B. Norton, 'The application of grazing management to increase sustainable livestock production', *Anim. Prod. Aust.*, vol. 22, pp. 15–26, Jan. 1998.

[90] K. Zaralis and S. Padel, 'Effects of High Stocking Grazing Density of Diverse Swards on Forage Production, Animal Performance and Soil Organic Matter: A Case Study', in *International Conference on Information and Communication Technologies in Agriculture, Food & Environment*, 2017, pp. 131–146.

[91] M. B. Machmuller, M. G. Kramer, T. K. Cyle, N. Hill, D. Hancock, and A. Thompson, 'Emerging land use practices rapidly increase soil organic matter', *Nat. Commun.*, vol. 6, no. 1, pp. 1–5, 2015.

[92] T. Rodríguez-Ortega, E. Oteros-Rozas, R. Ripoll-Bosch, M. Tichit, B. Martín-López, and A. Bernués, 'Applying the ecosystem services framework to pasture-based livestock farming systems in Europe', *animal*, vol. 8, no. 8, pp. 1361–1372, Aug. 2014, doi: 10.1017/S1751731114000421.

[93] B. R. Clarkson, A.-G. E. Ausseil, and P. Gerbeaux, 'Wetland ecosystem services', in *Ecosystem services in New Zealand – conditions and trends*, Lincoln, N.Z.: Manaaki Whenua Press, 2013, pp. 192–203.

[94] J. E. Losey and M. Vaughan, 'The Economic Value of Ecological Services Provided by Insects', *BioScience*, vol. 56, no. 4, p. 311, 2006, doi: 10.1641/0006-3568(2006)56[311:TEVOES]2.0.CO;2.

[95] F. J. F. Maseyk, E. J. Dominati, and A. D. Mackay, 'Change in ecosystem service provision within a lowland dairy landscape under different riparian margin scenarios', *Int. J. Biodivers. Sci. Ecosyst. Serv. Manag.*, vol. 14, no. 1, pp. 17–31, Jan. 2018, doi: 10.1080/21513732.2017.1411974.

[96] R. T. Conant, J. Six, and K. Paustian, 'Land use effects on soil carbon fractions in the southeastern United States. I. Management-intensive versus extensive grazing', *Biol. Fertil. Soils*, vol. 38, no. 6, pp. 386–392, Oct. 2003, doi: 10.1007/s00374-003-0652-z.

[97] X. Díaz de Otálora, L. Epelde, J. Arranz, C. Garbisu, R. Ruiz, and N. Mandaluniz, 'Regenerative rotational grazing management of dairy sheep increases springtime grass production and topsoil carbon storage', *Ecol. Indic.*, vol. 125, p. 107484, Jun. 2021, doi: 10.1016/j.ecolind.2021.107484.

[98] K. Sherren and C. Kent, 'Who's afraid of Allan Savory? Scientometric polarization on Holistic Management as competing understandings', *Renew. Agric. Food Syst.*, vol. 34, no. 1, pp. 77–92, Feb. 2019, doi: 10.1017/S1742170517000308.

[99] W. R. Teague *et al.*, 'The role of ruminants in reducing agriculture's carbon footprint in North America', *J. Soil Water Conserv.*, vol. 71, no. 2, pp. 156–164, Mar. 2016, doi: 10.2489/jswc.71.2.156.

[100] L. Klerkx, B. van Mierlo, and C. Leeuwis, 'Evolution of systems approaches to agricultural innovation: concepts, analysis and interventions', in *Farming Systems Research into the 21st Century: The New Dynamic*, I. Darnhofer, D. Gibbon, and B. Dedieu, Eds. Dordrecht: Springer Netherlands, 2012, pp. 457–483. doi: 10.1007/978-94-007-4503-2_20.

[101] A. Rae, C. Nixon, and R. Lattimore, 'Adjustment to agricultural policy reform: Issues and lessons from the New Zealand experience', New Zealand Institute of Economic Research, Wellington, New Zealand, NZ Trade Consortium Working Paper 35, 2004. Accessed: Nov. 04, 2021. [Online]. Available: https://www.econstor.eu/bitstream/10419/66075/1/49464205X.pdf

[102] J. Pretty *et al.*, 'Global assessment of agricultural system redesign for sustainable intensification', *Nat. Sustain.*, vol. 1, no. 8, Art. no. 8, Aug. 2018, doi: 10.1038/s41893-018-0114-0.

[103] M. Duru *et al.*, 'How to implement biodiversity-based agriculture to enhance ecosystem services: a review', *Agron. Sustain. Dev.*, vol. 35, no. 4, pp. 1259–1281, Oct. 2015, doi: 10.1007/s13593-015-0306-1.

[104] G. Vanloqueren and P. V. Baret, 'How agricultural research systems shape a technological regime that develops genetic engineering but locks out agroecological innovations', *Res. Policy*, vol. 38, no. 6, pp. 971–983, Jul. 2009, doi: 10.1016/j.respol.2009.02.008.

[105] A. Dubois and D. Carson, 'Sustainable agriculture and multifunctionality in South Australia's Mid North region', *Aust. Geogr.*, vol. 51, no. 4, pp. 509–534, Oct. 2020, doi: 10.1080/00049182.2020.1813960.

[106] M. Casey, T. Rhodes, T. Payne, M. Brown, and R. Dynes, *Over the Fence: Designing extension programmes to bring about practice change*. Wellington, New Zealand: Ministry for Primary Industries, 2015.

[107] J. Hopwood, S. Frischie, E. May, and E. Lee-Mader, *Farming with Soil Life: A Handbook for Supporting Soil Invertebrates and Soil Health on Farms*. Portland, OR, USA: Xerces Society for Insect Conservation, 2021.

[108] C. J. Rhodes, 'The Imperative for Regenerative Agriculture', *Sci. Prog.*, vol. 100, no. 1, pp. 80–129, Mar. 2017, doi: 10.3184/003685017X14876775256165.

[109] V. Seufert, N. Ramankutty, and J. A. Foley, 'Comparing the yields of organic and conventional agriculture', *Nature*, vol. 485, no. 7397, Art. no. 7397, May 2012, doi: 10.1038/nature11069.

[110] J. N. Pretty *et al.*, 'Resource-Conserving Agriculture Increases Yields in Developing Countries', *Environ. Sci. Technol.*, vol. 40, no. 4, pp. 1114–1119, Feb. 2006, doi: 10.1021/es051670d.

[111] G. Tamburini *et al.*, 'Agricultural diversification promotes multiple ecosystem services without compromising yield', *Sci. Adv.*, vol. 6, no. 45, p. eaba1715, Nov. 2020, doi: 10.1126/sciadv.aba1715.

[112] R. Dachelet, 'Agriculture régénératrice, émergence d'un concept', Master of Science, Université catholique de Louvain, France, 2020. [Online]. Available: http://hdl.handle.net/2078.1/thesis:25434

[113] Regenerative Organic Certified, 'Framework for Regenerative Organic Certification'. 2019.

[114] C. A. Francis, R. R. Harwood, and J. F. Parr, 'The potential for regenerative agriculture in the developing world', *Am. J. Altern. Agric.*, vol. 1, no. 2, pp. 65–74, 1986, doi: 10.1017/S0889189300000904.

[115] R. Rodale, ‘Breaking New Ground: The Search for a Sustainable Agriculture’, *Futurist*, vol. 17, no. 1, pp. 15–20, Feb. 1983.
[116] J. E. Rowntree *et al.*, ‘Ecosystem Impacts and Productive Capacity of a Multi-Species Pastured Livestock System’, *Front. Sustain. Food Syst.*, vol. 4, 2020, doi: 10.3389/fsufs.2020.544984.
[117] H. Gosnell, S. Charnley, and P. Stanley, ‘Climate change mitigation as a co-benefit of regenerative ranching: insights from Australia and the United States’, *Interface Focus*, vol. 10, no. 5, p. 20200027, Oct. 2020, doi: 10.1098/rsfs.2020.0027.
[118] C. J. Pearson, ‘Regenerative, Semiclosed Systems: A Priority for Twenty-First-Century Agriculture’, *BioScience*, vol. 57, no. 5, pp. 409–418, May 2007, doi: 10.1641/B570506.
[119] A. Jurgilevich *et al.*, ‘Transition towards Circular Economy in the Food System’, *Sustainability*, vol. 8, no. 1, p. 69, Jan. 2016, doi: 10.3390/su8010069.
[120] P. Morseletto, ‘Restorative and regenerative: Exploring the concepts in the circular economy’, *J. Ind. Ecol.*, vol. 24, no. 4, pp. 763–773, 2020, doi: 10.1111/jiec.12987.
[121] B. Reed, ‘Shifting from “sustainability” to regeneration’, *Build. Res. Inf.*, vol. 35, no. 6, pp. 674–680, Nov. 2007, doi: 10.1080/09613210701475753.
[122] L. Schreefel, R. P. O. Schulte, I. J. M. de Boer, A. P. Schrijver, and H. H. E. van Zanten, ‘Regenerative agriculture – the soil is the base’, *Glob. Food Secur.*, vol. 26, p. 100404, Sep. 2020, doi: 10.1016/j.gfs.2020.100404.
[123] T. L. D. Fenster *et al.*, ‘Defining and validating regenerative farm systems using a composite of ranked agricultural practices’, *F1000Research*, vol. 10, p. 115, Feb. 2021, doi: 10.12688/f1000research.28450.1.
[124] C. E. LaCanne and J. G. Lundgren, ‘Regenerative agriculture: merging farming and natural resource conservation profitably’, *PeerJ*, vol. 6, p. e4428, 2018.
[125] M. Thorbecke and J. Dettling, ‘Carbon Footprint Evaluation of Regenerative Grazing at White Oak Pastures’, Quantis, Feb. 2019.
[126] K. Brown, J. Schirmer, and P. Upton, ‘Regenerative farming and human wellbeing: Are subjective wellbeing measures useful indicators for sustainable farming systems?’, *Environ. Sustain. Indic.*, vol. 11, p. 100132, Sep. 2021, doi: 10.1016/j.indic.2021.100132.
[127] R. Teague and M. Barnes, ‘Grazing management that regenerates ecosystem function and grazing land livelihoods’, *Afr. J. Range Forage Sci.*, vol. 34, no. 2, pp. 77–86, 2017.
[128] R. Luján Soto, M. Martínez-Mena, M. Cuéllar Padilla, and J. de Vente, ‘Restoring soil quality of woody agroecosystems in Mediterranean drylands through regenerative agriculture’, *Agric. Ecosyst. Environ.*, vol. 306, p. 107191, Feb. 2021, doi: 10.1016/j.agee.2020.107191.
[129] R. Luján Soto, M. Cuéllar Padilla, and J. de Vente, ‘Participatory selection of soil quality indicators for monitoring the impacts of regenerative agriculture on ecosystem services’, *Ecosyst. Serv.*, vol. 45, p. 101157, Oct. 2020, doi: 10.1016/j.ecoser.2020.101157.
[130] S. M. Junge, J. Pfister, R. Wedemeyer, and M. R. Finckh, ‘Regenerative Landwirtschaft – Bewertung des Systems durch die Erweiterte Spatendiagnose am Beispiel Kartoffel’, presented at the Wissenschaftstagung Ökologischer Landbau, 2019.
[131] L. M. Condron *et al.*, ‘A comparison of soil and environmental quality under organic and conventional farming systems in New Zealand’, *N. Z. J. Agric. Res.*, vol. 43, no. 4, pp. 443–466, Dec. 2000, doi: 10.1080/00288233.2000.9513442.
[132] C. Elevitch, D. Mazaroli, and D. Ragone, ‘Agroforestry Standards for Regenerative Agriculture’, *Sustainability*, vol. 10, no. 9, p. 3337, Sep. 2018, doi: 10.3390/su10093337.
[133] S. Sherwood and N. Uphoff, ‘Soil health: research, practice and policy for a more regenerative agriculture’, *Appl. Soil Ecol.*, vol. 15, no. 1, pp. 85–97, Aug. 2000, doi: 10.1016/S0929-1393(00)00074-3.
[134] T. A. Colley, S. I. Olsen, M. Birkved, and M. Z. Hauschild, ‘Delta Life Cycle Assessment of Regenerative Agriculture in a Sheep Farming System’, *Integr. Environ. Assess. Manag.*, vol. 16, no. 2, pp. 282–290, 2020.
[135] T. Duncan, ‘Case Study: Taranaki Farm Regenerative Agriculture. Pathways to Integrated Ecological Farming’, in *Land Restoration*, Elsevier, 2016, pp. 271–287. doi: 10.1016/B978-0-12-801231-4.00022-7.
[136] B. Dougherty, ‘Regenerative Agriculture: The Path to Healing Agroecosystems and Feeding the World in the 21st Century’, Nuffield International, 2019.
[137] J. McCaman, *When Weeds Talk*, 1st ed. MO, 2013.
[138] A. J. Franzluebbers, O. Wendroth, N. G. Creamer, and G. G. Feng, ‘Focusing the future of farming on agroecology’, *Agric. Environ. Lett.*, vol. 5, no. 1, p. e20034, 2020, doi: 10.1002/ael2.20034.
[139] Greenpeace Aotearoa, ‘The regenerative farming revolution’, *Greenpeace Aotearoa*. https://www.greenpeace.org/aotearoa/campaign/regenerative-farming-revolution (accessed Jun. 14, 2021).
[140] J. B. Callicott, ‘Agroecology in context’, *J. Agric. Ethics*, vol. 1, no. 1, pp. 3–9, Mar. 1988, doi: 10.1007/BF02014458.
[141] R. Teague, ‘Deficiencies in the Briske et al. Rebuttal of the Savory Method’, *Rangelands*, vol. 36, no. 1, pp. 37–38, Feb. 2014, doi: 10.2111/1551-501X-36.1.37.
[142] M. Peel and M. Stalmans, ‘The effect of Holistic Planned Grazing^{TM} on African rangelands: a case study from Zimbabwe’, *Afr. J. Range Forage Sci.*, vol. 35, no. 1, pp. 23–31, May 2018, doi: 10.2989/10220119.2018.1440630.
[143] H. Moller *et al.*, ‘Intensification of New Zealand agriculture: Implications for biodiversity’, *N. Z. J. Agric. Res.*, vol. 51, no. 3, pp. 253–263, Sep. 2008, doi: 10.1080/00288230809510453.
[144] J. Craig *et al.*, ‘Conservation Issues in New Zealand’, *Annu. Rev. Ecol. Syst.*, vol. 31, no. 1, pp. 61–78, Nov. 2000, doi: 10.1146/annurev.ecolsys.31.1.61.
[145] S. K. Lowder, J. Skoet, and T. Raney, ‘The Number, Size, and Distribution of Farms, Smallholder Farms, and Family Farms Worldwide’, *World Dev.*, vol. 87, pp. 16–29, Nov. 2016, doi: 10.1016/j.worlddev.2015.10.041.
[146] I. MacKinnon and A. Mackillop, ‘Plantation slavery and landownership in the west Highlands and Islands: legacies and lessons’, Community Land Scotland, Nov. 2020. Accessed: Jul. 07, 2021. [Online]. Available: https://www.communitylandscotland.org.uk/wp-content/uploads/2020/11/Plantation-slavery-and-landownership-in-the-west-Highlands-and-Islands-legacies-and-lessons.pdf
[147] C. Kremen, A. Iles, and C. Bacon, ‘Diversified Farming Systems: An Agroecological, Systems-based Alternative to Modern Industrial Agriculture’, *Ecol. Soc.*, vol. 17, no. 4, p. art44, 2012, doi: 10.5751/ES-05103-170444.
[148] V. Stead and J. Altman, Eds., *Labour Lines and Colonial Power: Indigenous and Pacific Islander Labour Mobility in Australia*, 1st ed. ANU Press, 2019. doi: 10.22459/LLCP.2019.
[149] N. Nunn and N. Qian, ‘The Columbian Exchange: A History of Disease, Food, and Ideas’, *J. Econ. Perspect.*, vol. 24, no. 2, pp. 163–188, Jun. 2010, doi: 10.1257/jep.24.2.163.
[150] J. Mt Pleasant, ‘The Paradox of Plows and Productivity: An Agronomic Comparison of Cereal Grain Production under Iroquois Hoe Culture and European Plow Culture in the Seventeenth and Eighteenth Centuries’, *Agric. Hist.*, vol. 85, no. 4, pp. 460–492, 2011, doi: 10.3098/ah.2011.85.4.460.
[151] *Indigenous Peoples’ food systems*. Rome, Italy: FAO, Alliance of Bioversity International, and CIAT, 2021. doi: 10.4060/cb5131en.
[152] R. Teague and U. Kreuter, ‘Managing Grazing to Restore Soil Health, Ecosystem Function, and Ecosystem Services’, *Front. Sustain. Food Syst.*, vol. 4, 2020, doi: 10.3389/fsufs.2020.534187.
[153] J. Mt Pleasant, ‘A New Paradigm for Pre-Columbian Agriculture in North America on JSTOR’, *Early Am. Stud.*, vol. 13, no. 2, pp. 374–412, 2015.
[154] C. Elevitch, D. Mazaroli, and D. Ragone, ‘Agroforestry Standards for Regenerative Agriculture’, *Sustainability*, vol. 10, no. 9, p. 3337, Sep. 2018, doi: 10.3390/su10093337.
[155] K. Leonard *et al.*, ‘Indigenous Conservation Practices Are Not a Monolith: Western cultural biases and a lack of engagement with Indigenous experts undermine studies of land stewardship’, EcoEvoRxiv, preprint, Jul. 2020. doi: 10.32942/osf.io/jmvqy.
[156] A. Koch, C. Brierley, M. M. Maslin, and S. L. Lewis, ‘Earth system impacts of the European arrival and Great Dying in the Americas after 1492’, *Quat. Sci. Rev.*, vol. 207, pp. 13–36, Mar. 2019, doi: 10.1016/j.quascirev.2018.12.004.
[157] J. G. de Souza *et al.*, ‘Pre-Columbian earth-builders settled along the entire southern rim of the Amazon’, *Nat. Commun.*, vol. 9, no. 1, p. 1125, Mar. 2018, doi: 10.1038/s41467-018-03510-7.
[158] B. Glaser, ‘Prehistorically modified soils of central Amazonia: a model for sustainable agriculture in the twenty-first century’, *Philos. Trans. R. Soc. B Biol. Sci.*, vol. 362, no. 1478, pp. 187–196, Feb. 2007, doi: 10.1098/rstb.2006.1978.

[159] S. Y. Maezumi *et al.*, 'The legacy of 4,500 years of polyculture agroforestry in the eastern Amazon', *Nat. Plants*, vol. 4, no. 8, pp. 540–547, Aug. 2018, doi: 10.1038/s41477-018-0205-y.

[160] G. B. Earp, *Hand-Book for Intending Emigrants to the Southern Settlements of New Zealand*, 2nd ed. London, England: W S Orr, 1849.

[161] A. Petro and R. Haslett-Marroquín, 'Regenerative Agriculture: A Radical, Revolutionary, Indigenous Concept', *Regenerative Agriculture Alliance*, Dec. 23, 2020. https://www.regenagalliance.org/blog/what-is-regenerative-agriculture (accessed Jun. 09, 2021).

[162] M. Huambachano, 'Enacting food sovereignty in Aotearoa New Zealand and Peru: revitalizing Indigenous knowledge, food practices and ecological philosophies', *Agroecol. Sustain. Food Syst.*, vol. 42, no. 9, pp. 1003–1028, Oct. 2018, doi: 10.1080/21683565.2018.1468380.

[163] L. T. Smith, *Decolonizing methodologies: research and indigenous peoples*, Third edition. London: Zed, 2021.

[164] R. Kiddle, Ed., *Imagining Decolonisation*, 1st ed. Bridget Williams Books, 2020. doi: 10.7810/9781988545783.

[165] A. J. Daigneault, F. V. Eppink, and W. G. Lee, 'A national riparian restoration programme in New Zealand: Is it value for money?', *J. Environ. Manage.*, vol. 187, pp. 166–177, Feb. 2017, doi: 10.1016/j.jenvman.2016.11.013.

[166] M. A. Fernandez and A. Daigneault, 'Erosion mitigation in the Waikato District, New Zealand: economic implications for agriculture', *Agric. Econ.*, p. 21, 2016.

[167] W. Hu, J. Drewry, M. Beare, A. Eger, and K. Müller, 'Compaction induced soil structural degradation affects productivity and environmental outcomes: A review and New Zealand case study', *Geoderma*, vol. 395, p. 115035, Aug. 2021, doi: 10.1016/j.geoderma.2021.115035.

[168] E. E. Oldfield, M. A. Bradford, and S. A. Wood, 'Global meta-analysis of the relationship between soil organic matter and crop yields', *Soil*, vol. 5, no. 1, pp. 15–32, 2019.

[169] L. E. Flint *et al.*, 'Increasing Soil Organic Carbon To Mitigate Greenhouse Gases And Increase Climate Resiliency For California', California Natural Resources Agency, CCCA4-CNRA-2018–006, Aug. 2018.

[170] D. J. Jacob and D. A. Winner, 'Effect of climate change on air quality', *Atmos. Environ.*, vol. 43, no. 1, pp. 51–63, Jan. 2009, doi: 10.1016/j.atmosenv.2008.09.051.

[171] Ministry for the Environment, *Water quality in selected dairy farming catchments: a baseline to support future water-quality trend assessments.* Wellington, N.Z.: Ministry for the Environment, 2009. Accessed: Mar. 02, 2021. [Online]. Available: http://www.mfe.govt.nz/publications/land/water-quality-selected-dairying-farming-catchments/water-quality-selected-dairying-farming-catchments.pdf

[172] J. Schullehner, B. Hansen, M. Thygesen, C. B. Pedersen, and T. Sigsgaard, 'Nitrate in drinking water and colorectal cancer risk: A nationwide population-based cohort study', *Int. J. Cancer*, vol. 143, no. 1, pp. 73–79, 2018, doi: 10.1002/ijc.31306.

[173] B. S. Griffiths *et al.*, 'Selecting cost effective and policy-relevant biological indicators for European monitoring of soil biodiversity and ecosystem function', *Ecol. Indic.*, vol. 69, pp. 213–223, Oct. 2016, doi: 10.1016/j.ecolind.2016.04.023.

[174] D. S. Powlson, 'Is "soil health" meaningful as a scientific concept or as terminology?', *Soil Use Manag.*, vol. 00, pp. 1–3, 2021, doi: 10.1111/sum.12721.

[175] P. C. Baveye, 'Soil health at a crossroad', *Soil Use Manag.*, vol. 37, no. 2, pp. 215–219, 2021, doi: 10.1111/sum.12703.

[176] H. H. Janzen, D. W. Janzen, and E. G. Gregorich, 'The "soil health" metaphor: Illuminating or illusory?', *Soil Biol. Biochem.*, vol. 159, p. 108167, Aug. 2021, doi: 10.1016/j.soilbio.2021.108167.

[177] E. K. Bünemann *et al.*, 'Soil quality – A critical review', *Soil Biol. Biochem.*, vol. 120, pp. 105–125, May 2018, doi: 10.1016/j.soilbio.2018.01.030.

[178] 'Soil Carbon Initiative - Carbon Underground'. https://www.soilcarboninitiative.org/executive-summary (accessed May 28, 2020).

[179] T. G. Shepherd, *Visual Soil Assessment (Vol 1): Field guide for cropping and pastoral grazing on flat to rolling country*, vol. 1. Palmerston North, N.Z.: Horizons.mw : Landcare Research, 2000.

[180] L. Mao, V. F. Bralts, Y. Pan, H. Liu, and T. Lei, 'Methods for measuring soil infiltration: State of the art', *Int J Agric Biol Eng*, vol. 1, no. 1, pp. 22–30, 2008.

[181] J. J. Drewry, R. P. Littlejohn, R. J. Paton, P. L. Singleton, R. M. Monaghan, and L. C. Smith, 'Dairy pasture responses to soil physical properties', *Soil Res.*, vol. 42, no. 1, pp. 99–105, 2004, doi: 10.1071/sr03055.

[182] J. J. Drewry, K. C. Cameron, and G. D. Buchan, 'Pasture yield and soil physical property responses to soil compaction from treading and grazing—a review', *Soil Res.*, vol. 46, no. 3, p. 237, 2008, doi: 10.1071/SR07125.

[183] R. Bryant *et al.*, 'BRIEF COMMUNICATION: Conventional or Albrecht-Kinsey fertiliser approach in a commercial-scale dairy farm systems comparison', *N. Z. J. Anim. Sci. Prod.*, vol. 79, pp. 100–102.

[184] R. L. Haney, E. B. Haney, D. R. Smith, R. D. Harmel, and M. J. White, 'The soil health tool—Theory and initial broad-scale application', *Appl. Soil Ecol.*, vol. 125, pp. 162–168, Apr. 2018, doi: 10.1016/j.apsoil.2017.07.035.

[185] J. Lehmann, D. A. Bossio, I. Kögel-Knabner, and M. C. Rillig, 'The concept and future prospects of soil health', *Nat. Rev. Earth Environ.*, vol. 1, no. 10, Art. no. 10, Oct. 2020, doi: 10.1038/s43017-020-0080-8.

[186] R. E. White and M. Andrew, 'Orthodox Soil Science versus Alternative Philosophies: A Clash of Cultures in a Modern Context', *Sustainability*, vol. 11, no. 10, p. 2919, May 2019, doi: 10.3390/su11102919.

[187] J. Bouma, 'The challenge of soil science meeting society's demands in a "post-truth", "fact free" world', *Geoderma*, vol. 310, pp. 22–28, Jan. 2018, doi: 10.1016/j.geoderma.2017.09.017.

[188] M. S. Strickland and J. Rousk, 'Considering fungal:bacterial dominance in soils – Methods, controls, and ecosystem implications', *Soil Biol. Biochem.*, vol. 42, no. 9, pp. 1385–1395, Sep. 2010, doi: 10.1016/j.soilbio.2010.05.007.

[189] E. Vukicevich, T. Lowery, P. Bowen, J. R. Úrbez-Torres, and M. Hart, 'Cover crops to increase soil microbial diversity and mitigate decline in perennial agriculture. A review', *Agron. Sustain. Dev.*, vol. 36, no. 3, p. 48, Sep. 2016, doi: 10.1007/s13593-016-0385-7.

[190] N. Fierer, M. S. Strickland, D. Liptzin, M. A. Bradford, and C. C. Cleveland, 'Global patterns in belowground communities', *Ecol. Lett.*, vol. 12, no. 11, pp. 1238–1249, 2009, doi: https://doi.org/10.1111/j.1461-0248.2009.01360.x.

[191] C. J. Bronick and R. Lal, 'Soil structure and management: a review', *Geoderma*, vol. 124, no. 1–2, pp. 3–22, Jan. 2005, doi: 10.1016/j.geoderma.2004.03.005.

[192] P. Sollins and J. W. Gregg, 'Soil organic matter accumulation in relation to changing soil volume, mass, and structure: Concepts and calculations', *Geoderma*, vol. 301, pp. 60–71, Sep. 2017, doi: 10.1016/j.geoderma.2017.04.013.

[193] R. Amundson and L. Biardeau, 'Opinion: Soil carbon sequestration is an elusive climate mitigation tool', *Proc. Natl. Acad. Sci.*, vol. 115, no. 46, pp. 11652–11656, Nov. 2018, doi: 10.1073/pnas.1815901115.

[194] X. Bai *et al.*, 'Responses of soil carbon sequestration to climate-smart agriculture practices: A meta-analysis', *Glob. Change Biol.*, vol. 25, no. 8, pp. 2591–2606, 2019, doi: 10.1111/gcb.14658.

[195] M. A. Bradford *et al.*, 'Soil carbon science for policy and practice', *Nat. Sustain.*, vol. 2, no. 12, pp. 1070–1072, Dec. 2019, doi: 10.1038/s41893-019-0431-y.

[196] J. W. van Groenigen, C. van Kessel, B. A. Hungate, O. Oenema, D. S. Powlson, and K. J. van Groenigen, 'Sequestering Soil Organic Carbon: A Nitrogen Dilemma', *Environ. Sci. Technol.*, vol. 51, no. 9, pp. 4738–4739, May 2017, doi: 10.1021/acs.est.7b01427.

[197] J.-F. Soussana, S. Lutfalla, P. Smith, R. Lal, C. Chenu, and P. Ciais, 'Letter to the Editor: Answer to the Viewpoint "Sequestering Soil Organic Carbon: A Nitrogen Dilemma"', *Environ. Sci. Technol.*, vol. 51, p. 11502, 2017, doi: 10.1021/acs.est.7b03932.

[198] A. Bispo *et al.*, 'Accounting for Carbon Stocks in Soils and Measuring GHGs Emission Fluxes from Soils: Do We Have the Necessary Standards?', *Front. Environ. Sci.*, vol. 5, 2017, doi: 10.3389/fenvs.2017.00041.

[199] C. Chenu, D. A. Angers, P. Barré, D. Derrien, D. Arrouays, and J. Balesdent, 'Increasing organic stocks in agricultural soils: Knowledge gaps and potential innovations', *Soil Tillage Res.*, vol. 188, pp. 41–52, May 2019, doi: 10.1016/j.still.2018.04.011.

[200] C. Poeplau, C. Vos, and A. Don, ‘Soil organic carbon stocks are systematically overestimated by misuse of the parameters bulk density and rock fragment content’, *SOIL*, vol. 3, no. 1, pp. 61–66, 2017, doi: 10.5194/soil-3-61-2017.

[201] J. W. Wendt and S. Hauser, ‘An equivalent soil mass procedure for monitoring soil organic carbon in multiple soil layers’, *Eur. J. Soil Sci.*, vol. 64, pp. 58–65, 2013, doi: 10.1111/ejss.12002.

[202] A. Mayer, Z. Hausfather, A. D. Jones, and W. L. Silver, ‘The potential of agricultural land management to contribute to lower global surface temperatures’, *Sci. Adv.*, vol. 4, no. 8, p. eaaq0932, Aug. 2018, doi: 10.1126/sciadv.aaq0932.

[203] A. Freibauer, M. D. A. Rounsevell, P. Smith, and J. Verhagen, ‘Carbon sequestration in the agricultural soils of Europe’, *Geoderma*, vol. 122, no. 1, pp. 1–23, Sep. 2004, doi: 10.1016/j.geoderma.2004.01.021.

[204] P. Poulton, J. Johnston, A. Macdonald, R. White, and D. Powlson, ‘Major limitations to achieving “4 per 1000” increases in soil organic carbon stock in temperate regions: Evidence from long-term experiments at Rothamsted Research, United Kingdom’, *Glob. Change Biol.*, vol. 24, no. 6, pp. 2563–2584, 2018, doi: https://doi.org/10.1111/gcb.14066.

[205] C. Oertel, J. Matschullat, K. Zurba, F. Zimmermann, and S. Erasmi, ‘Greenhouse gas emissions from soils—A review’, *Geochemistry*, vol. 76, no. 3, pp. 327–352, Oct. 2016, doi: 10.1016/j.chemer.2016.04.002.

[206] K. C. Cameron, H. J. Di, and J. L. Moir, ‘Nitrogen losses from the soil/plant system: a review’, *Ann. Appl. Biol.*, vol. 162, no. 2, pp. 145–173, 2013, doi: https://doi.org/10.1111/aab.12014.

[207] J. A. Ippolito, D. A. Laird, and W. J. Busscher, ‘Environmental Benefits of Biochar’, *J. Environ. Qual.*, vol. 41, no. 4, pp. 967–972, Jul. 2012, doi: 10.2134/jeq2012.0151.

[208] S. Jeffery, F. G. A. Verheijen, M. van der Velde, and A. C. Bastos, ‘A quantitative review of the effects of biochar application to soils on crop productivity using meta-analysis’, *Agric. Ecosyst. Environ.*, vol. 144, no. 1, pp. 175–187, Nov. 2011, doi: 10.1016/j.agee.2011.08.015.

[209] E. L. Balota, A. Colozzi-Filho, D. S. Andrade, and R. P. Dick, ‘Microbial biomass in soils under different tillage and crop rotation systems’, *Biol. Fertil. Soils*, vol. 38, no. 1, pp. 15–20, Jun. 2003, doi: 10.1007/s00374-003-0590-9.

[210] C. Liang, W. Amelung, J. Lehmann, and M. Kästner, ‘Quantitative assessment of microbial necromass contribution to soil organic matter’, *Glob. Change Biol.*, vol. 25, pp. 3578–3590, 2019, doi: 10.1111/gcb.14781.

[211] P. A. MacKinnon, J. G. Robertson, D. J. Scott, and C. N. Hale, ‘Legume inoculant usage in New Zealand’, *N. Z. J. Exp. Agric.*, vol. 5, no. 1, pp. 35–39, Mar. 1977, doi: 10.1080/03015521.1977.10425930.

[212] R. C. Winkworth, S. E. Bellgard, P. A. McLenachan, and P. J. Lockhart, ‘The mitogenome of Phytophthora agathidicida: Evidence for a not so recent arrival of the “kauri killing” Phytophthora in New Zealand’, *PLOS ONE*, vol. 16, no. 5, p. e0250422, May 2021, doi: 10.1371/journal.pone.0250422.

[213] S. Chen, D. Arrouays, D. A. Angers, M. P. Martin, and C. Walter, ‘Soil carbon stocks under different land uses and the applicability of the soil carbon saturation concept’, *Soil Tillage Res.*, vol. 188, pp. 53–58, May 2019, doi: 10.1016/j.still.2018.11.001.

[214] K. H. E. Meurer, N. R. Haddaway, M. A. Bolinder, and T. Kätterer, ‘Tillage intensity affects total SOC stocks in boreo-temperate regions only in the topsoil—A systematic review using an ESM approach’, *Earth-Sci. Rev.*, vol. 177, pp. 613–622, Feb. 2018, doi: 10.1016/j.earscirev.2017.12.015.

[215] B. W. Thomas *et al.*, ‘Soil health indicators after 21 yr of no-tillage in south coastal British Columbia’, *Can. J. Soil Sci.*, Feb. 2019, doi: 10.1139/cjss-2018-0146.

[216] J. M. Baker, T. E. Ochsner, R. T. Venterea, and T. J. Griffis, ‘Tillage and soil carbon sequestration—What do we really know?’, *Agric. Ecosyst. Environ.*, vol. 118, no. 1–4, pp. 1–5, Jan. 2007, doi: 10.1016/j.agee.2006.05.014.

[217] N. R. Haddaway *et al.*, ‘How does tillage intensity affect soil organic carbon? A systematic review’, *Environ. Evid.*, vol. 6, no. 1, p. 30, Dec. 2017, doi: 10.1186/s13750-017-0108-9.

[218] J. Lampurlanés, D. Plaza-Bonilla, J. Álvaro-Fuentes, and C. Cantero-Martínez, ‘Long-term analysis of soil water conservation and crop yield under different tillage systems in Mediterranean rainfed conditions’, *Field Crops Res.*, vol. 189, pp. 59–67, Mar. 2016, doi: 10.1016/j.fcr.2016.02.010.

[219] O. Pisani *et al.*, ‘Soil nitrogen dynamics and leaching under conservation tillage in the Atlantic Coastal Plain, Georgia, United States’, *J. Soil Water Conserv.*, vol. 72, no. 5, pp. 519–529, 2017, doi: 10.2489/jswc.72.5.519.

[220] N. M. Madden, R. J. Southard, and J. P. Mitchell, ‘Conservation tillage reduces PM10 emissions in dairy forage rotations’, *Atmos. Environ.*, vol. 42, no. 16, pp. 3795–3808, May 2008, doi: 10.1016/j.atmosenv.2007.12.058.

[221] K. L. Page *et al.*, ‘Changes in soil water storage with no-tillage and crop residue retention on a Vertisol: Impact on productivity and profitability over a 50 year period’, *Soil Tillage Res.*, vol. 194, p. 104319, Nov. 2019, doi: 10.1016/j.still.2019.104319.

[222] K. L. Page, Y. P. Dang, and R. C. Dalal, ‘The Ability of Conservation Agriculture to Conserve Soil Organic Carbon and the Subsequent Impact on Soil Physical, Chemical, and Biological Properties and Yield’, *Front. Sustain. Food Syst.*, vol. 4, p. 31, Mar. 2020, doi: 10.3389/fsufs.2020.00031.

[223] E. K. Rowen, K. H. Regan, M. E. Barbercheck, and J. F. Tooker, ‘Is tillage beneficial or detrimental for insect and slug management? A meta-analysis’, *Agric. Ecosyst. Environ.*, vol. 294, p. 106849, Jun. 2020, doi: 10.1016/j.agee.2020.106849.

[224] D. S. Powlson *et al.*, ‘Limited potential of no-till agriculture for climate change mitigation’, *Nat. Clim. Change*, vol. 4, no. 8, Art. no. 8, Aug. 2014, doi: 10.1038/nclimate2292.

[225] J. A. Delgado *et al.*, ‘Conservation practices to mitigate and adapt to climate change’, *J. Soil Water Conserv.*, vol. 66, no. 4, pp. 118A-129A, Jul. 2011, doi: 10.2489/jswc.66.4.118A.

[226] A. G. Power, ‘Ecosystem services and agriculture: tradeoffs and synergies’, *Philos. Trans. R. Soc. B Biol. Sci.*, vol. 365, no. 1554, pp. 2959–2971, 2010.

[227] C. Stoate *et al.*, ‘Ecological impacts of early 21st century agricultural change in Europe–a review’, *J. Environ. Manage.*, vol. 91, no. 1, pp. 22–46, 2009.

[228] C. A. J. Girardin *et al.*, ‘Nature-based solutions can help cool the planet — if we act now’, *Nature*, vol. 593, no. 7858, Art. no. 7858, May 2021, doi: 10.1038/d41586-021-01241-2.

[229] S. W. Wood and A. Cowie, ‘A review of greenhouse gas emission factors for fertiliser production’, Cooperative Research Centre for Greenhouse Accounting, 2004.

[230] D. P. Garrity *et al.*, ‘Evergreen Agriculture: a robust approach to sustainable food security in Africa’, *Food Secur.*, vol. 2, no. 3, pp. 197–214, Sep. 2010, doi: 10.1007/s12571-010-0070-7.

[231] Z. X. Tan, R. Lal, and K. D. Wiebe, ‘Global Soil Nutrient Depletion and Yield Reduction’, *J. Sustain. Agric.*, vol. 26, no. 1, pp. 123–146, Jun. 2005, doi: 10.1300/J064v26n01_10.

[232] R. Eckard, C. Grainger, and C. De Klein, ‘Options for the abatement of methane and nitrous oxide from ruminant production: A review’, *Livest. Sci.*, vol. 130, no. 1–3, pp. 47–56, May 2010, doi: 10.1016/j.livsci.2010.02.010.

[233] R. Ryals, M. Kaiser, M. S. Torn, A. A. Berhe, and W. L. Silver, ‘Impacts of organic matter amendments on carbon and nitrogen dynamics in grassland soils’, *Soil Biol. Biochem.*, vol. 68, pp. 52–61, Jan. 2014, doi: 10.1016/j.soilbio.2013.09.011.

[234] S. Brown and M. Cotton, ‘Changes in Soil Properties and Carbon Content Following Compost Application: Results of On-farm Sampling’, *Compost Sci. Util.*, vol. 19, no. 2, pp. 87–96, Mar. 2011, doi: 10.1080/1065657X.2011.10736983.

[235] M. Diacono and F. Montemurro, ‘Long-term effects of organic amendments on soil fertility. A review’, *Agron. Sustain. Dev.*, vol. 30, no. 2, pp. 401–422, Apr. 2010, doi: 10.1051/agro/2009040.

[236] D. Whitehead *et al.*, ‘Management practices to reduce losses or increase soil carbon stocks in temperate grazed grasslands: New Zealand as a case study’, *Agric. Ecosyst. Environ.*, vol. 265, pp. 432–443, 2018.

[237] S. De Gryze, M. Cullen, and L. Durschinger, ‘Evaluation of the Opportunities for Generating Carbon Offsets from Soil Sequestration of Biochar’. Terra Global Capital, Apr. 2010.

[238] Z. S. Venter, K. Jacobs, and H.-J. Hawkins, ‘The impact of crop rotation on soil microbial diversity: A meta-analysis’, *Pedobiologia*, vol. 59, no. 4, pp. 215–223, Jul. 2016, doi: 10.1016/j.pedobi.2016.04.001.
[239] W. E. Riedell, J. L. Pikul, A. A. Jaradat, and T. E. Schumacher, ‘Crop Rotation and Nitrogen Input Effects on Soil Fertility, Maize Mineral Nutrition, Yield, and Seed Composition’, *Agron. J.*, vol. 101, no. 4, pp. 870–879, Jul. 2009, doi: 10.2134/agronj2008.0186x.
[240] D. K. Letourneau *et al.*, ‘Does plant diversity benefit agroecosystems? A synthetic review’, *Ecol. Appl.*, vol. 21, no. 1, pp. 9–21, 2011, doi: 10.1890/09-2026.1.
[241] F. Isbell *et al.*, ‘Benefits of increasing plant diversity in sustainable agroecosystems’, *J. Ecol.*, vol. 105, no. 4, pp. 871–879, 2017, doi: 10.1111/1365-2745.12789.
[242] A. S. Davis, J. D. Hill, C. A. Chase, A. M. Johanns, and M. Liebman, ‘Increasing Cropping System Diversity Balances Productivity, Profitability and Environmental Health’, *PLOS ONE*, vol. 7, no. 10, p. e47149, Oct. 2012, doi: 10.1371/journal.pone.0047149.
[243] C. Poeplau and A. Don, ‘Carbon sequestration in agricultural soils via cultivation of cover crops – A meta-analysis’, *Agric. Ecosyst. Environ.*, vol. 200, pp. 33–41, Feb. 2015, doi: 10.1016/j.agee.2014.10.024.
[244] B. Malcolm, S. Maley, E. Teixeira, and P. Johnstone, ‘Performance of Winter-Sown Cereal Catch Crops after Simulated Forage Crop Grazing in Southland, New Zealand’, *Plants*, vol. 10, p. 108, 2021, doi: https://doi.org/10.3390/plants10010108.
[245] P. M. Fraser *et al.*, ‘Winter Nitrate Leaching under Different Tillage and Winter Cover Crop Management Practices’, *Soil Sci. Soc. Am. J.*, vol. 77, no. 4, pp. 1391–1401, Jul. 2013, doi: 10.2136/sssaj2012.0256.
[246] E. I. Teixeira *et al.*, ‘Sources of variability in the effectiveness of winter cover crops for mitigating N leaching’, *Agric. Ecosyst. Environ.*, vol. 220, pp. 226–235, Mar. 2016, doi: 10.1016/j.agee.2016.01.019.
[247] G. B. Witt, M. V. Noël, M. I. Bird, R. J. S. (Bob) Beeton, and N. W. Menzies, ‘Carbon sequestration and biodiversity restoration potential of semi-arid mulga lands of Australia interpreted from long-term grazing exclosures’, *Agric. Ecosyst. Environ.*, vol. 141, no. 1–2, pp. 108–118, Apr. 2011, doi: 10.1016/j.agee.2011.02.020.
[248] P. L. Stanley, J. E. Rowntree, D. K. Beede, M. S. DeLonge, and M. W. Hamm, ‘Impacts of soil carbon sequestration on life cycle greenhouse gas emissions in Midwestern USA beef finishing systems’, *Agric. Syst.*, vol. 162, pp. 249–258, May 2018, doi: 10.1016/j.agsy.2018.02.003.
[249] B. M. Shrestha *et al.*, ‘Adaptive Multi-Paddock Grazing Lowers Soil Greenhouse Gas Emission Potential by Altering Extracellular Enzyme Activity’, *Agronomy*, no. 17, p. 781, 2020.
[250] P. J. Gerber *et al.*, Eds., *Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities*. Rome: Food and Agriculture Organization of the United Nations, 2013.
[251] Á. S. Zubieta *et al.*, ‘Does grazing management provide opportunities to mitigate methane emissions by ruminants in pastoral ecosystems?’, *Sci. Total Environ.*, vol. 754, p. 142029, Feb. 2021, doi: 10.1016/j.scitotenv.2020.142029.
[252] M. Hillenbrand, R. Thompson, F. Wang, S. Apfelbaum, and R. Teague, ‘Impacts of holistic planned grazing with bison compared to continuous grazing with cattle in South Dakota shortgrass prairie’, *Agric. Ecosyst. Environ.*, vol. 279, pp. 156–168, Jul. 2019, doi: 10.1016/j.agee.2019.02.005.
[253] J.-Y. Park, S. Ale, and W. R. Teague, ‘Simulated water quality effects of alternate grazing management practices at the ranch and watershed scales’, *Ecol. Model.*, vol. 360, pp. 1–13, Sep. 2017, doi: 10.1016/j.ecolmodel.2017.06.019.
[254] J.-Y. Park, S. Ale, W. R. Teague, and J. Jeong, ‘Evaluating the ranch and watershed scale impacts of using traditional and adaptive multi-paddock grazing on runoff, sediment and nutrient losses in North Texas, USA’, *Agric. Ecosyst. Environ.*, vol. 240, pp. 32–44, Mar. 2017, doi: 10.1016/j.agee.2017.02.004.
[255] E. J. Jacobo, A. M. Rodríguez, N. Bartoloni, and V. A. Deregibus, ‘Rotational Grazing Effects on Rangeland Vegetation at a Farm Scale’, *Rangel. Ecol. Manag.*, vol. 59, no. 3, pp. 249–257, May 2006, doi: 10.2111/05-129R1.1.
[256] S. Mosier *et al.*, ‘Adaptive multi-paddock grazing enhances soil carbon and nitrogen stocks and stabilization through mineral association in southeastern U.S. grazing lands’, *J. Environ. Manage.*, vol. 288, p. 112409, Jun. 2021, doi: 10.1016/j.jenvman.2021.112409.
[257] R. Teague, F. Provenza, U. Kreuter, T. Steffens, and M. Barnes, ‘Multi-paddock grazing on rangelands: why the perceptual dichotomy between research results and rancher experience?’, *J. Environ. Manage.*, vol. 128, pp. 699–717, 2013.
[258] J. J. Drewry, R. J. Paton, J. J. Drewry, and R. J. Paton, ‘Soil physical quality under cattle grazing of a winter-fed brassica crop’, *Soil Res.*, vol. 43, no. 4, pp. 525–531, Jun. 2005, doi: 10.1071/SR04122.
[259] R. W. McDowell, ‘Phosphorus and Sediment Loss in a Catchment with Winter Forage Grazing of Cropland by Dairy Cattle’, *J. Environ. Qual.*, vol. 35, no. 2, pp. 575–583, 2006, doi: 10.2134/jeq2005.0364.
[260] R. W. McDowell and D. J. Houlbrooke, ‘Management options to decrease phosphorus and sediment losses from irrigated cropland grazed by cattle and sheep’, *Soil Use Manag.*, vol. 25, no. 3, pp. 224–233, 2009, doi: 10.1111/j.1475-2743.2009.00231.x.
[261] R. B. Schäfer *et al.*, ‘Effects of pesticide toxicity, salinity and other environmental variables on selected ecosystem functions in streams and the relevance for ecosystem services’, *Sci. Total Environ.*, vol. 415, pp. 69–78, Jan. 2012, doi: 10.1016/j.scitotenv.2011.05.063.
[262] T. Sauer, P. Havlík, U. A. Schneider, E. Schmid, G. Kindermann, and M. Obersteiner, ‘Agriculture and resource availability in a changing world: The role of irrigation’, *Water Resour. Res.*, vol. 46, no. 6, 2010, doi: 10.1029/2009WR007729.
[263] R. B. Schäfer, P. J. van den Brink, and M. Liess, ‘Impacts of Pesticides on Freshwater Ecosystems’, in *Ecological Impacts of Toxic Chemicals*, 2011, pp. 111–137.
[264] T. Gunstone, T. Cornelisse, K. Klein, A. Dubey, and N. Donley, ‘Pesticides and Soil Invertebrates: A Hazard Assessment’, *Front. Environ. Sci.*, vol. 9, p. 643847, May 2021, doi: 10.3389/fenvs.2021.643847.
[265] J. A. Harvey *et al.*, ‘International scientists formulate a roadmap for insect conservation and recovery’, *Nat. Ecol. Evol.*, vol. 4, no. 2, pp. 174–176, Feb. 2020, doi: 10.1038/s41559-019-1079-8.
[266] R. W. McDowell, P. Pletnyakov, A. Lim, and G. Salmon, ‘Implications of water quality policy on land use: a case study of the approach in New Zealand’, *Mar. Freshw. Res.*, vol. 72, no. 4, p. 451, 2021, doi: 10.1071/MF20201.
[267] Ministry for the Environment, ‘Action for healthy waterways - Decisions on the national direction for freshwater: an at-a-glance summary.’, Ministry for the Environment, Wellington, New Zealand, 2020. Accessed: Mar. 02, 2021. [Online]. Available: https://www.mfe.govt.nz/publications/fresh-water/decision-national-direction-freshwater-glance-summary
[268] J. D. Allan, ‘Landscapes and riverscapes: The influence of land use on stream ecosystems’, *Annu. Rev. Ecol. Evol. Syst.*, vol. 35, pp. 257–284, 2004.
[269] A. K. Sarmah, K. Müller, and R. Ahmad, ‘Fate and behaviour of pesticides in the agroecosystem—a review with a New Zealand perspective’, *Soil Res.*, vol. 42, no. 2, p. 125, 2004, doi: 10.1071/SR03100.
[270] P. L. Mudge, F. M. Kelliher, T. L. Knight, D. O’Connell, S. Fraser, and L. A. Schipper, ‘Irrigating grazed pasture decreases soil carbon and nitrogen stocks’, *Glob. Change Biol.*, vol. 23, no. 2, pp. 945–954, 2017, doi: 10.1111/gcb.13448.
[271] S. P. Schottler *et al.*, ‘Twentieth century agricultural drainage creates more erosive rivers’, *Hydrol. Process.*, vol. 28, no. 4, pp. 1951–1961, Feb. 2014, doi: 10.1002/hyp.9738.
[272] K. L. Blann, J. L. Anderson, G. R. Sands, and B. Vondracek, ‘Effects of Agricultural Drainage on Aquatic Ecosystems: A Review’, *Crit. Rev. Environ. Sci. Technol.*, vol. 39, no. 11, pp. 909–1001, Nov. 2009, doi: 10.1080/10643380801977966.
[273] Y. Wada, L. P. H. van Beek, C. M. van Kempen, J. W. T. M. Reckman, S. Vasak, and M. F. P. Bierkens, ‘Global depletion of groundwater resources’, *Geophys. Res. Lett.*, vol. 37, no. 20, 2010, doi: 10.1029/2010GL044571.
[274] S. Boone and S. Fragaszy, ‘Emerging scarcity and emerging commons: Water management groups and groundwater governance in Aotearoa New Zealand’, *Water Altern.*, vol. 11, no. 3, pp. 795–823, 2018.

[275] R. Young, G. Smart, and J. Harding, ‘Impacts of hydro-dams, irrigation schemes and river control works’, in *Freshwaters of New Zealand*, 2004, p. 37.1-37.14.

[276] S. W. Kienzle and J. Schmidt, ‘Hydrological impacts of irrigated agriculture in the Manuherikia catchment, Otago, New Zealand’, *J. Hydrol. N. Z.*, vol. 47, no. 2, pp. 67–83, 2008.

[277] S. N. Ngigi, H. H. G. Savenije, J. N. Thome, J. Rockström, and F. W. T. P. de Vries, ‘Agro-hydrological evaluation of on-farm rainwater storage systems for supplemental irrigation in Laikipia district, Kenya’, *Agric. Water Manag.*, vol. 73, no. 1, pp. 21–41, Apr. 2005, doi: 10.1016/j.agwat.2004.09.021.

[278] K. Van Oost, W. Van Muysen, G. Govers, J. Deckers, and T. A. Quine, ‘From water to tillage erosion dominated landform evolution’, *Geomorphology*, vol. 72, no. 1, pp. 193–203, Dec. 2005, doi: 10.1016/j.geomorph.2005.05.010.

[279] J. Balesdent *et al.*, ‘Atmosphere–soil carbon transfer as a function of soil depth’, *Nature*, vol. 559, no. 7715, Art. no. 7715, Jul. 2018, doi: 10.1038/s41586-018-0328-3.

[280] M. A. Beketov, B. J. Kefford, R. B. Schafer, and M. Liess, ‘Pesticides reduce regional biodiversity of stream invertebrates’, *Proc. Natl. Acad. Sci.*, vol. 110, no. 27, pp. 11039–11043, Jul. 2013, doi: 10.1073/pnas.1305618110.

[281] D. Fernández, K. Voss, M. Bundschuh, J. P. Zubrod, and R. B. Schäfer, ‘Effects of fungicides on decomposer communities and litter decomposition in vineyard streams’, *Sci. Total Environ.*, vol. 533, pp. 40–48, Nov. 2015, doi: 10.1016/j.scitotenv.2015.06.090.

[282] M. Kogan, ‘Integrated Pest Management: Historical Perspectives and Contemporary Developments’, *Annu. Rev. Entomol.*, vol. 43, no. 1, pp. 243–270, 1998, doi: 10.1146/annurev.ento.43.1.243.

[283] P. Vidon *et al.*, ‘Hot Spots and Hot Moments in Riparian Zones: Potential for Improved Water Quality Management’, *J. Am. Water Resour. Assoc.*, vol. 46, no. 2, pp. 278–298, Apr. 2010, doi: 10.1111/j.1752-1688.2010.00420.x.

[284] D. R. Selbie, L. E. Buckthought, and M. A. Shepherd, ‘The Challenge of the Urine Patch for Managing Nitrogen in Grazed Pasture Systems’, in *Advances in Agronomy*, vol. 129, Elsevier, 2015, pp. 229–292. doi: 10.1016/bs.agron.2014.09.004.

[285] H. J. Di and K. C. Cameron, ‘Nitrate leaching losses and pasture yields as affected by different rates of animal urine nitrogen returns and application of a nitrification inhibitor—a lysimeter study’, *Nutr. Cycl. Agroecosystems*, vol. 79, no. 3, pp. 281–290, Oct. 2007, doi: 10.1007/s10705-007-9115-5.

[286] Office of the Parliamentary Commissioner for the Environment, *Overseer and regulatory oversight: models, uncertainty and cleaning up our waterways*. Wellington, New Zealand: Parliamentary Commissioner for the Environment, 2018.

[287] S. Payen, S. Falconer, B. Carlson, W. Yang, and S. Ledgard, ‘Eutrophication and climate change impacts of a case study of New Zealand beef to the European market’, *Sci. Total Environ.*, vol. 710, p. 136120, 2020.

[288] H. M. Pereira and L. M. Navarro, Eds., *Rewilding European Landscapes*. Cham: Springer International Publishing, 2015. doi: 10.1007/978-3-319-12039-3.

[289] H. M. Franklin, B. H. Robinson, and N. M. Dickinson, ‘Plants for nitrogen management in riparian zones: A proposed trait-based framework to select effective species’, *Ecol. Manag. Restor.*, vol. 20, no. 3, pp. 202–213, 2019, doi: 10.1111/emr.12380.

[290] S. M. Parkyn, R. J. Davies-Colley, N. J. Halliday, K. J. Costley, and G. F. Croker, ‘Planted Riparian Buffer Zones in New Zealand: Do They Live Up to Expectations?’, *Restor. Ecol.*, vol. 11, no. 4, pp. 436–447, 2003, doi: 10.1046/j.1526-100X.2003.rec0260.x.

[291] T. R. Marapara, ‘Eco-hydrology interactions between trees, soil and water in terrestrial and wetland areas: The effect of tree planting on water flow dynamics in Wairarapa Wetlands, New Zealand’, Doctor of Philosophy, Victoria University of Wellington, Wellington, New Zealand, 2016.

[292] J. Fortier, B. Truax, D. Gagnon, and F. Lambert, ‘Biomass carbon, nitrogen and phosphorus stocks in hybrid poplar buffers, herbaceous buffers and natural woodlots in the riparian zone on agricultural land’, *J. Environ. Manage.*, vol. 154, pp. 333–345, May 2015, doi: 10.1016/j.jenvman.2015.02.039.

[293] J.-L. Peyraud, M. Taboada, and L. Delaby, ‘Integrated crop and livestock systems in Western Europe and South America: A review’, *Eur. J. Agron.*, vol. 57, pp. 31–42, Jul. 2014, doi: 10.1016/j.eja.2014.02.005.

[294] E. Noe and H. F. Alrøe, ‘Observing farming systems: Insights from social systems theory’, in *Farming Systems Research into the 21st Century: The New Dynamic*, I. Darnhofer, D. Gibbon, and B. Dedieu, Eds. Dordrecht: Springer Netherlands, 2012, pp. 387–403. doi: 10.1007/978-94-007-4503-2_17.

[295] T. Bonaudo *et al.*, ‘Agroecological principles for the redesign of integrated crop–livestock systems’, *Eur. J. Agron.*, vol. 57, pp. 43–51, Jul. 2014, doi: 10.1016/j.eja.2013.09.010.

[296] D. M. Finney and J. P. Kaye, ‘Functional diversity in cover crop polycultures increases multifunctionality of an agricultural system’, *J. Appl. Ecol.*, vol. 54, no. 2, pp. 509–517, 2017, doi: 10.1111/1365-2664.12765.

[297] A. L. Iverson *et al.*, ‘Do polycultures promote win-wins or trade-offs in agricultural ecosystem services? A meta-analysis’, *J. Appl. Ecol.*, vol. 51, no. 6, pp. 1593–1602, 2014, doi: 10.1111/1365-2664.12334.

[298] R. Alkemade, M. van Oorschot, L. Miles, C. Nellemann, M. Bakkenes, and B. ten Brink, ‘GLOBIO3: A Framework to Investigate Options for Reducing Global Terrestrial Biodiversity Loss’, *Ecosystems*, vol. 12, no. 3, pp. 374–390, Apr. 2009, doi: 10.1007/s10021-009-9229-5.

[299] M. Rutgers *et al.*, ‘A method to assess ecosystem services developed from soil attributes with stakeholders and data of four arable farms’, *Sci. Total Environ.*, vol. 415, pp. 39–48, Jan. 2012, doi: 10.1016/j.scitotenv.2011.04.041.

[300] G. Nugent, K. W. Fraser, G. W. Asher, and K. G. Tustin, ‘Advances in New Zealand mammalogy 1990–2000: Deer’, *J. R. Soc. N. Z.*, vol. 31, no. 1, pp. 263–298, Mar. 2001, doi: 10.1080/03014223.2001.9517654.

[301] R. Dollery, S. Li, and N. M. Dickinson, ‘Nutrient-enriched soils and native N-fixing plants in New Zealand’, *J. Plant Nutr. Soil Sci.*, vol. 182, no. 1, pp. 104–110, 2019, doi: 10.1002/jpln.201800482.

[302] Y.-N. Kim, B. Robinson, K.-A. Lee, S. Boyer, and N. Dickinson, ‘Interactions between earthworm burrowing, growth of a leguminous shrub and nitrogen cycling in a former agricultural soil’, *Appl. Soil Ecol.*, vol. 110, pp. 79–87, Feb. 2017, doi: 10.1016/j.apsoil.2016.10.011.

[303] C. J. Macleod, G. Blackwell, H. Moller, J. Innes, and R. Powlesland, ‘The forgotten 60%: bird ecology and management in New Zealand’s agricultural landscape’, *N. Z. J. Ecol.*, vol. 32, no. 2, pp. 240–255, 2008.

[304] J. Quinn, ‘Effects of rural land use (especially forestry) and riparian management on stream habitat’, *NZ J. For.*, no. February, pp. 16–19, 2005.

[305] D. Pearson, ‘Key Roles for Landscape Ecology in Transformative Agriculture Using Aotearoa—New Zealand as a Case Example’, *Land*, vol. 9, no. 5, p. 146, May 2020, doi: 10.3390/land9050146.

[306] D. X. Tran, D. Pearson, A. Palmer, and D. Gray, ‘Developing a Landscape Design Approach for the Sustainable Land Management of Hill Country Farms in New Zealand’, *Land*, vol. 9, no. 6, Art. no. 6, Jun. 2020, doi: 10.3390/land9060185.

[307] C. D. Meurk and S. R. Swaffield, ‘A landscape ecological framework for indigenous regeneration in rural New Zealand-Aotearoa’, *Landsc. Urban Plan.*, vol. 50, no. 1–3, pp. 129–144, Aug. 2000, doi: 10.1016/S0169-2046(00)00085-2.

[308] J. Serrano, S. Shahidian, and J. Marques da Silva, ‘Monitoring Seasonal Pasture Quality Degradation in the Mediterranean Montado Ecosystem: Proximal versus Remote Sensing’, *Water*, vol. 10, no. 10, p. 1422, Oct. 2018, doi: 10.3390/w10101422.

[309] R. Carson, *Silent Spring*, 40th anniversary ed., 1st Mariner Books ed. Boston: Houghton Mifflin, 2002.

[310] M. E. Close, ‘Assessment of pesticide contamination of groundwater in New Zealand: 2. Results of groundwater sampling’, *N. Z. J. Mar. Freshw. Res.*, vol. 27, no. 2, pp. 267–273, Jun. 1993, doi: 10.1080/00288330.1993.9516566.

[311] E. K. Bünemann, G. D. Schwenke, L. V. Zwieten, E. K. Bünemann, G. D. Schwenke, and L. V. Zwieten, ‘Impact of agricultural inputs on soil organisms—a review’, *Soil Res.*, vol. 44, no. 4, pp. 379–406, Jun. 2006, doi: 10.1071/SR05125.

[312] H. Ghanizadeh and K. C. Harrington, ‘Weed Management in New Zealand Pastures’, *Agronomy*, vol. 9, no. 8, p. 448, Aug. 2019, doi: 10.3390/agronomy9080448.

[313] A. H. van Bruggen, A. Gamliel, and M. R. Finckh, ‘Plant disease management in organic farming systems’, *Pest Manag. Sci.*, vol. 72, no. 1, pp. 30–44, 2016, doi: 10.1002/ps.4145.

[314] E. Nichols, S. Spector, J. Louzada, T. Larsen, S. Amezquita, and M. E. Favila, ‘Ecological functions and ecosystem services provided by Scarabaeinae dung beetles’, *Biol. Conserv.*, vol. 141, no. 6, pp. 1461–1474, Jun. 2008, doi: 10.1016/j.biocon.2008.04.011.

[315] E. M. Slade, T. Riutta, T. Roslin, and H. L. Tuomisto, ‘The role of dung beetles in reducing greenhouse gas emissions from cattle farming’, *Sci. Rep.*, vol. 6, Jan. 2016, doi: 10.1038/srep18140.

[316] S. A. Forgie, Q. Paynter, Z. Zhao, C. Flowers, and S. V. Fowler, ‘Newly released non-native dung beetle species provide enhanced ecosystem services in New Zealand pastures: Dung beetles enhance ecosystem services’, *Ecol. Entomol.*, vol. 43, no. 4, pp. 431–439, Aug. 2018, doi: 10.1111/een.12513.

[317] S. A. Forgie, Q. Paynter, Z. Zhao, C. Flowers, and S. V. Fowler, ‘The impact of tunnelling and dung burial by new exotic dung beetles (Coloptera: Scarabaeinae) on surface run-off, survivorship of a cattle helminth, and pasture foliage biomass in New Zealand pastures’, Dung Beetle Release Strategy Group, 2013.

[318] A. Dopheide, A. Makiola, K. H. Orwin, R. J. Holdaway, J. R. Wood, and I. A. Dickie, ‘Rarity is a more reliable indicator of land- use impacts on soil invertebrate communities than other diversity metrics’, *eLife*, vol. 9, p. 41, 2020, doi: https://doi.org/10.7554/eLife.52787.

[319] M. A. Sanderson, S. C. Goslee, K. J. Soder, R. H. Skinner, B. F. Tracy, and A. Deak, ‘Plant species diversity, ecosystem function, and pasture management—A perspective’, *Can. J. Plant Sci.*, vol. 87, no. 3, pp. 479–487, Jul. 2007, doi: 10.4141/P06-135.

[320] R. A. Distel, J. I. Arroquy, S. Lagrange, and J. J. Villalba, ‘Designing Diverse Agricultural Pastures for Improving Ruminant Production Systems’, *Front. Sustain. Food Syst.*, vol. 4, p. 596869, Oct. 2020, doi: 10.3389/fsufs.2020.596869.

[321] K. G. Pembleton, K. N. Tozer, G. R. Edwards, J. L. Jacobs, and L. R. Turner, ‘Simple versus diverse pastures: opportunities and challenges in dairy systems’, *Anim. Prod. Sci.*, vol. 55, no. 7, pp. 893–901, 2015.

[322] P. L. Simon, C. A. M. de Klein, W. Worth, A. J. Rutherford, and J. Dieckow, ‘The efficacy of Plantago lanceolata for mitigating nitrous oxide emissions from cattle urine patches’, *Sci. Total Environ.*, vol. 691, pp. 430–441, Nov. 2019, doi: 10.1016/j.scitotenv.2019.07.141.

[323] I. Vogeler, R. Vibart, and R. Cichota, ‘Potential benefits of diverse pasture swards for sheep and beef farming’, *Agric. Syst.*, vol. 154, pp. 78–89, Jun. 2017, doi: 10.1016/j.agsy.2017.03.015.

[324] R. H. Bryant, V. O. Snow, P. R. Shorten, and B. G. Welten, ‘Can alternative forages substantially reduce N leaching? findings from a review and associated modelling’, *N. Z. J. Agric. Res.*, vol. 63, no. 1, pp. 3–28, Jan. 2020, doi: 10.1080/00288233.2019.1680395.

[325] A. J. Romera, G. J. Doole, P. C. Beukes, N. Mason, and P. L. Mudge, ‘The role and value of diverse sward mixtures in dairy farm systems of New Zealand: An exploratory assessment’, *Agric. Syst.*, vol. 152, pp. 18–26, Mar. 2017, doi: 10.1016/j.agsy.2016.12.004.

[326] P. C. Beukes *et al.*, ‘The potential of diverse pastures to reduce nitrogen leaching on New Zealand dairy farms’, *Anim. Prod. Sci.*, vol. 54, no. 12, pp. 1971–1979, 2014.

[327] M. Seither, N. Wrage, and J. Isselstein, ‘Sward Composition and Grazer Species Effects on Nutritive Value and Herbage Accumulation’, *Agron. J.*, vol. 104, no. 2, pp. 497–506, 2012, doi: 10.2134/agronj2011.0322.

[328] D. Donaghy *et al.*, ‘Will current rotational grazing management recommendations suit future intensive pastoral systems?’, *NZGA Res. Pract. Ser.*, vol. 17, Sep. 2021, doi: 10.33584/rps.17.2021.3464.

[329] S. L. Woodward, C. D. Waugh, C. G. Roach, D. Fynn, and J. Phillips, ‘Are diverse species mixtures better pastures for dairy farming?’, *Proc. N. Z. Grassl. Assoc.*, vol. 75, pp. 79–84, 2013.

[330] G. D. Milne, ‘Can pasture persistence be improved through the use of nonryegrass species?’, *NZGA Res. Pract. Ser.*, vol. 15, pp. 157–162, Jan. 2011, doi: 10.33584/rps.15.2011.3197.

[331] D. A. Clark, ‘Changes in pastoral farming practices and pasture persistence - a review’, *NZGA Res. Pract. Ser.*, vol. 15, pp. 7–13, Jan. 2011, doi: 10.33584/rps.15.2011.3218.

[332] R. Brazendale, J. R. Bryant, M. G. Lambert, C. W. Holmes, and T. J. Fraser, ‘Pasture persistence: how much is it worth?’, *NZGA Res. Pract. Ser.*, vol. 15, pp. 3–6, Jan. 2011, doi: 10.33584/rps.15.2011.3213.

[333] A. R. Bray, T. J. Fraser, W. M. King, A. D. Mackay, D. Moot, and D. R. Stevens, ‘Pasture Improvement Needs and Options for New Zealand Sheep and Beef Farms’, in *Proceedings of the 22nd International Grassland Congress*, Sydney, Australia, 2013, p. 4.

[334] K. McCahon, A. McCahon, and G. Ussher, ‘Diversified pastures at the front line of climate change in Northland: farmers experiences, new directions and wider implications for other parts of the country’, *NZGA Res. Pract. Ser.*, vol. 17, Aug. 2021, doi: 10.33584/rps.17.2021.3474.

[335] M. Grafton and M. Manning, ‘Establishing a Risk Profile for New Zealand Pastoral Farms’, *Agriculture*, vol. 7, no. 81, p. 12, 2017.

[336] K. Tozer, G. Douglas, M. Dodd, and K. Müller, ‘Vegetation Options for Increasing Resilience in Pastoral Hill Country’, *Front. Sustain. Food Syst.*, vol. 5, no. 550334, 2021, doi: 10.3389/fsufs.2021.550334.

[337] F. Nobilly and R. H. Bryant, ‘Productivity of rotationally grazed simple and diverse pasture mixtures under irrigation in Canterbury’, p. 8, 2013.

[338] K. E. French, ‘Plant-Based Solutions to Global Livestock Anthelmintic Resistance’, *Ethnobiol. Lett.*, vol. 9, no. 2, pp. 110–123, 2018.

[339] D. Scott *et al.*, ‘Limitations to pasture production and choice of species’, *NZGA Res. Pract. Ser.*, vol. 3, pp. 9–15, Jan. 1985, doi: 10.33584/rps.3.1985.3320.

[340] M. Liebman and E. Dyck, ‘Crop Rotation and Intercropping Strategies for Weed Management’, *Ecol. Appl.*, vol. 3, no. 1, pp. 92–122, Feb. 1993, doi: 10.2307/1941795.

[341] S. Senturklu, D. Landblom, G. Abagandura, S. Kumar, and L. Cihacek, ‘Regenerative Crop Rotation and Livestock Grazing Reduce Nitrogen Input and Greenhouse Gas Fluxes.’, in *Geophysical Research Abstracts*, 2019, vol. 21.

[342] M. M. Anders, M. V. Potdar, and C. A. Francis, ‘Significance of Intercropping in Cropping Systems’, in *Dynamics of Roots and Nitrogen in Cropping Systems of the Semi-Arid Tropics*, Japan International Research Center for Agricultural Sciences, 1996.

[343] R. Benavides, G. B. Douglas, and K. Osoro, *Silvopastoralism in New Zealand: review of effects of evergreen and deciduous trees on pasture dynamics*. Springer, 2009.

[344] K. E. Collins, ‘Benefits of riparian planting: A case study of lowland streams in the Lake Ellesmere catchment’, Lincoln University, 2011.

[345] B. S. Case *et al.*, ‘The roles of non-production vegetation in agroecosystems: A research framework for filling process knowledge gaps in a social-ecological context’, *People Nat.*, vol. 2, no. 2, pp. 292–304, Jun. 2020, doi: 10.1002/pan3.10093.

[346] S. Wiesner, A. J. Duff, A. R. Desai, and K. Panke-Buisse, ‘Increasing Dairy Sustainability with Integrated Crop–Livestock Farming’, *Sustainability*, vol. 12, no. 3, Art. no. 3, Jan. 2020, doi: 10.3390/su12030765.

[347] M. T. Niles, R. D. Garrett, and D. Walsh, ‘Ecological and economic benefits of integrating sheep into viticulture production’, *Agron. Sustain. Dev.*, vol. 38, no. 1, p. 1, Feb. 2018, doi: 10.1007/s13593-017-0478-y.

[348] J. F. L. Charlton, G. B. Douglas, B. J. Wills, and J. E. Prebble, ‘Farmer experience with tree fodder’, *NZGA Res. Pract. Ser.*, vol. 10, pp. 7–15, Jan. 2003, doi: 10.33584/rps.10.2003.2989.

[349] V. O. Snow *et al.*, ‘Coppiced hardwood trees for reuse of farm dairy effluent’, *NZGA Res. Pract. Ser.*, vol. 10, pp. 73–83, Jan. 2003, doi: 10.33584/rps.10.2003.2982.

[350] B. Dumont *et al.*, ‘Forty research issues for the redesign of animal production systems in the 21st century’, *Animal*, vol. 8, no. 8, pp. 1382–1393, Jan. 2014, doi: 10.1017/S1751731114001281.

[351] B. van Selm, I. J. M. de Boer, S. F. Ledgard, and C. E. van Middelaar, ‘Reducing greenhouse gas emissions of New Zealand beef through better integration of dairy and beef production’, *Agric. Syst.*, vol. 186, p. 102936, Jan. 2021, doi: 10.1016/j.agsy.2020.102936.

[352] R. D. Garrett *et al.*, ‘Social and ecological analysis of commercial integrated crop livestock systems: Current knowledge and remaining uncertainty’, *Agric. Syst.*, vol. 155, pp. 136–146, Jul. 2017, doi: 10.1016/j.agsy.2017.05.003.

[353] M. A. Altieri, ‘The ecological role of biodiversity in agroecosystems’, *Agric. Ecosyst. Environ.*, vol. 74, pp. 19–31, 1999.

[354] E. J. Dominati *et al.*, ‘Farm scale assessment of the impacts of biodiversity enhancement on the financial and environmental performance of mixed livestock farms in New Zealand’, *Agric. Syst.*, vol. 187, p. 103007, 2021, doi: https://doi.org/10.1016/j.agsy.2020.103007.

[355] S. Goldson *et al.*, ‘New Zealand pest management: current and future challenges’, *J. R. Soc. N. Z.*, vol. 45, no. 1, pp. 31–58, Jan. 2015, doi: 10.1080/03036758.2014.1000343.

[356] N. Roskruge, ‘Ngā Kaihautū Tikanga Taiao Report (Application by Dung Beetle Strategy Release Group to import and release from containment 11 species of dung beetle for management of cattle and other herbivore dung)’. Environmental Protection Authority, Dec. 2010. Accessed: Nov. 04, 2021. [Online]. Available: https://www.epa.govt.nz/assets/FileAPI/hsno-ar/ERMA200599/41122d3f7f/ERMA200599-NKTT-report.pdf

[357] IPES-Food & ETC Group, ‘A Long Food Movement: Transforming Food Systems by 2045’. 2021.

[358] H. Gosnell, N. Gill, and M. Voyer, ‘Transformational adaptation on the farm: Processes of change and persistence in transitions to “climate-smart” regenerative agriculture’, *Glob. Environ. Change*, vol. 59, p. 101965, Nov. 2019, doi: 10.1016/j.gloenvcha.2019.101965.

[359] M. J. Casey, A. Meikle, G. A. Kerr, and D. R. Stevens, ‘Social media - a disruptive opportunity for science and extension in agriculture?’, *NZGA Res. Pract. Ser.*, vol. 16, pp. 53–60, Jan. 2016, doi: 10.33584/rps.16.2016.3248.

[360] T. Wang, H. Jin, U. Kreuter, and R. Teague, ‘Understanding producers’ perspectives on rotational grazing benefits across US Great Plains’, *Renew. Agric. Food Syst.*, pp. 1–12, Jun. 2021, doi: 10.1017/S1742170521000260.

[361] F. J. F. Maseyk, E. J. Dominati, T. White, and A. D. Mackay, ‘Farmer perspectives of the on-farm and off-farm pros and cons of planted multifunctional riparian margins’, *Land Use Policy*, vol. 61, pp. 160–170, Feb. 2017, doi: 10.1016/j.landusepol.2016.10.053.

[362] G. R. Harmsworth and S. Awatere, ‘Indigenous Māori knowledge and perspectives of ecosystems’, in *Ecosystem services in New Zealand – conditions and trends*, Lincoln, N.Z.: Manaaki Whenua Press, 2013, pp. 274–286.

[363] C. Mann and K. Sherren, ‘Holistic Management and Adaptive Grazing: A Trainers’ View’, *Sustainability*, vol. 10, no. 6, Art. no. 6, Jun. 2018, doi: 10.3390/su10061848.

[364] D. R. Stevens, M. J. Casey, and K. A. Cousins, ‘Farming systems research: purpose, history and impact in New Zealand hill country’, *NZGA Res. Pract. Ser.*, vol. 16, pp. 67–85, Jan. 2016, doi: 10.33584/rps.16.2016.3261.

[365] K. Sherren, J. Fischer, and I. Fazey, ‘Managing the grazing landscape: Insights for agricultural adaptation from a mid-drought photo-elicitation study in the Australian sheep-wheat belt’, *Agric. Syst.*, vol. 106, no. 1, pp. 72–83, Feb. 2012, doi: 10.1016/j.agsy.2011.11.001.

[366] D. Anderson, ‘Regenerative ag’s “mythology” questioned’, *Rural News Group*, Jun. 30, 2020. https://www.ruralnewsgroup.co.nz/rural-news/rural-general-news/regenerative-ag-s-mythology-questioned (accessed Oct. 22, 2020).

[367] ‘Beef + Lamb New Zealand research into Regenerative Agriculture’, *Beef + Lamb New Zealand*. https://beeflambnz.com/news-views/beef-lamb-new-zealand-research-regenerative-agriculture-market (accessed Oct. 15, 2020).

[368] B. Pittman *et al.*, ‘Whakaora Ngā Whenua Whāma: Utilising Mātauranga Māori And Western Science To Protect And Restore The Soil On Rural Farms In Tai Tokerau’, *Te Tai Tokerau Climate Change Action*, Jan. 01, 2020. https://northlandclimatechange.org/unesco-project/ (accessed Jul. 06, 2021).

[369] ‘Regenerative Agriculture Ta Ao Māori UNESCO project’, *Te Tai Tokerau Climate Change Action*, Jan. 01, 2020. https://northlandclimatechange.org/unesco-project/ (accessed Oct. 15, 2020).

[370] ‘FOMA Whenua Ora Tangata Ora Partnership Leads The Way Forward In Regenerative Agriculture | Scoop News’. https://www.scoop.co.nz/stories/BU2003/S00090/whenua-ora-tangata-ora-partnership-leads-the-way-forward-in-regenerative-agriculture.htm (accessed Oct. 15, 2020).

[371] N. Roskruge, ‘Hokia ki te whenua’, Doctor of Philosophy, Massey University, Palmerston North, N.Z., 2007.

[372] N. Roskruge, ‘Traditional Māori horticultural and ethnopedological praxis in the New Zealand landscape’, *Manag. Environ. Qual. Int. J.*, vol. 22, no. 2, pp. 200–212, Jan. 2011, doi: 10.1108/14777831111113383.

[373] H. Leach, ‘Gardens without weeds? Pre-European Maori gardens and inadvertent introductions’, *N. Z. J. Bot.*, vol. 43, no. 1, pp. 271–284, Jan. 2005, doi: 10.1080/0028825X.2005.9512954.

[374] I. G. Barber and T. F. G. Higham, ‘Archaeological science meets Māori knowledge to model pre-Columbian sweet potato (Ipomoea batatas) dispersal to Polynesia’s southernmost habitable margins’, *PLOS ONE*, vol. 16, no. 4, p. e0247643, Apr. 2021, doi: 10.1371/journal.pone.0247643.

[375] V. O’Malley, *The Great War for New Zealand: Waikato 1800-2000*. Wellington, New Zealand: Bridget Williams Books, 2016.

[376] L. Denmead, E. L. Deakin, and R. Didham, ‘Riches to rags: the ecological consequences of land-use intensification in New Zealand’, in *Land Use Intensification: Effects on Agriculture, Biodiversity and Ecological Processes*, Australia: CSIRO Publishing, 2012, pp. 73–83.

[377] J. K. Carson and A. R. East, ‘The cold chain in New Zealand – A review’, *Int. J. Refrig.*, vol. 87, pp. 185–192, Mar. 2018, doi: 10.1016/j.ijrefrig.2017.09.019.

[378] D. A. Norton *et al.*, ‘Achieving win-win outcomes for pastoral farming and biodiversity conservation in New Zealand’, *N. Z. J. Ecol.*, vol. 44, no. 2, p. 3408, 2020.

[379] K. Bayne, A. Wreford, P. Edwards, and A. Renwick, ‘Towards a bioeconomic vision for New Zealand – Unlocking barriers to enable new pathways and trajectories’, *New Biotechnol.*, vol. 60, pp. 138–145, Jan. 2021, doi: 10.1016/j.nbt.2020.09.004.

[380] W. G. Lee, C. D. Meurk, and B. D. Clarkson, ‘Agricultural intensification: Whither indigenous biodiversity?’, *N. Z. J. Agric. Res.*, vol. 51, no. 4, pp. 457–460, Dec. 2008, doi: 10.1080/00288230809510475.

[381] Ministry for the Environment and Stats NZ, ‘Our Freshwater 2020’, Ministry for the Environment and Stats NZ, 2020. Accessed: Apr. 12, 2021. [Online]. Available: https://www.mfe.govt.nz/sites/default/files/media/Environmental%20reporting/our-freshwater-2020.pdf

[382] Ministry for the Environment and Stats NZ, ‘Our Land 2021’, Wellington, New Zealand, 2021.

[383] G. Jones and S. Mowatt, ‘National image as a competitive disadvantage: the case of the New Zealand organic food industry’, *Bus. Hist.*, vol. 58, May 2016, doi: 10.1080/00076791.2016.1178721.

[384] G. Hutching, ‘Organic milk returns rocket as Fonterra announces $9.20 price for organic farmers’, *Stuff*, May 06, 2016. https://www.stuff.co.nz/business/farming/79699575/fonterra-announces-920-price-for-organic-farmers (accessed Mar. 02, 2021).

[385] Organics Aotearoa, ‘Time for Action: 2020/2021 New Zealand Organic Sector Market Report’, 2021. Accessed: Aug. 02, 2021. [Online]. Available: https://drive.google.com/file/d/1soMkI1mOGHUzfgKA_6NJ7RM1rrafuXcZ/view?usp=embed_facebook

[386] K. Stein, ‘Māori Women Promoting Food Sovereignty in Aotearoa (New Zealand)’, Thesis, University of Otago, 2018. Accessed: Jun. 14, 2021. [Online]. Available: https://ourarchive.otago.ac.nz/handle/10523/8434

[387] M. Johnson and C. Perley, ‘He Ahuwhenua Taketake Indigenous Agroecology’, Ngā Pae o te Māramatanga, Auckland, New Zealand, 11RF02-BHUOT, Dec. 2015.

[388] V. Smith, P. Edwards, J. Perrott, H. Buckley, D. Norton, and L. Walker, ‘Indigenizing agroecology in Aotearoa’, *NZES*, Jun. 15, 2020. https://newzealandecology.org/indigenizing-agroecology-aotearoa (accessed Jun. 08, 2021).

[389] A. Moore *et al.*, ‘Integrating agroecology and sustainable tourism: applying geodesign to farm management in Aotearoa New Zealand’, *J. Sustain. Tour.*, vol. 26, no. 9, pp. 1543–1561, Sep. 2018, doi: 10.1080/09669582.2018.1484751.

[390] D. C. Evison, ‘Estimating annual investment returns from forestry and agriculture in New Zealand’, *J. For. Econ.*, vol. 33, pp. 105–111, 2018.

[391] K. J. Foote, ‘The cost of milk : environmental deterioration vs. profit in the New Zealand dairy industry’, Master of Environmental Management, Massey University, Palmerston North, N.Z., 2014.

[392] C. Basset-Mens, S. Ledgard, and M. Boyes, ‘Eco-efficiency of intensification scenarios for milk production in New Zealand’, *Ecol. Econ.*, vol. 68, no. 6, pp. 1615–1625, Apr. 2009, doi: 10.1016/j.ecolecon.2007.11.017.

[393] N. Z. C. Authority, *Protecting New Zealand’s Rivers*. New Zealand Conservation Authority, 2011.

[394] M. W. Stewart-Harawira, ‘Troubled waters: Maori values and ethics for freshwater management and New Zealand’s fresh water crisis’, *WIREs Water*, vol. 7, no. e1464, Sep. 2020, doi: 10.1002/wat2.1464.

[395] Ministry for the Environment, ‘Net emissions and removals from vegetation and soils on sheep and beef farmland’, Ministry for the Environment, Wellington, New Zealand, Mar. 2021.

[396] D. A. Norton, H. L. Buckley, B. S. Case, and J. L. Pannell, ‘The New Zealand Beef and Sheep Sector’s Contribution to Biodiversity and Carbon Sequestration’, *Proceedings*, vol. 8, no. 1, p. 48, Mar. 2019, doi: 10.3390/proceedings2019008048.

[397] D. Anderson, ‘Are vulnerable workers really protected in New Zealand?’, *N. Z. J. Employ. Relat.*, vol. 39, no. 1, pp. 52–67, 2014, doi: 10.3316/informit.676461205163558.

[398] R. Tipples, P. Rawlinson, and J. Greenhalgh, ‘Vulnerability in New Zealand dairy farming: The case of Filipino migrants’, *N. Z. J. Employ. Relat.*, vol. 37, no. 3, pp. 13–33, 2013, doi: 10.3316/informit.431896196808694.

[399] P. Stahlmann-Brown, ‘Survey of Rural Decision Makers 2021’. Landcare Research NZ Ltd, 2021. doi: 10.7931/3TCS-WB24.

[400]F. Maseyk, B. Small, R. Henwood, J. Pannell, H. Buckley, and D. Norton, ‘Managing and protecting native biodiversity on-farm – what do sheep and beef farmers think?’, *N. Z. J. Ecol.*, 2021, doi: 10.20417/nzjecol.45.1.

[401] S. J. E. McNeill, N. Golubiewski, and J. Barringer, ‘Development and calibration of a soil carbon inventory model for New Zealand’, *Soil Res.*, vol. 52, no. 8, p. 789, 2014, doi: 10.1071/SR14020.

[402] L. A. Schipper *et al.*, ‘A review of soil carbon change in New Zealand’s grazed grasslands’, *N. Z. J. Agric. Res.*, vol. 60, no. 2, pp. 93–118, Apr. 2017, doi: 10.1080/00288233.2017.1284134.

[403] S. R. McNally *et al.*, ‘Soil carbon sequestration potential of permanent pasture and continuous cropping soils in New Zealand’, *Glob. Change Biol.*, vol. 23, no. 11, pp. 4544–4555, Nov. 2017, doi: 10.1111/gcb.13720.

[404]N. Dickinson, M. Marmiroli, B. Das, D. McLaughlin, D. Leung, and B. Robinson, ‘Endemic Plants as Browse Crops in Agricultural Landscapes of New Zealand’, *Agroecol. Sustain. Food Syst.*, vol. 39, no. 2, pp. 224–242, Feb. 2015, doi: 10.1080/21683565.2014.967438.

[405] P. J. Bellingham *et al.*, ‘New Zealand island restoration: seabirds, predators, and the importance of history’, *N. Z. J. Ecol.*, vol. 34, no. 1, p. 22, 2010.

[406]R. M. Ewers, A. D. Kliskey, S. Walker, D. Rutledge, J. S. Harding, and R. K. Didham, ‘Past and future trajectories of forest loss in New Zealand’, *Biol. Conserv.*, vol. 133, no. 3, pp. 312–325, Dec. 2006, doi: 10.1016/j.biocon.2006.06.018.

[407] S. C. Myers, B. R. Clarkson, P. N. Reeves, and B. D. Clarkson, ‘Wetland management in New Zealand: Are current approaches and policies sustaining wetland ecosystems in agricultural landscapes?’, *Ecol. Eng.*, vol. 56, pp. 107–120, 2013.

[408]Department of Conservation, ‘New Zealand’s Sixth National Report to the United Nations Convention on Biological Diversity (Reporting Period: 2014-2018)’, Department of Conservation, Wellington, New Zealand, 6, 2019.

[409]F. Maseyk, E. Dominati, and A. Mackay, ‘More than a “nice to have”: integrating indigenous biodiversity into agroecosystems in New Zealand’, *N. Z. J. Ecol.*, vol. 43, no. 2, May 2019, doi: 10.20417/nzjecol.43.20.

[410] D. A. Norton, P. R. Espie, W. Murray, and J. Murray, ‘Influence of pastoral management on plant biodiversity in a depleted short tussock grassland, Mackenzie Basin’, *N. Z. J. Ecol.*, vol. 30, no. 3, pp. 335–344, 2006.

[411] M. K. Stewart and P. L. Aitchison-Earl, ‘Irrigation return flow causing a nitrate hotspot and denitrification imprints in groundwater at Tinwald, New Zealand’, *Hydrol. Earth Syst. Sci.*, vol. 24, no. 7, pp. 3583–3601, Jul. 2020, doi: 10.5194/hess-24-3583-2020.

[412] A.-G. E. Ausseil, H. Jamali, B. R. Clarkson, and N. E. Golubiewski, ‘Soil carbon stocks in wetlands of New Zealand and impact of land conversion since European settlement’, *Wetl. Ecol. Manag.*, vol. 23, no. 5, pp. 947–961, Oct. 2015, doi: 10.1007/s11273-015-9432-4.

[413] R. W. McDowell, N. Cox, and T. H. Snelder, ‘Assessing the Yield and Load of Contaminants with Stream Order: Would Policy Requiring Livestock to Be Fenced Out of High-Order Streams Decrease Catchment Contaminant Loads?’, *J. Environ. Qual.*, vol. 46, no. 5, pp. 1038–1047, Sep. 2017, doi: 10.2134/jeq2017.05.0212.

[414] T. P. Moore, C. M. Febria, A. R. McIntosh, H. J. Warburton, and J. S. Harding, ‘Benthic Invertebrate Indices Show No Response to High Nitrate-Nitrogen in Lowland Agricultural Streams’, *Water. Air. Soil Pollut.*, vol. 232, no. 7, p. 263, Jun. 2021, doi: 10.1007/s11270-021-05169-1.

[415] M. J. Greenwood, J. S. Harding, D. K. Niyogi, and A. R. McIntosh, ‘Improving the effectiveness of riparian management for aquatic invertebrates in a degraded agricultural landscape: stream size and land-use legacies’, *J. Appl. Ecol.*, vol. 49, pp. 213–222, Feb. 2012, doi: 10.1111/j.1365-2664.2011.02092.x.

[416] L. Basher, ‘Erosion processes and their control in New Zealand.’, in *Ecosystem services in New Zealand–conditions and trends 2013*, 2013, pp. 363–374.

[417] A. A. Berhe, J. Harte, J. W. Harden, and M. S. Torn, ‘The Significance of the Erosion-induced Terrestrial Carbon Sink’, *BioScience*, vol. 57, no. 4, pp. 337–346, Apr. 2007, doi: 10.1641/B570408.

[418] S. Doetterl, A. A. Behre, E. Nadeu, Z. Wang, M. Sommer, and P. Fiener, ‘Erosion, deposition and soil carbon: A review of process-level controls, experimental tools and models to address C cycling in dynamic landscapes’, *Earth-Sci. Rev.*, vol. 154, pp. 102–122, 2016.

[419] D. A. Clark, J. R. Caradus, R. M. Monaghan, P. Sharp, and B. S. Thorrold, ‘Issues and options for future dairy farming in New Zealand’, *N. Z. J. Agric. Res.*, vol. 50, no. 2, pp. 203–221, 2007.

[420] R. McDowell, R. Monaghan, W. Dougherty, C. Gourley, R. Vibart, and M. Shepherd, ‘Balancing water-quality threats from nutrients and production in Australian and New Zealand dairy farms under low profit margins’, *Anim. Prod. Sci.*, vol. 57, Jan. 2017, doi: 10.1071/AN16646.

[421] R. W. McDowell, T. J. van der Weerden, and J. Campbell, ‘Nutrient losses associated with irrigation, intensification and management of land use: A study of large scale irrigation in North Otago, New Zealand’, *Agric. Water Manag.*, vol. 98, no. 5, pp. 877–885, Mar. 2011, doi: 10.1016/j.agwat.2010.12.014.

[422] L. A. Schipper, R. L. Parfitt, S. Fraser, R. A. Littler, W. T. Baisden, and C. Ross, ‘Soil order and grazing management effects on changes in soil C and N in New Zealand pastures’, *Agric. Ecosyst. Environ.*, vol. 184, pp. 67–75, Feb. 2014, doi: 10.1016/j.agee.2013.11.012.

[423] S. T. Larned, J. Moores, J. Gadd, B. Baillie, and M. Schallenberg, ‘Evidence for the effects of land use on freshwater ecosystems in New Zealand’, *N. Z. J. Mar. Freshw. Res.*, vol. 54, no. 3, pp. 551–591, 2019, doi: https://doi.org/10.1080/00288330.2019.1695634.

[424] L. A. Schipper and G. P. Sparling, ‘Accumulation of soil organic C and change in C:N ratio after establishment of pastures on reverted scrubland in New Zealand’, *Biogeochemistry*, vol. 104, no. 1, pp. 49–58, Jul. 2011, doi: 10.1007/s10533-009-9367-z.

[425] Federation of Māori Authorities, ‘Whenua Ora Tangata Ora Partnership Leads The Way Forward In Regenerative Agriculture | Scoop News’, *Scoop*, Mar. 05, 2020. https://www.scoop.co.nz/stories/BU2003/S00090/whenua-ora-tangata-ora-partnership-leads-the-way-forward-in-regenerative-agriculture.htm (accessed Nov. 04, 2021).

[426] J. Bellarby, R. Tirado, A. Leip, F. Weiss, J. P. Lesschen, and P. Smith, ‘Livestock greenhouse gas emissions and mitigation potential in Europe’, *Glob. Change Biol.*, vol. 19, no. 1, pp. 3–18, Jan. 2013, doi: 10.1111/j.1365-2486.2012.02786.x.

[427] A. Mazzetto, S. Falconer, and S. Ledgard, ‘Mapping the carbon footprint of milk for dairy cows’, DairyNZ, RE450/2020/081, Feb. 2021.

[428] W. J. Wales and E. S. Kolver, ‘Challenges of feeding dairy cows in Australia and New Zealand’, *Anim. Prod. Sci.*, vol. 57, no. 7, p. 1366, 2017, doi: 10.1071/AN16828.

[429] C. Hermani, ‘Regenerative Agriculture and the Quest for Sustainability - Inquiry of an Emerging Concept (Master Thesis)’, 2020. doi: 10.13140/RG.2.2.36015.97447.

[430] M. Schiedung, C. S. Tregurtha, M. H. Beare, S. M. Thomas, and A. Don, 'Deep soil flipping increases carbon stocks of New Zealand grasslands', *Glob. Change Biol.*, vol. 25, no. 7, pp. 2296–2309, 2019, doi: 10.1111/gcb.14588.
[431] R. Lal and J. M. Kimble, 'Conservation tillage for carbon sequestration', *Nutr. Cycl. Agroecosystems*, vol. 49, no. 1–3, pp. 243–253, 1997.
[432] P. Mudge, S. McNeill, C. Hedley, P. Roudier, M. Poggio, and M. Beare, 'Design of an on-farm soil carbon benchmarking and monitoring approach for individual pastoral farms', New Zealand Ministry for Primary Industries | Manatū Ahu Matua, Wellington, New Zealand, MPI Technical Report 2020/02, Jun. 2019.
[433] K. Curtis, M. H. Bowie, and S. Hodge, 'Can native plantings encourage native and beneficial invertebrates on Canterbury dairy farms?', *N. Z. Entomol.*, vol. 42, no. 2, pp. 67–78, Jul. 2019, doi: 10.1080/00779962.2019.1660450.
[434] P. Wardle, 'War of the lupins', *New Zealand Geographic*, no. 137, Jan. 2016. Accessed: May 17, 2021. [Online]. Available: https://www.nzgeo.com/stories/war-of-the-lupins/
[435] R. J. Holdaway and A. D. Sparrow, 'Assembly rules operating along a primary riverbed–grassland successional sequence', *J. Ecol.*, vol. 94, no. 6, pp. 1092–1102, 2006, doi: 10.1111/j.1365-2745.2006.01170.x.
[436] K. N. Tozer and G. B. Douglas, 'Pasture establishment on non-cultivable hill country: a review of the New Zealand literature', *NZGA Res. Pract. Ser.*, vol. 16, pp. 213–224, Jan. 2016, doi: 10.33584/rps.16.2016.3233.
[437] K. N. Tozer *et al.*, 'Effect of seed mix, sowing time, summer fallow, site location and aspect on the establishment of sown pasture species on uncultivable hill country', *N. Z. J. Agric. Res.*, vol. 59, no. 4, pp. 389–411, Oct. 2016, doi: 10.1080/00288233.2016.1224768.
[438] J. Herron, D. Hennessy, T. Curran, A. Moloney, and D. O'Brien, 'The simulated environmental impact of incorporating white clover into pasture-based dairy production systems', *J. Dairy Sci.*, Apr. 2021, doi: 10.3168/jds.2020-19077.
[439] K. N. Tozer, G. M. Barker, C. A. Cameron, and N. Loick, 'New Zealand dryland pastures: effects of sown pasture species diversity on the ingress of unsown species', Christchurch, NZ, 2010, pp. 298–301.
[440]B. G. Ferguson *et al.*, 'Sustainability of holistic and conventional cattle ranching in the seasonally dry tropics of Chiapas, Mexico', *Agric. Syst.*, vol. 120, pp. 38–48, Sep. 2013, doi: 10.1016/j.agsy.2013.05.005.
[441] C. T. Hayward, 'The financial implications of regenerative agriculture in the Southern Cape and the subsequent impact on future animal and winter cereal crop production.', Master of Agricultural Administration, Stellenbosch University, 2021.
[442] W. J. Anderson, B. J. Ridler, W. J. Anderson, and B. J. Ridler, 'The effect of dairy farm intensification on farm operation, economics and risk: a marginal analysis', *Anim. Prod. Sci.*, vol. 57, no. 7, pp. 1350–1356, Mar. 2017, doi: 10.1071/AN16457.
[443] E. Negussie *et al.*, 'Large-scale indirect measurements for enteric methane emissions in dairy cattle: A review of proxies and their potential for use in management and breeding decisions', *J. Dairy Sci.*, vol. 100, pp. 2433–2453, 2017, doi: https://doi.org/10.3168/jds.2016-12030.
[444]R. N. Jensen, D. A. Clark, and K. A. Macdonald, 'Resource Efficient Dairying trial: measurement criteria for farm systems over a range of resource use', *Proc. N. Z. Grassl. Assoc.*, pp. 47–52, Jan. 2005, doi: 10.33584/jnzg.2005.67.2592.
[445] C. Glassey, C. Roach, J. Lee, and D. Clark, 'The impact of farming without nitrogen fertiliser for ten years on pasture yield and composition, milksolids production and profitability; a research farmlet comparison', *Proc. N. Z. Grassl. Assoc.*, vol. 75, no. 71–78, Nov. 2013.
[446]D. S. Wratt, 'Climate change, climate variability, and the future', *Proc. N. Z. Grassl. Assoc.*, pp. 57–59, Jan. 2009, doi: 10.33584/jnzg.2009.71.2771.
[447] A. Daigneault, 'Economic Impacts of Multiple Agro-Environmental Policies on New Zealand Land Use', *Environ. Resour. Econ.*, vol. 69, no. 4, pp. 763–785, 2018, doi: https://doi.org/10.1007/s10640-016-0103-6.
[448]V. T. Burggraaf, G. M. Lucci, S. F. Ledgard, D. L. Antille, and V. O. Snow, 'Application of circular economy principles to New Zealand pastoral farming systems', *J. N. Z. Grassl.*, vol. 82, pp. 53–59, 2020.
[449] C. Basset-Mens, S. Ledgard, and A. Carran, 'First Life Cycle Assessment of Milk Production from New Zealand Dairy Farm Systems', in *Proceedings of the Australian and New Zealand Ecological Economics in Action Conference*, 2005, pp. 258–265.
[450] McCain Foods, 'Sustainability - Smart & Sustainable Farming | McCain Foods', *McCain Foods Global Corporate*. http://www.mccain.com/sustainability/smart-sustainable-farming/ (accessed Jul. 21, 2021).
[451] Cargill, 'We're Building Farmer-Focused, Regenerative Agriculture Relationships | Cargill'. https://www.cargill.com/sustainability/regenerative-agriculture (accessed Jul. 21, 2021).
[452] General Mills, 'Regenerative Agriculture 2020'. http://www.generalmills.com/en/Responsibility/Sustainability/Regenerative-agriculture (accessed Jul. 21, 2021).
[453] 'Regenerative agriculture - Danone', *World food company - Danone*, Nov. 07, 2019. https://www.danone.com/impact/planet/regenerative-agriculture.html (accessed Aug. 06, 2021).
[454] S. C. Leahy, L. Kearney, A. Reisinger, and H. Clark, 'Mitigating greenhouse gas emissions from New Zealand pasture-based livestock farm systems', *J. N. Z. Grassl.*, pp. 101–110, Oct. 2019, doi: 10.33584/jnzg.2019.81.417.
[455] P. R. Beatson, S. Meier, N. G. Cullen, and H. Eding, 'Genetic variation in milk urea nitrogen concentration of dairy cattle and its implications for reducing urinary nitrogen excretion', *Animal*, vol. 13, no. 10, pp. 2164–2171, 2019, doi: 10.1017/S1751731119000235.
[456] C. J. Marshall, 'Grazing dairy cows with low milk urea nitrogen breeding values excrete less urinary urea nitrogen', *Sci. Total Environ.*, p. 8, 2020.
[457] 'Sustainable Finance', *The Aotearoa Circle*. https://www.theaotearoacircle.nz/sustainablefinance (accessed Oct. 23, 2020).
[458] EU Technical Export Group on Sustainable Finance, 'Taxonomy: Final report of the Technical Expert Group on Sustainable Finance', European Union, Mar. 2020.
[459] 'Climate Bonds Initiative Agriculture Criteria', *Climate Bonds Initiative*, Mar. 03, 2019. https://www.climatebonds.net/agriculture (accessed Oct. 21, 2020).
[460]J. R. Dymond, A.-G. E. Ausseil, D. A. Peltzer, and A. Herzig, 'Conditions and Trends of Ecosystem Services in New Zealand—a Synopsis', *Solut. J.*, vol. 5, pp. 38–45, 2014.

TOHA
Science