Whakaora ngā whenua whāma

Utilising mātauranga Māori and Western science to protect and restore the soil on rural farms in Te Tai Tokerau.

A report prepared for UNESCO New Zealand

NorthTec
TAI TOKERAU WĀNANGA

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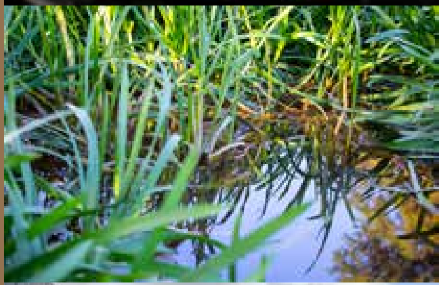






Contents

1. Executive summary

The Final Report to UNESCO NZ entitled, *Whakaora ngā whenua whāma: Utilising mātauranga Māori and Western science to protect and restore the soil on rural farms in Te Tai Tokerau*, is submitted in fulfilment of the funding granted to NorthTec and Unitec. The process and planning of the project cover the team formation, the team constitution, and the idea development. From the rural communities of Waiotu and Takahiwai, two older Māori people [kaumātua] collaborated with the Unitec/NorthTec based researchers to utilise te reo Māori me ngā tikanga and Western research methodologies—qualitative and quantitative—to produce scientific evidence and Indigenous Māori knowledge to support the emerging concept of regenerative farming with the purpose to diminish and transform the adverse impacts of industrial farming production on the land, air, and water. The project commenced on 1 October2019 and was scheduled to end on 30 June 2020, but given the impact of Covid-19 this date was extended to 30 November 2020.

A broad review of the literature in the research areas of Māori language and culture, or more specifically, mātauranga Māori, and industrial and regenerative farming practices has been undertaken by the senior investigator. The pilot study has involved the researchers interviewing a female and a male kaumātua who have lived or are living on shared ancestral land in rural northern Aotearoa New Zealand; both of them hold doctoral qualifications in Education and Health, respectively. Two farmers, whose ancestors are Māori, have also been interviewed for the research. Their Pākehā (European New Zealander) wives have been supportive of their husbands' participation in and contributions to the study. Two secondary school leavers have been trained as Photographer Researchers; they are daughters of the farmers and their wives. Farming and technical experts have contributed their experiences and skills through two seminars and a field study of soil health. Through the broad, rich, people-centred research approaches, the study has provided for older and younger, male and female, Māori and Pākehā peoples to share their knowledges [Western science] and wisdoms [mātauranga Māori] about producing healthy food in healthy soil.

For the creation of a co-designed research project, finding time when we could all get together was challenging. Initially, the co-designing research method involved the research team in a great of travelling to meet the;

- Kaumātua and to visit the site of ancestral land in Takahiwai;
- Farmers and their families and to visit their farms in Mata;
- Photographer researchers, in Mata, with the senior researcher from Unitec, Auckland; and then to
- Collaborate as a group and combine the people, the land, the equipment, skills and knowledge for a reliable completion of the project.

At the Cultural Interface of Māori and Pākehā, critical, reflective dialogue has taken place to enable an innovative, co-designed study to better understand soil health at Takahiwai and Mata, specifically. In lengthy conversations with the kaumātua, together with e-mail communication, Māori approaches to care for Papātuānuku [Earth Mother] have been researched.

In a similar dialogical research method, the experts have given freely of their knowledge to identify multi-factors and processes that influence soil health on a farm using regenerative methods, such as pasture diversity, plant root depth, soil porosity, mycorrhizal associations, grazing intensities, carbon levels, and soil microbiome. The pilot research study has brought together Māori and Pākehā people successfully in a new conversation about farming methods to improve soil health in Te Tai Tokerau, throughout Aotearoa New Zealand, and the world.

Recommendations in the conclusion of this report range from practical next steps for those promoting regenerative agriculture to more aspirational recommendations for the wider community. These are summarised here. See the conclusion for supporting narrative.

1. Strengthen research in Tai Tokerau to support regeneration of the environment, society and economy.
2. Promote mātauranga Māori as an essential support for regenerative thinking.
3. Further research on the impacts of the hydrological cycle and its implication for land use in Tai Tokerau.
4. Curate an annotated and well-structured repository of practical material about how to manage land regeneratively, designed to maximise ease of access and reference for farmers, other land users, educators and policy-makers.
5. Identify support for transition for farmers, especially Māori farmers.
6. Create stronger networks between those with interests in the regeneration of landscapes including farmers, those involved in ecosystem regeneration, permaculturalists and regenerative foresters.
7. Create a database of farmers for Tai Tokerau.

2. Introduction

In a broader sense than their given definition, many Māori language terms reveal a sense and process of interaction and self-development; including kaumātua [older, elder, senior people], mātauranga Māori [Māori knowledge], wairua [spirit or soul], mauri [the force that gives something its vitality or strength], whakapapa [shared ancestry], whenua [shared land], and kaitiakitanga [shared care]. There is a sense of bringing forth more or growing that highlights the mysterious spirit of Te Ao Māori [the Māori world] rather than a certainty that sets in advance how a thing is to be viewed in the world. In Te Ao Māori, the people's attention is drawn to think of the spiritual as part of everyday human affairs.

With the growth of Western science in agriculture, for example, Māori researchers have been faced with the drive to produce knowledge. When the "knowledge economy" was unleashed on New Zealand, the term "mātauranga Māori" grew to prominence.

In English language, the term "knowledge" tends towards a calculative and logical way of talking about things in the world, both in everyday life and scientific discourse. Thus, the preordained ground (prior lived experience) means the appearance of a thing as a solid, calculable entity in advance, which is the basis on which people encounter things as already given. This encroaching idea of a firm, preordained ground has been and continues to be a very real threat to Māori beliefs in the presence of the supernatural.

In social, political, and deeply philosophical senses, Māori tribal society has been affected by this scientific, calculative, logical ground of belief. Māori, for instance, are constantly asked to provide their Iwi [tribe] details in the census and urged to be present 'in the flesh' at school, in the courthouse, in the surgery, and the lecture theatre.

Since the beginning of colonisation, Māori have been instructed to view our gods as solid, identifiable entities (preferably one solid, identifiable or universal entity). Māori have been taught to think of our land as a solid, visible entity capable of definition by land block names.

The people have been urged to think of Māori language, carvings, and arts as phenomena separate from our mysterious origins. Through the primary mode of communication – the English language – Māori have been pressured to think of strictly adhering to linguistic conventions which are distinctly Western.

In the project called, *Whakaora ngā whenua whāma: Utilising mātauranga Māori and Western science to protect and restore the soil on rural farms in Te Tai Tokerau*, the research team has begun to address the notion of a Cultural Interface that draws attention to Māori beliefs, interaction, and self-development in organic and regenerative agriculture across Te Tai Tokerau, Aotearoa New Zealand, and the world.

3. Literature review

3.1. Cultural context

A motivation for this project is to mitigate climate change. In the context of the climate crisis in Te Tai Tokerau, Māori and Pākehā people are grappling with their diverse cultural, political, and economic dynamics or relations that lock in human behaviours accelerating the climate emergency. The research team anticipates that regenerative agriculture, with its diverse roots in Western science, and the unleashing of Mātauranga Māori is the interface in which to effect change to the climate crisis.

Intense learning and action are required to avert the worst of the crisis. This aversion merits a brief exploration of how people and cultures learn. When Edgar Schein defined culture, it was in the context of organisations, his definition though is broad enough to encompass diverse human communities.

> The culture of a group can now be defined as a pattern of shared basic assumptions that the group learned as it solved its problems of external adaptation and internal integration, that has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems (Edgar Schein). [1]

From the processes that Schein has outlined, people generate knowledge and embed ways of knowing in their culture.

External changes

At least two major external shocks that Māori were exposed to since their arrival in Aotearoa have been firstly, the challenge of adapting tropical and sub-tropical crops to a much colder environment.[2] The second change to their ways of living was the arrival of Europeans from Great Britain, among other colonial settlers. The tropical uwhi (yam) and aute (paper mulberry tree) did survive into the post-European contact period but appear to have been supplanted or replaced. Māori quickly adapted their new crops to the extent that they traded and helped to sustain settlers and adopted new technologies such as ship building. The avalanche of environmental impacts accelerated their colonisation through the British legal system, political machinations and new financial instruments such as taxes, rates, currency and debt[3].

While Indigenous cultures around the world retained an holistic world view and ways of knowing, developments in Europe set Western science on a different trajectory. Late Renaissance thinkers such as Kepler, Galileo and Descartes precipitated the Age of Reason (Enlightenment) and what Mere Roberts calls the nature-culture divide[4]. The Industrial Revolution accelerated the Western disconnect from nature. While the pace of colonisation was accelerating in New Zealand, in 1859 Darwin published *Origin of the Species*, a book misappropriated to support notions of social inequality, racism and eugenics[5]. Science had usurped the moral authority of religion, developed its own ideology, privileging illusory 'objectivity' and spawning social movements that accelerated the disjuncture with indigenous ways of knowing.

The material benefits ensuing from Western science are indisputable, but at what cost?

> "Recently, indigenous soil knowledge has been recognised as a vital source for most scientists to be used to change and improve natural resource management without neglecting the social and cultural values of the local environment… there is a diversity of local or traditional knowledge and practices in soil management. These include plant species selection, landscape management, succession or fallow management, ways to observe soil degradation, and practices of responding to ecological problems in soils (i.e., fertility, acidity, erosion, biodiversity)… a more complete understanding of soil processes needs to be developed, not only based on local observations, but also in terms of philosophies and methodologies of transferring the knowledge." (Handayani & Prawito)[6]

3.2. Mātauranga Māori

Māori traditions and practices for improved soil health

Māori traditions and practices for improved soil health: Through generations of observation, Māori developed many practices to improve soil health. The various Māori names for different soil types (including clay, alluvial soil, gravel soil, fertile dark soil, sandy soil, and a stiff brown soil, which was fertile but needed breaking up and to have sand or gravel added)[7] is another indication of the level of familiarity tangata whenua traditionally had with their soils. Gardening practices or their particular implementation often varied from place to place[8] to suit different environmental circumstances and characteristics such as soil type, soil fertility, climatic conditions and endemic plant species[9]. Despite this, adding mulch, burned vegetation ash, or sand, gravel or other coarse materials to soil[10] was common, as was the practice of minimalist soil-tilling, and leaving earth fallow.

Archaeological stone features such as rows and mounds have also been recorded, but there is debate as to the functional relationship of these features to the soil. [11]

Māori came to appreciate the best soil types for different crops. For example, kūmara were known to prefer porous, sandy or gravelly, free-draining soil due to its ability to absorb moisture and, attract and retain heat.[12] To augment these innate soil characteristics, stones were strategically added into the earth as a passive heating mechanism to regulate soil temperature[13] . Supports for plant growth also included constructing shelter and windbreaks.[14]

As observed by Best in 1876[15] structure and order in traditional food production practices was evident. This went beyond merely an aesthetic "neatness and weed-free state of Māori gardens". This well-ordered approach was apparent in practical knowledge, for example regarding which kinds of plants grew best together, such as gourds and taro, which both preferred damp soils[16]. Combined with discipline and powers of physical perception, orderliness at a more metaphysical level - such as practitioners' intuitive and spiritual connectedness with the land, crops and natural surroundings - facilitated Māori harmonisation with seasonal patterns as well as responsiveness to environmental changes.

Values underpinning traditional Māori practices

While there are many present-day accounts and perspectives of Māori concepts, commentators remind us that colonisation has profoundly changed the context and interpretation of mātauranga Māori, values and practices compared to their original meaning. A good illustrative example is the modern concept of "kaitiakitanga", commonly associated in New Zealand today with notions of human-led guardianship and conservation, but which was originally used in reference to a particular supernatural being (taniwha) who cared for particular environmental site.[17]

Wairua

Wairuatanga (spirituality) was a foundational feature of traditional Māori gardening practice. The application of wairua in the exercise of māra kai activities through karakia (prayer, invocation, incantation) connected the practitioner with "divine energies" which provided integrity to one's mahi. The "observance of ritual associated with the planting and harvesting of kūmara", for example, played a significant part in determining where kūmara were planted separately from other crops. (Furey, 2006, p17). Wairua also enhanced people's abilities (including keen observational awareness, intuition and other metaphysical capacities) which helped to create healthy kai.[18]

> Drawing on the kaupapa of wairua strengthens awareness [. . .], sharpening observational skills and bringing new perspectives to bear on the relatedness of soil, soil moisture, soil biodiversity and seasonal changes.[19]" (Hutchings, Smith & Harmsworth, p. 99)

In short, "Practising wairuatanga[. . .] builds greater literacy about the vibrations of nature as a living, breathing entity".[20]

Whakapapa

Māori people's connection with the land is apparent, among other things, through diverse traditional, cosmological belief systems. A key aspect is Māori whakapapa me korero (kin relations and narratives) tradition linked to numerous deities, most notably Papatūānuku (Earth mother), and Hine-ahu-one (the first woman formed from soil by the son of Papatūānuku), Tāne Mahuta, (Lord of the forests and humankind). This whakapapa "places Māori in an environmental context with all other flora and fauna and natural resources as part of a hierarchical genetic assemblage",[21] and reinforces the direct, deep, respectful connection between the traditional land-based territories and by association, the soil and humankind. It instilled a strong sense of obligation and responsibility to the land as one might expect between a child and their parent. These embedded multifaceted layers of information have been described as a "cognitive template [. . .] a genealogical framework upon which spiritual, spatial, temporal and biophysical information about a particular place is located."[22] Inherent in whakapapa Māori are also descriptions of:

> Key ecosystems or habitats and their functional inter-relationships; the cosmogonical origins and history of the phenomena in that whakapapa; moral instruction; and provision of a useful mnemonic facilitating retention and recall. [23]

The theme of whakapapa as the relationship between humanity and nature is reflected in the traditional understanding that "a handful of soil [. . .] embodies a complex whakapapa of relationships with mutually sustaining obligations",[24] not just an extractive attitude about what the soil can provide for people.[25] The other practical aspect of whakapapa knowledge relates to understanding the cause-and-effect relationship of materials used, like compost or chemicals which enrich (or degrade) soil health. A tendency towards a Māori aversion to fertiliser use may well originate from cultural beliefs in this regard especially, for example, using fertilisers sourced from human waste, particularly in relation to food crops.[26] Hutchings et al[27] encourage us to question all fertilisation materials in terms of their positive or negative effect on the relationship between soil and people.

Whakapapa implies a holistic approach to soil management as reflected, for example, in the Māori saying "Ki Uta Ki Tai" – from the mountains to the sea. Bear in mind the variety of functional relationships that may exist between human and nature, and the imperative for all of those individual 'actors' and processes to be healthy for the whole to be healthy. Similarly, with mahinga kai which is "more than just a process of food gathering":

> It provides Māori simultaneously with spiritual nourishment as well as nourishment of the heart. It is thus impossible to separate what takes place on the farm from the surrounding environment.[28]

Mauri ora

Another related concept is "mauri ora" or life force. According to Te Parawhau hapū, mauri ora was transferred by Tāne Mahuta to Hine-ahu-one thereby emphasising the essential relationship between mauri and soil. As an observable force, Māori expertise can be employed to measure mauri levels to assess the wellbeing of land, food, plants or other resources, and inform what actions must accordingly be taken to "enhance, protect or restore" mauri levels and, therefore, wellbeing. [29]

Mana

Hutchings et al.,[30] have pointed out that soil wields its own mana [power and authority] as a vital component to sustain life in the same way that air and water is indispensable for all biodiversity's existence. Several traditional concepts elaborate the understanding of "mana" in relation to soil and people's wellbeing. These include mana whenua [traditional authority affiliated to and deriving from the land] and manaaki [caring] which literally means to induce or encourage [aki] the act of filling making "ki" with mana. The exercise of manaaki which respects and supports soil health and 'sovereignty' in turn enhances mana tangata [people's self-determination], for example in terms of how food sovereignty, derived from healthy soil, creates food security for the affected peoples which enhances their political autonomy.[31] Therefore, soil mana enhancement (or depletion), as with other elements in nature, mirrors the mana of the people as expressed in daily social, cultural, spiritual, economic and political life.

Other principles and concepts

There are a myriad of other interrelated Māori principles relating to healthy soil, such as those contained in the Hua Parakore kaupapa Māori framework for growing organic kai[32]. Māramatanga [knowing] relates to one's level of understanding and insight of all the applicable aspects of nature that impact food production;[33] and Te Ao Tūroa [the natural order of the living world][34] emphasises respect for the "sanctity and integrity" of all life, which correspondingly calls for active challenge and resistance against any elements that risk disrupting the natural order such as chemical fertilisers, pesticides or genetic modification.[35]

The abovementioned self-reinforcing key cultural components are considered part of a system underpinning traditional values such as kaitiakitanga, the nearest corresponding Western concept for which in an environmental context is a preservation and protection resource management tool. Kaitiakitanga includes addressing any imbalance of mauri[36] or other environmental dynamic, and, according to Walker is given sense and meaning by virtue of the whakapapa and geography within which it is contextualised:

> Without the concept of whakapapa, the act of kaitiakitanga can become meaningless and remove the spiritual connection that Māori share with their surroundings. It is therefore paramount that those practicing Kaitiakitanga have a sound knowledge of whakapapa connected with the area. (Walker, 2016, p 21)[37]

Therefore, notions such as stewardship are incapable of defining kaitiakitanga as they denote ownership as opposed to the primacy of *relationships* between people and the land. Māori terms with dual or multiple meanings depending on context, such as whenua [meaning land, but also placenta or afterbirth] or wai [meaning water, but also referencing the nature of wairua or the human spirit] also reinforce direct relationship ties to the land, and therefore one's obligations to care for it as one would with one's own kin. These interconnected concepts reinforce the practical necessity for protocol and methodical approaches when engaging in land, ocean or environment-based activities. Just as significantly, they provide a framework to guide compliance with immutable natural forces and laws of cause-and-effect which, if violated, were believed to have severe consequences.

Social effects of improving soil health through the use of mātauranga Māori

With respect to food gardening culture and increasing soil health, the practice of such customary traditions maintained an intimate bond of mutually beneficial value exchange between people and the land that transcended generations, as the following whakataukī [Māori proverb] illustrates.[38]

> "Ko ngā mana ko ngā mauri o te whenua kei raro iho i ngā tikanga a o tātou tūpuna." [The prestige and life force of the land is enhanced beneath the mantle of our ancestral traditions].

Exercising tradition in itself naturally led to positive outcomes such as strengthening relationships between whānau and hapū members, as was the case regarding, for example, kaitiakitanga:

> In order for Kaitiakitanga to be practiced and understood appropriately, whānau and hapū must have a shared and similar understanding of the mātauranga that is handed down to them.[39]

Practising kaitiakitanga to working the land also went beyond merely providing food for the people. Walker says that the impact of the māra kai extended to providing sustenance for the local native bird and insect population as well. Conceptually, this concept of broader purpose could be applied to providing for the extensive community of organisms in the soil itself. The case for a broader concept of manaaki also aligns well with the Māori custom of wāhine [women] holding prominent and important nurturing roles in the transmission of knowledge. Traditionally recognised was the necessity of the female element, or nurturing energies, with regards to caring for the land/ soil, upon which the welfare of humankind ultimately depends:

> [T]here is a synergy between women and land, and that without one or the other (or both) man will not survive.[40]

Hutchings et al,[41] remind us that practising mātauranga Māori, particularly in the sense of revitalising the soil's sovereignty and integrity and its relationship with people and their lands, can also be seen as a response to colonial land alienation, the destructive effects which were later exacerbated with the advent of industrial agriculture. Therefore, traditional soil restoration practice was a revolutionary act inextricably tied to more overarching Māori sovereign aspirations:

> [R]esisting the reduction of land, water and earth—our soil—as a commodity [. . .] understanding soil as a living, breathing entity—as Hine-ahu-one [is. . .] a step perhaps as revolutionary as those taken to acknowledge the personhood (as a living entity) of Te Urewera and Whanganui River.[42]

As one tangata whenua practitioner comments:

> Working with the whenua and the soil is deeply healing and connective. [. . .] Māori food sovereignty is [. . .] about decolonisation, it is about reducing structural inequities and racism so that Māori communities and whānau have access to safe, nutritious and culturally appropriate food and can again return to eat the landscapes of which we come from.[43]

In summary, to engage in customary practices of increasing soil health includes a recognition that to do so is a critical political act which supports strong traditional culture, including reconnecting people with their wairuatanga [the metaphysical realm being the ultimate foundation of all sovereignty]. As Hutchings et al.[44] therefore observe, the "stakes" could not be higher for Māori in creating soil health.

External transformation

Colonisation has marginalised indigenous knowledge around the globe. Judith Swartz in her text entitled, *The Reindeer Chronicles*,[45] has begun to grapple with the enormity of the damage—human, ecological, spiritual—that colonialism has wrought across the world. In Norway, she has observed that the exploitation of land by external powers seeps into every area of life of the Indigenous Sami peoples from access to local water, now branded and put into bottles, to a person's identity and dignity. Imperial societies have imposed the worldview that nature has value only to the extent that the natural world can be turned into products; that forests, arable soils, and wildlife represent "resources" or wealth. To think otherwise, to see, for instance Indigenous Peoples' agency and consciousness in nature, is to be primitive.

Swartz has related that she grew up with the idea that European exploration and America's westward settlement represented progress, and that her cohort would become part of this story and, therefore, fulfil their purpose. In her childhood Swartz never gave a thought to the name of the upstate New York town of Niskayuna ("extensive corn flats" in the Mohawk language) in which she lived, the Iroquois Middle School she attended, Algonquin Road where she played with friends, and the polyester shirts she sold at Mohawk Mall and what these names told her and friends about the true nature and history of the place. In her adulthood, Swartz finds her lack of inquisitiveness appalling and now does her best to learn what she had failed to learn when young. The important question for Swartz has been: Where does genuine interest in Indigenous Peoples' language, profound love of place, their ancestors' realisation that without nature there is no life end and cultural appropriation begin? The question is vital to understanding the cultural interface between mātauranga Māori and regenerative agriculture.

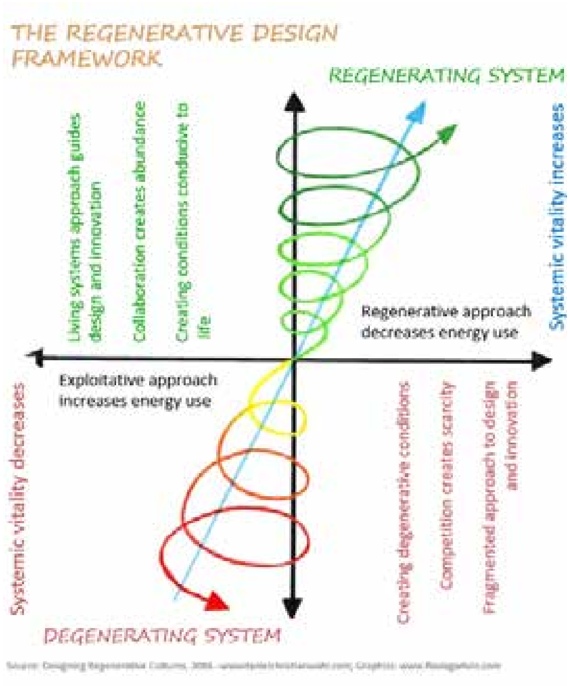
3.3. From industrial food systems to regenerative food systems

A food system's perspective reveals the impact of the production, distribution, processing and selling of food on the environment, society and economy. Industrial food systems emerged in New Zealand alongside the trajectory of colonisation. Along with the impacts of colonisation and consumerism, industrial food systems have created significant impacts on people's health, social cohesion and the economy. See Appendix one for more detail.

Figure 1: Timeline for the forces that shaped our food system

The International Panel of Experts on Sustainable Food Systems (IPES-Food) provide a systemic view of food systems and advocate a shift from industrial food systems to sustainable food systems. Their work catalogues the excesses of industrial food systems and elaborates on locks-ins that inhibit the further development of sustainable food systems. These include the concentration of power in agribusiness, short-term and compartmentalised thinking, the export orientation and the expectation of cheap food.[46] Small landholders (defined as 25 acres or less) grow over 70% of the world's food. Those using agroecological methods may be two to four times more energy-efficient than large conventional farms, in terms of total energy input/output ratios.[47]

Regenerative food systems offer an alternative to industrial food systems. Daniel Wahl states that sustainability is "100% less bad" and points to regeneration as the aspirational goal.



Regenerative
Appropriate participation and design as nature.

Reconciliatory
Reintegrating humans as integral parts of nature.

Restorative
Humans doing things to nature.

Sustainable
Neutral point of not doing any more damage.

Green
Relative improvements.

Conventional practice
Compliance to avoid legal actions.

Figure 2: The regenerative design framework (Daniel Wahl) [48]

In the diagram above, conventional practice is identified as degenerative, with sustainability at a neutral point. Restoration and reconciliation are better but are still human-centric, with people fixing nature. Regenerative systems learn from nature and work with natural systems. When we achieve regenerative practices, we co-create with the natural world.

> …we are co-creative participants in a 14-billion-year process of universe becoming conscious of itself. We are a keystone species capable of creating conditions conducive to all life. We can design for human, ecosystems and planetary health, and nurture resilience, adaptability, transformability and vitality.[49] (Daniel Wahl)

Thus, regeneration appears compatible with mātauranga Māori in that humans as part of nature is assumed.

Agriculture is well positioned to rediscover and further develop regenerative practices. Other economic activity, for example manufacturing, struggle to achieve sustainability or carbon neutral status. Rare examples are Interface Carpets in the U.S. and EcoStore in New Zealand.[50] Interface have taken decades and are now nearing carbon zero status.[51] With effect management farms can move beyond zero carbon status.

"Regenerative agriculture" is used here to include all relevant farming methods such as organic, biodynamic, biological and tikanga Māori.

Agriculture's key pathway for regeneration is enhancing photosynthesis and supporting a benign soil environment to increase the amount of carbon stored in the soil. Additional soil carbon creates multiple benefits including improved soil structure, leading to better water retention and drainage, improved soil chemistry and biology, leading to improved plant health and consequently animal and human health. These benefits scale up to improve catchment resilience. Increasing soil carbon can grow topsoil. [52] [53]

3.4. Soil carbon sequestration

Of the planet's global carbon stocks, the majority, 39,000 gigatonnes (GT), or 93% is in the oceans. Soil contains more than half of the remainder (1,580 GT, or 3.77%). The atmosphere and vegetation contain 750 GT (1.79%) and 610 GT (1.45%) respectively. Since the industrial revolution, an estimated 50 to 100 GT of carbon have been lost from the soil to the atmosphere.[54] If that carbon was lost from the soil, it must be possible for it to be, at least, restored.

The presence of carbon enables the transformation of minerals into soil to then sustain plant life. Over 200 million tonnes of sediment bearing about 4.8 million tonnes of carbon washes into the ocean from New Zealand every year.[55]

Carbon is incorporated into soil when plants capture carbon from the air by photosynthesis. Most of the carbohydrates produced are incorporated into plants with some exported to the soil via the soil microbiome.

David Johnson of New Mexico University has demonstrated that photosynthetic capacity can be increased with careful crop husbandry. He claims that the intensive production (IP) system developed at their research centre for crops…

> has the capability to absorb current total anthropogenic CO2 emissions (30,398 million tons CO2/year) through adoption of year round IP production on 17% of the world's arable cropland or through the growth and incorporation of ~4 tons/acre dry biomass on cropland worldwide.[56]

Pasture is also widely acknowledged for its potential to sequester carbon. [57] [58] A meta-analysis of 74 publications identified changes in soil carbon stocks between pasture, plantation, native forest and crops. Land converted from pasture to plantation lost 10% of soil carbon and from pasture to crops lost 59%. Conversely, converting from crop to pasture increased soil carbon by 19% and native forest to pasture, 8%.[59] Project Drawdown calculates that we need to reduce emissions of, or sequester 1049 gigatonnes of CO2 equivalents by 2050. Of the 80 solutions it proposes, 31% are from the food system. Solutions include silvopasture (ranked 9th) regenerative agriculture (ranked 11th), conservation agriculture (ranked 16th) tree intercropping (ranked 17th) and managed grazing (ranked 19th).[60]

The co-existence of pasture and herds of large ruminants over millennia, created deep, carbon rich soils, such as the North American prairie.[61] In New Zealand approximately 50% of our land cover is pasture and interaction with ruminants can produce a similar beneficial dynamic.

It should be noted that science around soil carbon is contested in New Zealand, with some advocating that it is in equilibrium in the soil and levels can't easily be increased[62]. Conversely the New South Wales Government[63] and the French organisation 4 per 1000 [64] advocate soil carbon sequestration. On 14 March 2019, the Australian Government paid out the first carbon credits for carbon sequestered on an Australian farm.[65]

3.5. Regenerative practice in Tai Tokerau

Five case studies of farms in Tai Tokerau reveal regenerative practices.[66]

Farms are characterised by the exclusion of artificial fertiliser and diminishing use of natural fertilisers. Those used include fish fertiliser, lime and dolomite, seaweed and efficient microorganisms (EM).
Soil health and fertility is promoted by diverse pasture species, leading to greater microbial activity.[67] The soil microbiome flourishes in the

absence of agrichemicals and agriceuticals. Macro invertebrates also thrive in their paddocks. Alistair Crawford's farm is approaching a large population of dung beetles which rapidly recycle cow manure.

Figure 3: Dung beetle activity on Alistair Crawford's farm. Note the casts in the lower right of the image.

This biological activity combined with diverse pastures and managed grazing builds soil structure leading to improved infiltration of rainfall and better soil moisture retention. Alistair Crawford has noticed that when rain comes after dry periods, water quickly drains off neighbours' farms indicating soils are more compacted, while drains from his paddocks are still dry, confirming that the best place to store water is where it lands. He reported that his farm is notably greener in droughts. Infiltration capacity is especially important when the first rains come to break dry spells.

Pasture diversity also promotes animal health by providing dietary diversity. Case study farmers reported decreasing dependency on veterinary services, to the point where they were only needed for compliance purposes and stock injuries. Important reductions were in the use of antibiotics and drenches. Two farmers used homeopathics extensively - a practice often criticised by science.[68 69] Pasture species reported included ryes, various clovers, kikuyu, Yorkshire fog, plantains, dock, and chicory, with one farmer identifying 18 species. A farmer recognised how diversity supports mineral diversity - daisies accumulate potassium, and plantain accumulates silica. One of the farmers, Janette Perrett has published a book, *You Have Been Given a Gift*, about her experiences as a dairy farmer.

> To be able to administer the correct homeopathic solution the correct diagnosis is very important. Ultimately, we found ourselves reading the animals with so much more empathy and awareness of the situation that requires treatment. For mastitis we now had several solutions we could use depending on the description of the mastitis at the time. There was no 'one jab fits all' regime like we were used to. We now had to look and feel all the symptoms; her temperature, what side she laid on, was she eating, was the udder cold, how is she walking, did the symptoms appear suddenly? We learned to paint a picture of the disease and look at the cause as well as symptoms (Janette Perrett p. 59 to 60).[70]

Figure 4: Australian soil scientist, Dr Christine Jones examining Linda Matson's pasture and soil at her Maungatapere farm.

Pasture management is a continuing challenge. Regenerative farmers aspire to longer grazing rotations as advocated by Allan Savory[71] and Gabe Brown.[72] Adapting principles for dryland grazing to New Zealand requires a lot of observation and learning. Factors of pasture composition and growth, climatic conditions and seasonal changes combine dynamically to continually challenge farmers striving to lengthen grazing rotations.

Figure 5: Pasture ready for grazing (left) and post grazing with 2-year-old heifers on the Matson farm. (Photo credit, Linda Matson).

One of the farms studies used a "techno-system". So far 164 hectares are strip grazed with the stock moved every two days, up and down lanes of pasture. Staff use labour-saving ways to shift the stock - they use electric fencing and modified quads to be able to run over the top of the fence, catching the wire in a boom on front of the bike so the wire slides underneath on skids. This method approaches Allan Savory's method of intensive grazing by moving stock on quickly, so the pasture is not grazed too hard. The manager commented that the pasture recovers much more quickly and the system is controlling a problematic weed. The network of regenerative farmers is still small with many geographically isolated, but what impresses, is their intense learning. They keep pasture management records, rely heavily on observation and experimentation and are open to learning.

> We said farewell to chemical fertilisers, antibiotics and a bucketful of 'cides'; insecticides, pesticides, herbicides and fungicides. We were not going to kill anymore. We were going to walk alongside mother nature and learn her ways much as possible (*Janette Perrett*, p. 58).

3.6. Soil and carbon

The thin mantle of soil that feeds us evolved. Carbon is both the catalyst and essential ingredient of soil formation. Devoid of carbon, mineral rock cannot sustain diverse plant life, but as photosynthesis and microbial activity supports carbon accumulation, and where conditions are favourable, soil development begins. Plant life depends on the combination of photosynthesis derived sugars and minerals mined by chemical, physical and biological weathering. Lichen, growing on rock or plastics (e.g. spoutings) illustrates how this happens. It is a composite organism photosynthesizing from its algal nature and extracting minerals from its fungal nature.

Soil development is evident at the coast. At high water mark the sand is mostly devoid of carbon, but progressing inland, first crossing dunes, the pioneer plants begin the process of carbon accumulation through photosynthesis. Further inland, other species colonise, and the soil becomes darker, evidencing carbon. Thus, soil builds.

As one of nature's ecosystem services, the value of soil is hard to quantify, yet we sometimes call it dirt. For almost all human communities, soil is essential to life. In addition to the food it provides, soil enables the plant life that transforms our landscapes making them more hospitable and aesthetically pleasing.

The focus on soil organic carbon (SOC) in this project is its sequestration potential. Only with growing concern about climate change has this been considered of value. The accelerated development of the science of chemistry in the nineteenth century shifted the focus of food production toward chemical deficiencies setting it on a trajectory that persists today. Alternative agricultural methods emerged evidenced by the pioneering work of those such as Sir Albert, Gabrielle and Louise Howard. Howard's book *An Agricultural Testament* in 1942[73] sought an integration of pre-industrial agriculture with insights from science. This knowledge has been implemented around the globe under the guise of designations such as organic, biodynamic, biological and regenerative agriculture, by the farmers and growers arguably most interested in the dynamics of soil.

Benefits of soil carbon

In addition to carbon sequestration, soil carbon:

- Develops soil structure, providing improved infiltration, drainage and retention of water, makes the soil more resilient to compaction and erosion.
- Improves water quality through reduced nutrient loss and sedimentation.
- Enhances soil nutrition leading to improved plant growth and health.
- Enhances human health based on the consumption of healthier animal and plant products.

SOC-centred regenerative practices could not only mitigate greenhouse gas (GHG) emissions but also provide multiple benefits such as enhancing food security and farm income, reducing poverty and malnutrition, providing essential ecosystem services (climate and hydrological regulation, biodiversity maintenance, and nutrient cycling, among others), contributing to the achievement of the Sustainable Development Goals (SDGs) and building resilience to extreme climatic events. (Food and Agriculture Organisation)[74]

In addition, those that focus on soil health, develop agricultural practices that lead to a reduced need for external inputs, including artificial fertilisers, agrichemicals and agriceuticals. Use of these chemicals is linked to human health issues,[75] species degradation,[76] (including pollinators),[77] and environmental degradation.[78]

Carbon zero or carbon balance?

Carbon zero is a misleading aspiration. Carbon balance is more desirable. Human activity has distorted the carbon cycle through the burning of fossil fuels and the degradation of ecosystems, so carbon that should be sequestered deep in the planet or in soil and vegetation is now in the air and ocean.

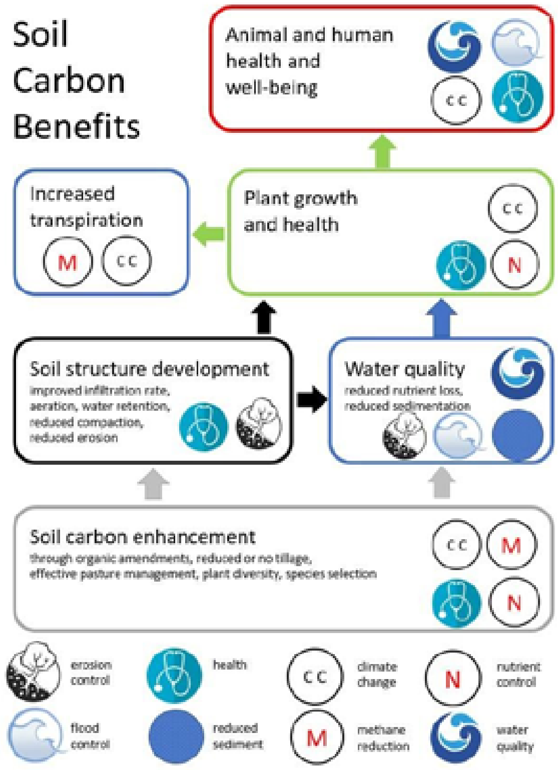


Figure 6: Soil carbon benefits

"Farms are seeing soil carbon levels rise from a baseline of 1 to 2 percent up to 5 to 8 percent over ten or more years, which can add up to 25 to 60 tons of carbon per acre" (Hawken, 2018, p 55). A New Zealand study postulates that increasing our 11 million hectares of pasture by 2 gms of carbon/ kg of soil would increase carbon by 66 million tonnes (0.07 gigatonnes)[79]. If 5.28% of pastoral land was under effective soil husbandry, sequestering just 1% of carbon in a modest 10 cm soil profile, this achieves the 582,682 tonnes of additional carbon, offsetting Northland's agricultural emissions[80]. For context, New Zealand's gross emissions in 2016 were 78.73 million tonnes of CO2 equivalents.[81]

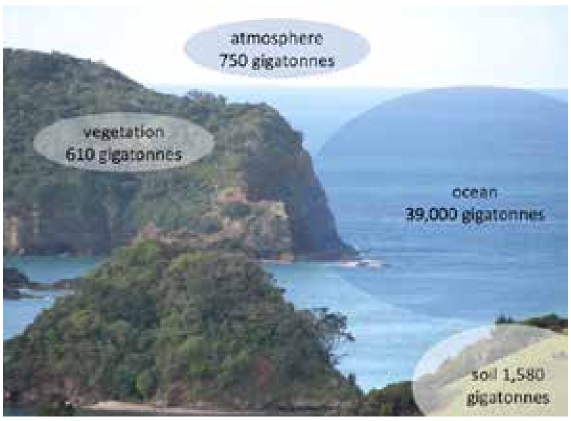


Figure 7: Global carbon sinks

3.7. The politics of soil carbon

In New Zealand, agriculture is positioned as problematic, with the narrative focusing on when agriculture will be brought into the ETS. This narrative is supported and reinforced by Government publications such as the *Low Emissions Economy* that calls for more trees and fewer livestock.[82] In July 2019, the Ministry for the Environment released *Action on Agricultural Emissions*,[83] to seek feedback on two options. The first was pricing livestock and fertiliser emissions at the processor level via the Emissions Trading Scheme (ETS). The second was a formal sector government agreement to support reductions in farm emissions. The first option had potential to penalise those farmers who are already actively sequestering carbon and reducing emissions.

In the same month, a coalition of the primary sector including Beef + Lamb, Dairy NZ, Horticulture New Zealand and the Federation of Māori Authorities published *He Waka Eke Noa: Our Future in Our Hands*.[84] In recognising our commitments under the Paris Agreement, the document announced an intention of work in partnership with the Government.

> The primary sector will work in good faith with government and iwi/Māori to design a practical and cost-effective system for reducing emissions at farm level by 2025. The sector will work with government to design a pricing mechanism where any price is part of a broader framework to support on-farm practice change, set at the margin and only to the extent necessary to incentivise the uptake of economically viable opportunities that contribute to lower global emissions. The primary sector's proposed 5-year programme of action is aimed at ensuring farmers and growers are equipped with the knowledge and tools they need to deliver emissions reductions while maintaining profitability.

The Government accepted this document while retaining the option to legislate if the proposed voluntary actions fell short of targets. Thus, we now have an opportunity to promote regenerative agriculture as a strong option for both emissions reductions and sequestration.

When land management practices change, the IPPC uses 20 years as a default period to elapse before soil carbon reaches a new equilibrium.[85] Thus, soil carbon sequestration is a good option for rebalancing the nation's carbon footprint.[86] Other strong options, such as electrification of the vehicle fleet will take decades, even if all annual imports of light vehicles were electric vehicles.

3.8. Citizen science

Evaluating soil data methods for sample selection and analysis is based on their validity and reliability. There is another layer of criteria for this project. Methods will ideally *be open source or inexpensive and designed to empower farmers' decision making*. Farmers work in complex environments, striving to keep animals healthy and productive, while coping with weather, soil, pasture and the wider social environmental dynamics. Especially in Tai Tokerau where soils are so diverse, each farm can create a unique manifestation of these dynamics and thus the farmer ideally becomes the expert on that land, immersed in annual cycles of observation, hypothesis and experimentation.

Agribusiness has evolved to extract value from primary producers. Transforming agriculture will also require transformations of economic and social systems away from predatory extractive practices (for example, banking[87] and government). [88] Jeremy Rifkin's vision outlined in the *Zero-Marginal Cost Society*[89] and that of Otto Scharmer in *Leading From the Emerging Future*[90] illustrate how we can create an environment based on co-creation rather than extraction. A characteristic of this will be the increasing democratisation of open-sourced knowledge and design, enabled through the commons, displacing proprietary knowledge that is only accessible through commercial pay walls.

This future is illustrated, in the context of this project, by the people from the our-sci.net website. They intend to "support the development of research capacity in communities through software, hardware, and training".

> Any community is capable of solving even the hardest problems using their own skills and resources. The cornerstones of successful community research is comparability of data and methods, validation of tools and people, scientific quality instrumentation, and a collaborative and equitable process. We focus on these as core design criteria to advance science and research in the real world.[91]

Their work includes a hand-held reflectometer for testing soil in the field, linking to soil metadata. The design for hardware and software is opensource and available through a GitLab.[92]

3.9. Measuring soil carbon

Measuring soil carbon is both complex and problematic. In New Zealand, some have identified soil carbon sequestration as a quantifiable option, but the prevailing view has been that carbon is in equilibrium in the soil, or too difficult to quantify. Without a pathway to resolve this disjuncture, we restrict options for mitigating agricultural emissions. Forests and reducing pastoral agriculture are favoured options advocated by influential government advisors, further positioning farming as a problem.[93]

The complexities are largely about the dynamic interaction of factors such as soil type, topography, plant species, soil moisture status and microbial activity. This is further complicated when we attempt to measure soil carbon. To what depth should we measure? How extensive and frequent should our sampling be, and what methods of analysis should we use? These questions are critical with the possibility of farmers being paid carbon credits as is now happening in Australia.[94]

The recently published paper, *How to measure, report and verify soil carbon change to realise the potential of soil carbon sequestration for atmospheric greenhouse gas removal* summarises the measuring/monitoring, reporting and verification (MRV) of soil carbon stocks. Many variables are discussed throughout the paper. The growing response to the climate crisis has accelerated interest in soil carbon sequestration resulting in increased research in soil carbon and innovations in its measurement. Here is a brief summary of some measurement options.

The image below from Manaaki Whenua Landcare Research reveals variations in soil carbon between 2.6 and 11.8% in an area of approximately 1.6 hectares.[95]

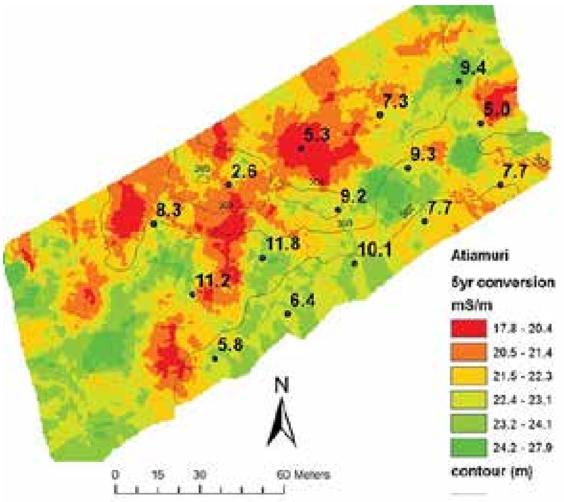


Figure 8: Soil electrical conductivity map showing soil C content [numbers on map] varying between 2.6% and 11.8% in a paddock where pine forest has recently been converted to pasture.[96]

IPCC Measures

The IPPC outlines good practice for quantifying carbon in two key documents.

- *2006 Guidelines for National Greenhouse Gas Inventories*
- *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol*

The 2006 Guidelines were updated in the *2019 Refinement to the 2006 Guidelines for National Greenhouse Gas Inventories*. Volume 4 covers agriculture, forestry and other land use[97]. Soil organic carbon (SOC) estimation methods are covered in section 2.3.3.1 of chapter two of volume four. They are based on modelling and the assumption that land management changes will produce a linear change in soc levels until equilibrium is re-established in 20 years. The 2013 document outlines a similar approach.

> Ideally, the management of each land would be tracked explicitly. But such data may not always be available. An alternative approach may be to estimate the average history of lands and soil now under a given management (page 2.56)[98]

Both documents point to emerging scanning technologies to assist greater resolution of soc variations. For example, terrestrial laser scanning can quantify vegetation structure, but not estimate soil carbon. In this case carbon in vegetation is more accurately quantified and will provide more accurate modelling for the estimation of SOC.

The IPCC methods appear more suited to regional or national level carbon accounting. The Ministry for the Environment's webpage on measuring soil carbon links to these IPCC guidelines.

The 4 per 1000 initiative

A major study investigating the potential of achieving the 4 per 1000 carbon sequestration goal established at the 2015 COP 21 Paris, reported on sequestration potential for 20 countries including New Zealand. The report found the 4 per 1000 goal was achievable but variable based on factors such as soil type, temperature and latitude. New Zealand has relatively high soil carbon stocks, but has potential for sequestration through "Improved management of grasslands; increased root inputs of C; targeting specific soil types (e.g., allophanic soils), and/or specific landscape positions; establishment and reestablishment of wetlands."[99]

Notably the report recommends starting sequestration initiatives immediately, as initial results can be scaled up quickly and buy time as other options for sequestration and emission reductions are implemented. The 4 per 1000 initiative has no apparent MRV protocols.

Twenty-one countries or territories had committed to the consortium by 2017. Global organisations, including the Food and Agriculture Organisation (FAO) and the International Fund for Agricultural Development (IFAD), development banks and foundations signed up, as did many agricultural organisations, research institutions, NGOs and commercial companies.[100]

Australian protocols

The *Carbon Credits (Carbon Farming Initiative) Act 2011* made provision for credits for emissions reductions and carbon sequestration in soil or vegetation. These provisions were further developed with the establishment of the Emissions Reductions Fund.[101] The methodology determination was developed with version 1.0, *The Supplement to the Carbon Credits (Carbon Farming Initiative—Measurement of Soil Carbon Sequestration in Agricultural Systems) Methodology Determination* published in 2018.[102] At 48 pages, this document outlines detailed requirements for sampling locations, sampling methods, analysis and validation. The document requires either dry combustion analysis or spectroscopic modelling. For spectrometers, three levels of wavelength are specified.

India

The work of Subhash Palekar has inspired the establishment of Zero Budget Natural Farming (ZBNF) across India. Industrial food systems with its heavy reliance on agrichemicals and synthetic fertilisers led to negative externalities across food system stakeholders. These included contaminated groundwater, reduced soil fertility, biodiversity loss and high levels of farmer debt. The ZBNF system is based on four practices: Seed treatments using cow dung and urine-based formulations, the use of cow dung and urine for fertility, mulching and water vapour condensation. These practices promote soil biology as the driver of fertility. In 2015, the Government of the state of Andhra Pradesh set up an organisation to introduce ZBNF to all farmers. Notably the programme is referenced to all 17 of the United Nation's Sustainable Development Goals.[103]

Figure 9: ZBNF four practices, p. 2. [104]

ZBNF aligns science and tradition. “Its greatest strength is that it is based on the latest scientific discoveries in Agriculture, and, at the same time it is rooted in Indian tradition.”[105] Dr Vijaya Kumar states that women are more receptive to trialling ZBNF. ZBNF promotes that farmers are citizen scientists and the programme is grass-roots rather than government-led[106]. The programme is also promoted as a climate resilience initiative, but quantifying sequestration seems secondary to the many co-benefits of increased soil carbon.[107]

New Zealand

Agencies such as Manaaki Whenua - Landcare Research and the New Zealand Agricultural Climate Greenhouse Gas Research Centre are working on soil carbon projects. A 2014 paper acknowledged New Zealand’s reporting commitments and explored options for modelling based on variables such as land use, soil and climate classifications, and erosivity.[108] A current Landcare and Waikato University research project is developing methods for determining soil carbon at farm level in New Zealand.[109]

A 2010 Manaaki Whenua - Landcare Research report identified four main groups of soil carbon determination methodologies:

- conventional approaches using lab analysis of soil cores
- direct measurements of ecosystem carbon exchange
- emerging technologies such as infrared sensing instrumentation
- developing technologies based on laser spectroscopy and other methods using radioactivity[110].

Their summary of these methods finds that conventional methods are reliable with established protocols, but very expensive if scaled up. Significantly, they recommend automated dry combustion as a preferred method of laboratory analysis.

Newer methods of SOC determination are combining data streams and modelling. According to Steve Vanek:

> Accurate modelling of soil carbon accumulation or decline is . . . probably the best way to get going right now on assessing and motiving carbon capture in soils, combined with all the other data streams over time to improve the models over time.[111]

As more information is incorporated to further refine models, those models will become more accurate and reduce the need for costly and time-consuming sampling. Districts and regions in New Zealand will want to calculate carbon footprints and identify land management practices that sequester soil carbon.

Chemical methods

New Zealand research in publication has identified the hot water extractable carbon (HWEC) and cold-water extractable carbon (CWEC) tests to be the most reliable of those tested.[112] This project uses Hill Laboratories’ orthodox methods of sampling and analysing soil carbon and other attributes, including HWEC, but will also test newer or less expensive methods to calibrate them. Methods identified so far are chemical kits, and light mediated analysis.

Chemical kits

A U.S. study found chemical test kits to be "not very precise". These kits were testing N, P and K, and not carbon.[113] They work in a similar manner to pH test strips or solutions.

Light mediated analysis

There are a variety of devices that use the light spectrum and properties of light to analyse soil. These include a hand-held reflectometer from Our-sci.net that correlates the UV/VIS/NIR spectra to soil organic carbon.[114] Manaaki Whenua - Landcare Research [115] and electromagnetic mapping to determine SOC at paddock scale (see figure three)[116] Light mediated devices integrate with datasets, often specific to a location or country, thus creating complexities for field testing. Over time, the further development of these technologies in combination with mobile phone technologies will simplify their use.

Measuring the soil biome

Soil organic carbon is a component of soil organic matter that is processed by the soil biome. The measure discussed above quantify the carbon content of the soil, but quantifying the biome indicates the health of the soil and its ability to continue to generate carbon resources. Several methods are available including visual soil analysis, respiration tests and the microbiometer.

Visual soil analysis (VSA)

The VSA is a New Zealand resource used for field assessment of physical, biological and chemical qualities of soil. Earthworms and other macro-organisms and clover nodulation are assessed. Visual assessment can include the agglomeration of the soil biome on roots. The second edition of the field guide includes environmental scorecards for nutrient loss, carbon sequestration and greenhouse gases.

Figure 10: Root - microbiome association on a kikuyu root

Respiration tests

Soil biome activity is evidenced by respiration of CO2. A U.S. study identified the Solvita[117] Field Respiration Test as having the highest correlations with laboratory tests.[118]

Brix refractometer

The Brix refractometer test measures predominantly the percentage of sucrose in plant sap or fruit juice. This measure will include all other soluble compounds in the sap or juice solution, and could include fructans, minerals, proteins, lipids, pectins and acids, thus providing an indication of nutrient density.[119]

Nutri-Tech Solutions microBIOMETER

The microBIOMETER is a low-cost in-field tool for measuring microbial activity of soils and microbial amendments. It uses a solution and test card that is interpreted by a smart phone app. A numerical rating of the microbiome ranges from <200 (very poor) to >500 (excellent). An advantage of field testing is the avoidance of time delays that impact the quality of the sample.

Measuring soil structure and properties

Carbon dramatically influences soil structure. There are, for example, correlations between soil carbon levels and the infiltration rate of water into the soil. Methods selected here are the VSA (discussed earlier) and an infiltration rate test.

Infiltration rate

Soils with fast infiltration rates reduce risk of flooding as water infiltrates the soil reducing runoff. They are also more drought resistant, as rainfall that enters the soil is more likely to be stored there. Surface compaction and the loss of soil carbon increases the soil's susceptibility to cycles of flooding and drought. The Food and Agriculture Organisation has a protocol for an infiltration test.[120]

Measuring temperature?

Given that many are advocating measuring soil carbon to potentially reward drawing down carbon, perhaps a more direct, accurate and less expensive measure would be temperature? Walter Jehne reports that significant cooling can be achieved locally and regionally. This is supported by the work of Willie Smits who reported that when deforested land in Borneo was regenerated back to forest, the region's climate was significantly cooled, and rainfall resumed its earlier patterns.[121]

3.10. Summary of methods

Method	Ease of use	Empowerment	Cost	Comments
Chemical kits (e.g. Soils1 kit)	2	2	$87 (discounted)	Chemical testing. Level of accuracy for carbon testing is probably low.
Light mediated, e.g.	1	3	still under development	F[122]rom Quick Carbon and our-sci.net. "Quick Carbon's research mission is to create an accessible measurement system that empowers individuals to generate reliable soil carbon data for ecological understanding, decision making, and markets."
Visual Soil Analysis	2	3	$50 (excluding GST)	From Bioagrinomics. Updated guide has environmental scorecards including a soil carbon assessment tool.
Microbiometer	2	2	$352	From Nutri-Tech Solutions in Australia. A simple test kit to provide an indication of the microbiome for soil and amendments.
Respiration tests (e.g Solvita)	1	2	$2,700 plus freight (Master Kit)	The Solvita Kit (U.S.) samples and measures soil microbial respiration. Noted to be accurate.
Infiltration rate	2	3	Can be made for minimal cost[123].	From the Food and Agriculture Organisation. The infiltration rate is a good indicator of catchment resilience and soil structure.

Table 1: Summary of selected soil data measures
Key for Ease of use: 1 = complex, 2 = moderate, 3 = easy
Key for Empowerment: 1 = low, 2 = moderate, 3 = high
Costs are expressed in $NZ. Currency conversions as at 13.01.2020

3.11. The hydrological cycle

Walter Jehne claims that CO2 only accounts for 4% of the influences driving the climate. The hydrological (water) cycle accounts for 95%.[124] By clearing 70% of the world's primary forests, oxidising soils and creating five billion hectares of desert, we have degraded the hydrological cycle. Our activity has also created humic hazes that prevent heat from escaping into space, especially at night.

This suggests that a singular focus on sequestering or reducing emissions of CO2 compromises the impact we might have. Fortunately, building soil carbon is effective for both sequestering carbon and enhancing the hydrological cycles.

> Over the past 10,000, but particularly past 300 years we have cleared and burnt forests, oxidised soils and created over 5 billion hectares of man-made desert. This has greatly altered the capacity of over 70% of the land surface to; infiltrate and retain rainwater, shade, cool and protect soil surfaces from solar heating and erosion and sustain its former transpiration, cooling and cloud dynamics[125]. (Walter Jehne)

Walter outlines three major strategies to reverse this trend, directly cooling the climate, sequestering carbon and reinforcing the resilience of natural and agricultural biosystems. He names soil "the carbon sponge", noting that every gram of carbon can retain up to eight grams of extra soil water. Carbon improves the infiltration and retention of water making carbon rich soils "in-soil water reservoirs". Healthy carbon rich soils promote plant growth, and the engine of plant growth and all food production, photosynthesis. Walter Jehne explains that water transpired from plants creates cooling as it requires almost 600 calories to transpire a cubic centimetre of water. Consequently, tropical forests can be up to 15 oC cooler than adjacent cleared areas and forested urban areas in Canberra, up to 7 oC cooler than similar areas without trees.

3.12 The interface of mātauranga Māori and regenerative farming

Earlier we outlined aspects of mātauranga Māori relevant to agriculture. This section explores some specific practices that evidence the interface.

Pre-European carbon farming

Before carbon sequestration was a thing, there is evidence that Māori had agricultural practices that deliberately built soil through the mineral and organic amendments. Early tribes of the northern South Island, Waitaha and Rapuwai enhanced the natural fertility of soils with the addition of organic materials, ash, sand and fine gravel. On the Waimea plains over 400 hectares of soils were altered. Borrow pits up to two metres deep from which selective grades of gravel were extracted can still be seen today. Radio-carbon technology dates these gardens back over 500 years.

> These ancient Māori garden sites have long been recognised as the most fertile soils on the Waimea Plains. Even after sixty years of European cultivation, farmers in the 1920s who were situated on the 'Māori soils', required only a fraction of the added phosphate, potash and lime needed on the neighbouring 'natural' soils.[126]

The amendments made required significant labour and the transport of raw materials. The improvements to the soil increased their heat absorption, drainage and fertility. Large stones were also used to absorb heat during the day to be slowly re-radiated at night to keep the soil warm. These soils are reminiscent of the terra preta soils of South America, developed by the indigenous people and persisting for centuries.[127]

In a 1923 edition of *The Journal of Polynesian Society*, authors T Rigg and J.A. Bruce, comment on the quality of these soils and suggest manuka ash as the tree is a rich source phosphates, potassium and calcium.[128]

Biodynamics

Biodynamics can be regarded as a type of regenerative farming practice in that it focuses on the health of the soil. Some of its practices appear to interface with concepts of mātauranga Māori discussed earlier, such as mauri [life force, essence] and wairua [spirit or soul]. Biodynamics originated with a series of lectures to farmers by the German Rudolf Steiner in 1924, just a year before his death. Dr. Steiner warned of the excesses of Western civilisation stating that it would gradually bring "destruction to itself and the earth if it did not begin to develop an objective understanding of the spiritual world and its interrelationship with the physical world".[129]

Steiner's work has created innovations in many fields, including education, banking, medicine, psychology, the arts and agriculture. His work is based on the harmonisation of diverse worldviews, the spiritual, scientific, philosophical and cultural. He acknowledges a wisdom in rural peasants (meaning farmers) that demands their respect rather than their subjugation by material philosophies. Written over 100 years ago, this passage expresses regret for the passing of that collective wisdom.

> When I was a young man I had the idea to write a kind of "peasants' philosophy," setting down the conceptual life of the peasants in all the things that touch their lives. It might have been very beautiful. . . A subtle wisdom would have emerged a philosophy contained in the very formation of the words. One marvels to see how much the peasant knows of what is going on in Nature. Today, however, it would no longer be possible to write a peasants' philosophy. These things have been almost entirely lost. It is no longer as it was forty or fifty years ago. Yet it was wonderfully significant; you could learn far more from peasants than from the University. ... It was a kind of cultural philosophy.[130]

Biodynamic farming practice incorporates principles similar to the maramataka, guided by the influence of the stars and the moon. To impart biodynamic preparations into water, farmers use the vortex motion mimicking the vortices found in waterways. The liquid is stirred in one direction, creating a vortex and then in reverse, creating chaos before the new vortex develops.

The efficacy of bio-dynamic practices are hard to analyse using reductive science. Often, as with homeopathics, there is no measurable active ingredient. However, biodynamic farming works well for biodynamic farmers.

Nature, the multidisciplinary journal founded in 1869, has third and fourth rank in the *Scimago Journal and Country Rank.*[131] In 2018 it published a report comparing a biodynamic and organic farm with two conventional farms observing a 40.2% reduction in N2O emissions per hectare in the organic farms. Contributing factors besides nitrogen were pH, organic carbon and microbial biomass. The study concluded that "organic farming systems can be a viable measure contributing to greenhouse gas mitigation in the agricultural sector".[132]

3.13. Conclusion

Rebalancing soil carbon stocks between soil and air is a strong option for climate change mitigation. With nations now addressing the complexity of carbon accounting, global interest is mounting in measuring/ monitoring, reporting and verification of soil carbon stocks. Often these measures are at a macro level, based on broad variables such as vegetation, soil type, climate and landform.

In 2019, the New Zealand Government moved away from imposing levies at food processing to accept the logic of measuring carbon at farm level. This allows for consideration of farm management practices – a variable not possible at the macro level, and provides an incentive for innovation. Regenerative farmers are well positioned to respond.

Ideally there will be IPCC sanctioned methodologies for soil carbon MRV, but that may take some years to eventuate. Fortunately, in addition to climate mitigation, soil carbon has many co-benefits. While we wait for soil carbon MRV protocols, we can help to improve knowledge of soil carbon and its co-benefits and experiment with methodologies that support farmers as citizen scientists. The best outcome will be cash credits for building soil carbon stocks. A lesser benefit would be the change in public perception about farming, accompanied by an abandonment of indiscriminate punitive levies or taxes. But failing this, farmers who learn to maximise soil life and carbon will enjoy the co-benefits that lead to reduced inputs and improved food quality.

There is further potential in better understanding the impact of the hydrological cycle as outlined by Walter Jehne. The advantages that he points to align nicely with the aspiration to sequester carbon.

Any of these solutions can only be enhanced by paying more respect to mātauranga Māori and bringing back this knowledge from the margins to the centre of our thinking.

Figure 11: The biodynamic vortex[175] and the pounamu koru[176]

4. Methodology

This section outlines our research intentions and what actually happened.

4.1. Dynamic methodology

Our initial intention for this project was to use community based-participative research and kaupapa Māori methodologies. Community-based participatory research has emerged from the humanities and from Lewin's Action Research.[133] It is now showing up in food system related research. "A key element in the transformation of the food system is how we share and create new knowledge that supports this transition towards a food system that delivers good food for all."[134]

It is more an approach to research rather than a method. The researchers are members of the community and probably involved in the community in roles other than their research roles. Participants are not subjects, but collaborators in the research process. In pursuing reciprocity, respectful relationships, shared power and operating from a humble posture of learning, researchers seek to be part of a process that builds local capacity and to foster reflexivity. Researchers and the community learn from cycles of research, action and reflection.

While the two NorthTec researchers are not members of the Takahiwai community, there is a kinship through whakapapa and their connection to the Northland region.

CBPR challenges researchers to listen to, learn from, solicit and respect the contributions of, and share power, information, and credit for accomplishments with the groups that they are working with.

Our intended research approach: Kaupapa Māori research

Māori are wary of researchers objectifying Māori "in the same way a scientist looks at an insect"[135] (Linda Tuhiwai Smith, page 58).

As the participants are Māori, consideration of Kaupapa Māori research is essential. Te Awekotuku (cited in Palmer,)[136] stated that ideally, people researching Māori should be Māori and of the same tribe. This acknowledges specific and distinct epistemologies, not just of Māori, but of distinct tribes. The range of parameters for Māori Kaupapa research outlined by Smith and Palmer are daunting. They are designed to keep research participants safe, and to resist colonising epistemology.

In respect of Kaupapa Māori, the following design elements are included in the research:

1. The researchers sought kaumātua guidance.
2. The proposal was approved by the Unitec Research Ethics Committee.
3. The research will be conducted in a spirit of partnership between researchers and participants.
4. Participants will be selected from the researchers' and participants networks and will be people with established relationships.
5. An appreciative enquiry focus anticipates surfacing positive insights that will contribute to the development of Māori communities.
6. One of the NorthTec researchers whakapapa's to Northland Iwi and the second is an associate member of Te Runanga o Ngāti Pū through marriage.

4.2. Our intended research approach: Soil science

Protocols for some soil tests are well established. For example, our intention was to use Hill Laboratories for soil carbon analysis. More details follow.

4.3. Kaumātua interviews

The process of connecting with kaumātua happened at the proposal stage of the project. Peter Bruce-Iri contacted Dr Benjamin Pittman, (Ngāpuhi: Ngāti Hao – Te Popoto; Te Parawhau; Ngāti Hau), who recommended that Peter contact Mira Norris of Te Parawhau, who in turn referred him to Dr Mere Kepa (Ngāti Whātua, Te Whakatōhea, Te Whānau ā Rūtaia, Ngāpuhi, and Ngāi Tūhoe) at Takahiwai. After a series of informal hui with Dr Kepa, Takahiwai was selected as a site for the project.

The project was blessed by having access to kaumātua who are deeply connected to the whenua in the sense of whakapapa, role and responsibility to their whānau [a group of extended family]. Both of them hold a doctoral qualification. Dr Mere Kepa has retired from the University of Auckland but remains an active researcher. Dr Benjamin Pittman is actively involved with the artistic community in Tai Tokerau and is the Chair of Creative Northland.

Dr Kepa's guidance around both mātauranga Māori and research methodology was invaluable. Peter would suggest that interview participants would be identified by "snowballing". Mere gently insisted it was whakawhanaungatanga [making connections through kin relations].

The interviews with kaumātua aimed to inform the development of the bi-lingual narrative referred to in the fifth project objective and to further iterate the research co-design for subsequent interviews.

> 5. Produce an evidenced based, bi-lingual narrative around the intersection between Māori approaches to farming and regenerative farming, and the potential of regenerative farming practice to improve soil health.

The project aspired to use a range of parameters for Kaupapa Māori research outlined by Dr Linda Tuhiwai Smith.[137] They are designed to keep research participants safe and to resist a colonising epistemology. For this project, the two Takahiwai kaumātua, Dr Mere Kēpa and Dr Benjamin Pittman have guided and mentored the research and the research team. Catherine Murupaenga-Ikenn (Ngāti Kuri, Te Rarawa) was the lead researcher for intercultural conversations.

The research questions were developed first as draft questions and provided to the kaumātua before the interview for their input.

Questions are:

1. What is your connection with this whenua?
2. What do you recall about how the land was farmed for animal and plant produce?
3. What do you perceive to be the values that guided food production here?
4. What have you noticed about changes to the state of the environment here over the decades?
5. What do you observe about farming practices now, compared to what you observed as a young person?
6. Assuming that most contemporary farming is grounded in Western science, what concepts or practices, if any, are shared by Western science and mātauranga Māori to restore health to the soil?
7. Regenerative farming methods include those of organic farmers, biodynamic farmers, biological farmers or those guided by tikanga. What concepts, if any, are shared by regenerative farming practices and mātauranga Māori to restore health to the soil?
8. Do you have any other comments?

The project was formally launched at a hui at Ruakaka on 13 December 2019. The first kaumātua interview was later that afternoon at Takahiwai. The kaumātua signed the consent forms included in the ethics application. Catherine Murupaenga-Ikenn was the lead interviewer. We had prepared a list of questions, but the interview emerged as a conversation, lightly guided by the occasional prompting question. The interview was not recorded but notes were taken by both interviewers. The interviewers drafted a summary of the interview that was emailed to both kaumātua who suggested several edits and a second conversation. This happened on Friday 24 January. What emerged

was another conversation and an exploration of emergent themes. Again, the interviewers revised their narrative and drafted themes. Further feedback from the kaumātua was integrated into the document. Both interviews were characterised by a sense of collegiality and mutual respect.

4.4. Farmer interviews – Takahiwai and Mata farms

Two farmers were interviewed. A whānau member from Takahiwai owns a farm at Mata and leases whānau land at neighbouring Takahiwai. The project's objectives dictated that one was a regenerative farm. Fortunately, one of the few Māori organic farmers in Tai Tokerau farmed nearby the Takahiwai/Mata farm. As the farms are whānau farms, whānau were invited to participate in the interview.

The semi-structured interview questions were deliberately broad and open.

1. How have you learned to farm?
2. What guides your current practice?
3. What are your aspirations for this farm?
4. Tell us about the barriers that are blocking your progress.

These questions focus on the farming experience. Information about pastoral management practices were gathered alongside soil samples.

4.5 Regenerative farmer interviews

Regenerative farmer interviews were added to the project after completing the soils work. The VSA emerged as a good prospect for soil analysis consistent with the aims of this project. The research team wanted to enquire about what soil testing processes might complement it. Six farmers with a minimum of ten years of organic experience were selected, five from Tai Tokerau and one from Hauraki. Five were interviewed remotely with either video conferencing or phone, and one farming couple were interviewed in person. All interviews were recoded. These were semi-structured interviews starting with the question "What observation have you made on your farm that provides insights into soil quality?". Other questions followed.

4.6. Analysis

The interviews were analysed for common themes and significant points of knowledge. They assisted the project team to glean a shared understanding of the intersection between Māori approaches to farming and regenerative farming and informed the next phase of the project[138].

Data was processed and stored in accordance with the Ethics form. Kaumātua will be asked for permission to record the interviews and photograph them.

4.7. Soil data plan

Purpose

Soil data were obtained to support project objectives 1, 2, 3 and 5 repeated here.

1. Work with kaumātua and landowners in the Takahiwai Kāinga to co-create a research plan to identify indigenous ways of managing soil health.
2. Utilise existing literature, conversations with Māori and Pākehā landowners and field trials to develop basic soil health data from two participating Takahiwai farms.
3. Identify multi-factors and processes that influence soil health on a farm using regenerative methods (e.g. pasture diversity, plant root depth, soil porosity, mycorrhizal associations, grazing intensities, carbon levels, soil microbiome) and compare to a non-regenerative farm.
5. Produce an evidenced based, bi-lingual narrative around the intersection between Māori approaches to farming and regenerative farming, and the potential of regenerative farming practice to improve soil health.

The draft soil data plan was edited and approved by Dr Brent Clothier, the science lead for the project and project kaumātua. The farmers included in the study were also consulted.

Background

The first project objective calls for us to co-design a research plan to identify indigenous ways of managing soil health. On reflection, pastoral farming was not practiced here in pre-European times, and whatever we do will be at the cultural interface of the three influences of mātauranga Māori, Western science and regenerative practice, with the spectre of economic drivers hovering in the background. Hopefully we can reframe this malign influence into a source of oranga [good health, flourishing lives].

How do we bring indigenous perspectives to the fore? The bias of Western science in relation to agriculture is the focus on chemical deficiencies and to overlook soil biology. One of the research team was told by a biodynamic farmer that her daughter is completing an agricultural science degree.

Figure 12: Project farms - The organic farm is bottom centre and the conventional farm is top centre

She told her mum that she has had to write what her lecturers expect, so her knowledge of the magic of soil was excluded.

This focus on soil chemistry manifests in the current practice of farmers, or perhaps strangers, walking on to the whenua and taking samples to be sent off to a lab to be analysed. The soil biology is ignored and there is no acknowledgement of mauri and interconnected nature of the complex and miraculous systems that science can only know so much about. Often those samples are from just the topsoil. A determination is then made of what should be applied to remedy deficiencies. Cynically, this might be influenced by the need to shift stock in a fertiliser yard. Weep for Papatūānuku. We can call this chemical colonisation.

Mātauranga Māori might bring some perspective to the practice. We started these processes with karakia and respect for the mauri of the whenua. Karakia is not just a ritual, it ideally imbues reverence for the land and what it gives us. Ideally an outcome of this project will be to identify the tools that farmers can use to have a more complete knowledge of the soil. The principle here is possibly tino rangatiratanga, with farmers controlling the process rather than being manipulated by agribusiness.

Steps

1. Identifying and mapping farms

In consultation with kaumātua, farms were identified at Takahiwai and Mata. These farms are in the same catchment and both sites have alluvial soils on river flats.

2. Site selections

Sites selected were:

- Organic farm: Pump shed paddock below the house.
- Conventional farm: First flat paddock down the race.

The two chosen sites are 1.66 km apart.

3. Tests and analysis

Graham Shepherd, author of *Visual Soil Assessment: Pastoral grazing & cropping on flat to rolling country*[139] led the soil sampling process on 2 July 2020. Mr Shepherd's VSA method has been widely adopted around the globe and published by the U.N.'s FAO. The day was fine and sunny.

A range of tests were conducted on both properties. Methods are summarised here with more detail provided in the analysis.

Test	Method
1. Visual Soil Analysis (VSA)	Used the VSA Guide to determine 5 soil indicators and 5 plant indicators.
2. Chemical status, bulk density and total organic carbon	A hole approximately 400 x 600 mm was dug to the water table (700 mm on the organic farm and 550 mm on the conventional farm. Soil rings were used to extract samples for each horizon. A second set of samples of each horizon was taken to determine total organic carbon and chemical status (for the Ah1 horizon only). Pasture samples of rye grass were collected from the Matenga farm.
3. Infiltration rate	We used Landcare Research guidelines with a 300 mm external and 150 mm internal cylinder. Water was poured into the external cylinder and then 1.7 litres was poured into the internal cylinder. An inverted nail was positioned in the centre of the nail to create a meniscus and the time taken for the water to infiltrate was measured. This was repeated six times on the Matenga farm to ensure the last four times recorded were relatively stable. It was repeated 9 times on the conventional farm.
4. Pasture diversity	Pasture species were visually identified in a 1 metre by 1 metre grid randomly selected. Approximate coverage of each species was recorded.
5. Brix readings	Samples of perennial rye were crushed with sap extracted in a garlic press and measured using a Brix refractometer. The electrical conductivity of both the pasture sap and the soil was measured.
6. Soil chemistry	Topsoil was tested using a Soils1 test kit, but results were indeterminate.

Table 2: Soil testing methods

On Thursday 9 July pasture samples were taken from the same paddock. Rye grass was selected using scissors and avoiding dung and urine patches.

4.8. Soil data limitations

This project is not designed solely to generate scientific data about soil. It aspires to use “existing literature, conversations with Māori and Pākehā landowners and field trials to develop basic soil health data from two participating Takahiwai farms”.

The literature has revealed deep complexity in accurately determining soil carbon and this project does not have the resources to resolve these complexities and to contribute meaningfully to a narrowly focused scientific discussion. Our intention is to provide a broader cultural and historical context that calls for contextualised use of soil data.

While we are using a wide range of measures, the limited number of farms sampled, and the number of samples on each farm will not provide sufficient data for conclusive comparisons of regenerative and conventional farms.

5. Findings

5.1. Findings – kaumātua interviews

Takahiwai, at the southern side of the Whangārei Harbour, lies towards the Northeast and is protected from the prevailing southerly wind by Takahiwai Hills and Forest. For generations, the whenua [ancestral land owned in common] and Whangārei Te Rerenga Paraoa Harbour have sustained the Hau Kainga [homelands] of and Te Parawhau including Patuharakeke hapū [sub tribe]. Through colonisation and industrial agriculture, the landscape has been changed. The white beaches that used to provide the Tangatawhenua [First people of the land] with ready access to the harbour for kai moana [seafood] and recreation are now submerged under silt. Mangrove forests are growing wild between the land and the harbour which is, now, just a thin blue line in the distance.

For Indigenous communities, internationally, growing and harvesting food is the dominant activity that shapes and underpins culture and the social order. The Peoples have developed food systems that have been shaped by the available plant and animal resources and the environment. A food systems perspective helps them to understand how change has happened imperceptibly or not, like the gradual accumulation of silt along Whangārei Te Rerenga Paraoa Harbour. This perspective also enables an evaluation of how food systems add or erode value for the communities.

The stories and memories of two kaumātua with strong associations with Takahiwai kainga help to unpack food system changes. Dr Mere Kepa lives on ancestral land in Takahiwai. Dr Benjamin Pittman, a relation of Mere's, has contributed to the narration as well. Their Kukupa, Tauwhitu, Pirihi and Pitman ancestors have been buried in Takahiwai since 1893.

Benjamin's memories are both of Takahiwai and Waiotu.

Waiotu is Ngāti Hau. Benjamin's grandmother, Hoana Hohaia (c.1868-1935), married Okeroa Pitman. Her father, Hohaia (c.1825-1901), was one of 12 children from four wives of Patuone of Ngāti Hao/Te Popoto, Te Roroa. Hoana's mother was Kateao Te Takupu of Ngāti Hau. Her father, Te Takupu was a half-brother of Hongi Hika. Okeroa's connection is to Te Parawhau/Te Koiwi/ Patuharakeke and hence, to Takahiwai where his Pākehā father, Benjamin Pitman and mother, Ani Whareaitu/Tauwhitu, are buried. Other Te Parawhau relatives also married into Ngāti Hau along with other hapū and iwi groups. (Ngāti Hau marae are Akerama, Pehiaweri, Te Maruata, Whakapara and Maraenui.) Although there are very close connections to Ngāti Hau in the Hokianga, who descend from Hauangiangi, the Ngāti Hau of Hoana takes its name from Hautakowera, who was from there. His son, Kahukuri, left the Hokianga because of his being over-shadowed by an older brother and, "founded" the Ngāti Hau of these discussions). These details indicate the complexities of connections and descent within Te Parawhau and Ngāpuhi. So, Waiotu and Takahiwai are connected through inter-marriage.

Social structures, values

Before colonisation, mostly by the British, the Indigenous food system in Aotearoa was based around kainga gardens. At Takahiwai, by the early decades of twentieth century, the alienation of land and the introduction of changes to the ownership structures were affecting kainga social structures. This ultimately led to a steady decline in the practice of Te reo Māori me ngā tikanga [Māori language and culture], local Māori knowledge, and traditions associated with the land. There evolved a shift to large household food gardens (kūmara, rīwai, taro and other vegetables) and fruit orchards centred around homes with typically three generations residing therein. Ornamental flower gardens were also popular.

Kaumātua (women and men) remained the respected leaders who guided community activity. In those days, people placed greater value on interconnections with extended family members - especially well-respected and knowledgeable kaumātua - rather than identifying as hapū or iwi per se. Everyone had a strong sense of their whakapapa (who they were related to). New people to the community would be welcomed with an explanation by the kaumātua of their family connections.

Growing up, there was an innate unspoken understanding that the health of the land and environment was tied to the wellbeing of the people. Life was sophisticated and hard physical work was the expectation. However, everyone's basic dietary and other needs were provided for and people were generally healthy (obesity was not problematic). Mere has reflected on the understanding that good (unprocessed) food was rongoā (medicine). The people did not think of themselves as poor, as they had land, a home, and their health – the Māori locals even had enough kai to feed the resident Pākehā during the Depression. Benjamin remembers his father paid cash for everything he bought on their monthly shopping trips. However, he was frugal and rarely if ever openly talked about money. In 1952 he bought an adjacent piece of land from a cousin, paying cash, £152.

There was a strong sense of community belonging, with community services (tennis courts, post office, public transport, telephone exchange, movie theatre) and events (organised rugby and other sports tournaments, dances where people dressed up, A&P shows). Everyone got along and helped one another, Māori and Pākehā.

While life was not always idyllic, people were more trusting, respectful, caring and compassionate to one another in those days – even to the odd few who weren't so nice. The concept of utu, or maintaining things in a state of balance, was also real and important (this is different to today's concept of utu as predominantly being about retribution). People were aware about how the principle of reciprocity and the practice of 'give and take' affected one's own welfare in the community. Coupled with an abundance of kai, it was commonplace for those with a surplus of kai to share with those in need. Nobody ever went hungry.

Knowledge transfer

As children, Mere and Benjamin were both trained by intergenerational knowing, learning how to live as Māori through our grandparents, parents, and cousins.

> We essentially learned "on-the-job". We were shown things through explanation and doing. This including planting and garden management, getting rongoā from the bush, preparing kuta and kōrari for weaving, fencing, farming – all the "essential" skills. And, all of this was governed by tikanga, which was never taught formally but again, applied learning. A clip around the ears or worse was an indication of a mistake having been made under tikanga! What is more, the "New Zealand Education" system virtually denied Māori existence let alone failing to give it any credence or value. There were certain mythologies perpetuated, such as New Zealand's "discovery" by Abel Tasman in 1642 and Māori arriving as the Great Fleet in 1250 but that was it. The only positive I ever got about all things Māori was at home and in the whānau/hapū setting. Of course, this set up real conflicts and I realised very early on that the Pākehā system was one of denial and a con job. The other things negative about being Māori in the 1950s were having ear/hearing and sores checks and being referred to variously as "half-caste" or "quarter-caste" Māori. I attended many hui and sittings of the Māori Land Court with Okeroa, especially before I started school at Hukerenui in 1952 and so, on the one hand, saw a different world in action and on the other, two systems in conflict and compromised. (Benjamin Pittman)

In the same manner that can be seen today in the operation of marae, the young learn what to do by the example of their elders. They also learned by their mistakes (or, rather, the punishments dispensed for violations). Mere could not recall wānanga (formal structured learning spaces) being held in the kainga, despite the concept having now become familiar and mainstream. Neither was there emphasis on measuring and formal analytical monitoring of ecosystem health indictors as there is today. The understanding seemed to be that if we observed people to be healthy and organisms to be plentiful in their natural environment, then our food production practices must have been in harmony. It was an intellectual, spiritual, and practical or integrated or holistic approach to living life.

Benjamin also spoke about more metaphysical knowledge, such as the lines of energy that ran across the land (kaumātua referred to them as "lines of light"), and a kaitiaki entity that would pass across the sky indicating an impending significant event about to happen. Tikanga around the correct use of items having tapu and noa energies [items with restrictions, and those of an ordinary or less restricted nature respectively] was much more strictly applied. These tikanga [Māori customs] are grounded in the sense of knowing that life is lived in the balance and harmony of people, the flora and fauna, and the spirits.

All activity was guided by karakia, and there were a variety of karakia for different activities.

The mana of the kaumātua was evident in the way work in the kainga happened efficiently. While household gardens reflected sites of whānau responsibility and oversight, those whānau came together for seasonal food production: preparing the land for planting, cultivation, harvesting, and food processing. Some people had specialised skills and knowledge, such as land management, prized fishing spots, medicinal plant gathering and preparation, traditional animal pest and noxious weed control methods, food preservation (e.g. fruit bottling). Okeroa, Benjamin's grandfather and a resident of Waiotu, grew 13 different rīwai varieties, each with their own kaupapa (particular characteristics, attributes and associated cultivation practices). Benjamin's sister still cultivates six of those varieties, Tūtaekuri, Peruperu, Whataroa, Karuparerā, Huakaroro, Moemoe.

Different resident animals and their behaviour also had particular meanings in different contexts. For example, a large black koukou (owl) was a kaitiaki which often heralded an impending bereavement. It is interesting to note, as an indicator of environmental health, the sharp decline in the variety and number of certain insects today (bees, centipedes, weta, caterpillars, Pennydoctor larvae, moths), as well as the rise in others (such as wasps). There are also fewer worms; on a rainy day, Mere recalls how worms used to carpet the metal road at Takahiwai.

Food production

Food was produced within the traditional land and sea boundaries. Māori predominantly started out as food gatherers, fisher people and horticulturalists. They adapted to agriculture and animal husbandry, spurred among other things by the ability of trade in meat and dairy for money which enabled greater participation in the post-industrial era.

At Waiotu the homestead garden included watercress, kānga pirau [fermented or 'rotten' black or yellow corn] etc. Young people were involved in harvesting. The young also foraged for the fungi, hakeka. This grew on dead wood in the bush and was gathered, dried and sold to the Chinese greengrocer in Whangārei for pocket money.

Notions and practice of wairua and mauri infused a reverence for the whenua and moana. Work was timed in harmony with the seasons and weather patterns and events. Like an orchestra, everyone also had their different roles, and everyone knew who was to be in charge of a particular mahi or operation (much like how a tangihanga comes together – except the teamwork wasn't just for three days, but ongoing). People didn't have to be too cajoled to do the mahi – they just got stuck in and did it. In that sense, people had a strong work ethic. And people had a range of practical skills; they could fix machines, do fencing, cook, even divine hidden water sources.

Okeroa used a maramataka (lunar calendar) that guided gardening and fishing and was much preferred over the 'Farmers' Almanac' (Benjamin still has a copy of Okeroa's maramataka which was undoubtedly based on generations of ancestors' observation and experience). Mere's father also farmed and fished by the maramataka; he would have learned to do this from his father, uncles, mother, at least. He would joke about folks who ignorantly fished at the wrong time of day (the best time being morning and evening when fish were known to be feeding).

Dried shark was a popular favourite of Okeroa's. Shark meat would be hung high in trees, where there were no flies. Fish was also smoked using 44-gallon drums with Manuka brush the tamariki collected.

Another of the children's chores was to fill sugar bags with seaweed from the moana (when the coast was an accessible beach area – now, mangroves have smothered it). They'd soak the seaweed for a period of time before bucketing the juice onto the gardens. The seaweed acted as ground cover. Certain seaweeds, like karengo, would be eaten.

Okeroa would not allow chemicals on the land up to his passing in 1959. To keep the land clear of gorse, wiwi and other weeds, these were routinely removed by hand: laborious and time-consuming, but effective. Soil was tilled using a horse-pulled harrow, and later tractor-pulled discs.

With such large orchards, whānau would come together for fruit preserving days. The children would pick the fruit, and different aunties had their specialty (pears, peaches, etc).

Cows were hand-milked until the 1960's. Milk was used to feed the domestic pigs as well as for the local families. Cow manure and milking shed run-off was composted or applied directly as a fertilizer resource for nearby food gardens. Animals were kept away from water sources, and separate lines were used for different water purposes. The cattle were generally healthy with only the rare visit from the vet for a difficult calf birth. Families would make their own butter (the cream was rich and yellow, unlike today).

The risk of farm dogs contracting Hydatids was mitigated by cooking the sheep offal before feeding it to them.

The traditional pātaka kai (food storage house) principles were still being practised in Okeroa's time to store kūmara. Racks were arranged on stilts to prevent access by rats. The platforms were covered with ponga ferns as their spores were a disease deterrent and preservative. Another method was to dig a pit into the earth sheltered with a roof. Other food 'stores' were kept in places that caught the breeze – like trees, the garden, or off the kitchen bench in an external air safe. There was also a cool safe buried in the garden, which had a secure lid.

A certain stream was used for making kānga pirau [fermented, or "rotten", corn]. Corn cobs would be stripped and, put into sugar bags which were weighted down and submerged for a period of time. That was back when streams had good clean-running water.

Once a month would be shopping day for any other essentials, but other items were generally a luxury. As ice became available, Benjamin's family would transport it back with them for placement into the cool store over summer. He remembers the first fridge, washing machine and electric stove arriving around 1953. These changed things considerably and made life easier. Generally, the only things bought were flour, sugar, tea, coffee, spices, salt, cornflour, bananas, rice and some canned foods for an emergency. All the rest was made, grown or provided from the farm. Kūmara and rīwai [potatoes] were grown as large one-acre plots, on a collective basis with another related whānau and both labour and crops were shared.

Food distribution

All fruit and vegetables harvested were enjoyed by whānau or shared with wider community. None was sold. On the other hand, locally produced meat and dairy was sold to provide income for other purchases. On this basis, people would come from all around to trade, exchange and share produce. Takahiwai and Waiotu tuna (eel) was one local delicacy which was highly sought after by visitors, and Takahiwai and Waiotu whānau likewise enjoyed the toheroa that people from other coastal areas brought with them. Mere's home farm had a four-bail cowshed. Cream was sold. At Waiotu, cream was sent off to the Hikurangi Co-operative Dairy Company for butter.). All manure from the cow shed was retained in a series of pits and after it had become soil-like was used on the gardens. The vegetable garden at Waiotu was located next to the cowshed and provided carrots, parsnips, potatoes, onions, spring onions, cabbage, lettuce, kamokamo, paukena, merengi, silver beet, beans, tomatoes. In 1960, more exotic things were added: green peppers, chillies, ginger and eggplant. The orchard was large and also provided fruit: lemons, oranges, mandarins, bananas, plums, nectarines, peaches of various kinds, plums of various kinds, apples, apricots, cherries and pears. Taro was also an important crop, grown by Okeroa in a water plantation – a garden where running spring water was channelled through. Both the tubers and leaves were eaten. Apart from wild, pūhā and watercress (both water-grown and dry-land watercress) there was also rengamutu, a native spinach.

The post war era

The post Second World War era brought pros and cons. Changes in the commercial environment offered opportunities. For example, Benjamin recalls making pocket money by picking a particular fungus (hakeka - rubbery texture, with a blue/ grey interior) and selling it to a local Chinaman's shop. This was sold to restaurants and also sent to China.

Peacetime also saw surpluses and production capacity for fertilisers (what used to be used for explosives), agrichemicals and farm equipment. Returning pilots found employment with aerial topdressing. The kaumātua recall the planes spreading fertiliser on a local farm. This was the start of a seismic shift in food systems ushering in industrial agriculture that dominates the country today. The first supermarket in the country opened in 1958 in Ōtāhuhu.

Figure 13: Taro tubers and leaves from Waiotu

A trip to Whāngarei was still a major outing, but as cars became faster and more common, people became more mobile. The urban drift accelerated in the 1960s, as did the era of convenience. Money became the currency of more transactional, time-saving, and even self-centred goods and services exchange, replacing traditional whānau and community collaborative efforts for the kaupapa of food production or other shared or socially valuable interests. Mere recalls it was about this time when it became noticeable that fewer whānau did the giving and sustained their involvement with, and for the collective interests of the kainga to the point that now urban whānau's expectations and reliance on the ahi kaa has significantly increased, arguably to the point of dysfunction These trends started the demise of the household garden with plots first reducing in size and then in number. The people of Takahiwai began "eating other people's landscapes" (Rebecca Hutchings):[140] orchards fell into disrepair, horticultural and traditional food production knowledge stopped being practiced and the whenua and moana that were once the community's 'pantry' became replaced by grocery stores.

Over the course of the last century, other developments have led to environmental degradation. On the coast, mangroves became well established, and what were once weeds in Mere's and Benjamin's parents' time have taken over as the dominant species of ground cover. To the north, Golden Bay Cement was polluting the environment from the 1920s[141] and in 1964 the refinery at Marsden Point began production. The combination of agricultural and other sources of industrial pollution means that it is now unsafe to collect puha, watercress and other plant foods from ditches or berms. Public Works Act confiscation of the Takahiwai Hills water catchment area, and construction of a dam (currently in possession of the Whangārei District Council)[142] has contributed to water depletion. There is a similar occurrence on Benjamin's family land, nine strong-flowing freshwater springs are now reduced to a trickle.

> My father, Manira Pitman, kept Okeroa's traditions going right up until his death in 1969 and the family continued thereafter. The farm was only sold to a cousin in February 2019. By that stage, however, the old gardens were no longer cultivated and, in the orchard, the only tree remaining was the jam plum tree from 1907. This cousin is working on re-establishing the old practices and cultivations, without agrichemicals. (Benjamin Pittman)

Conclusion

Assaults on the quality of life of the people of Takahiwai that began with alienation from land was compounded with manufacturing and agricultural industries that despoiled the environment. The ongoing loss of land eroded the Māori capital base and impeded fuller participation in the economy.

If we evaluate the community food systems of the early to middle decades of the twentieth century at Takahiwai, most notably, people were fed, had a rich social life and were healthy. There was an absence of agrichemicals and overly processed food. The subsequent half century of industrial agriculture has impacted on the people of Takahiwai and the uri of those who lived there. It is beyond the scope of this project to determine their health and other life quality indicators, but the increase of non-communicable disease is well documented. The family farm is under threat as farms coalesce into larger units, and some younger farmers struggle with debt.

The emergence of regenerative agriculture gives hope that we can transition away from industrialised farming and rediscover ways of working with the land that reverses social deprivation and environmental degradation.

We cannot unravel ourselves back to the community food system of the early to middle decades of the twentieth century, but we can learn from how community developed systems to feed and nourish its people while treading lightly on the land.

5.2. Findings – Takahiwai and Mata farmer interviews

The following is a summary of the key themes emerging from interviews with two farming whānau located south of Whangārei: a 90-hectare organic dairy farm of 130 cows, and a conventional 50-hectare dairy farm of 130 cows.

Getting started in farming

Of the families interviewed, both saw an opportunity to change, and believed change for the better was possible: the organic farm, from conventional dairying to organics; the conventional farm from engineering into dairying. Motivation for the organic farm owners included improving the health of their animals, reducing the use of chemicals on the land, creating a healthy home environment for their children, and being inspired by others' successes.

There was a lot of self-education, trial and error involved for both families in their transition experience which, at times, was quite stressful, requiring a degree of mental toughness. Both families faced barriers to overcome, often multiple converging or consecutive challenges. These ranged from technical, to legal, to financial issues, as well as long working hours. For the organic farmers, transition to organic farming, with little information available in what might be looked at as those "pioneering" days, the shift was particularly testing.

Both whānau recognised the impact of external situations on their viability (from fluctuating dairy prices, changing Government policy and regulations, relationships with 'the bank', to access to foreign markets, the Global Financial Crisis and the weather). Managing farm debt was a common concern for both farms, with operational compliance costs continuing to increase over the years. From an organic farming perspective, the threat of mainstream competition was also constant. Understandably, all these factors created strain for the whānau, and the journey felt in moments quite isolating (especially with regard to the organics transition). But the families came out the stronger for it. Now, organic farming and their standards are more acceptable, the organic community is well-established, so engaging with others and finding support is much easier. Both farming families have also experienced positive attitudinal shifts among the wider farming community. Where before, general weed eradication was commonplace for example, the organic farmers noticed that recognising that certain 'weeds' had value was becoming more accepted.

Key areas for farming success

For both whānau, a reciprocal relationship with the land was key: in the organic farmer's words, "if you take care of the land, it will give back to you". Similarly, the conventional farmers believed most farmers understood that nature and people must coexist, otherwise you damage the environment and your income, and you don't eat. Knowing the farm well, and what areas need attention, was also critical to success. The conventional farmers raised production at the different Southland farms they worked at or managed. They were selective about where they worked, but also attributed their success to doing the farming basics well. They learned about the importance of balancing starchy and protein-rich feed crops for optimising milk volumes, the value of vegetable crops' variety for animal health (like kale, swedes and beet), and much more.

For the organic farms, while the term "regenerative" farming was still fairly new, they did observe some overlap with organic methods. They observed that a strong soil foundation built in farm drought resilience, with neighbours commenting that their organic farm looked comparatively greener during drier months.

Soil sampling every 5-10 years revealed something new each time, including surprising increases in topsoil due to good ground cover acting as "solar panels" which transfer captured sunlight energy and nutrients into the ground. They noticed how full their cows seemed to be by eating less amounts of nutrient-dense organic grass, while observing a different 'pavlova' consistency in the cow dung (compared to the high liquid content typical in many conventionally-farmed cows). The organic farmers also believed that including a diversity of fruiting, browsing and other plants in and around paddocks supported overall farm health. They learned about and actively leveraged the indicator value of certain species conventionally considered "weeds" – for example, some could be turned into liquid form and sprayed around the property for particular purposes, some which could be planted to rejuvenate soil, while the prevalence of others were a sign of soil nutrient deficiency. The integration of micro-climates, shaded areas and of course water conservation were also important, and different everyday indicators like hair swirls on cows (a sign of an animal's productive state) or an abundance of frogs, pointed to the health of the environment and/ or its inhabitants.

Prevention with nature-based remedies (e.g. herbal tinctures and homeopathic medicine) were the preferred health management practice for the organic farmer's animals (as compared with, say, industrial pharmaceutical animal products administered by injection). They also saw similarities between biodynamics (based on energy and spiritual practices) and Māori concepts of working with mauri (the energetic life force in all things), and wairuatanga (spirituality). Faith featured strongly for the conventional farmers too, having adopted Christianity at the start of their farming journey. The conventional farmer believed that increasing profits, and maintaining functional family relationships through tough times, were evidence of the positive influence of daily prayer and other faith-based practices. He struggled to comprehend how a person would have survived without it under such challenging conditions. The organic farmer also acknowledged the role intuition played, often guiding farm management decisions to their benefit (evidencing that correlation fell outside the scope of this research, however).

Although having management control had its obvious appeal, the conventional farmers were mindful that they were often forced to use conventional practices due to operational realities and constraints. With regard to working the soil for example, this sometimes meant operating against what they preferred, and they expressed interest in improving current methods or transitioning to organic or regenerative approaches. However, they believed the security of a stronger financial position was necessary before making that shift.

Restoring or maintaining soil and animal health meant for the organic farmers achieving balance regarding natural versus conventional farming practices. They found rushes, for example, to be so invasive that there was no choice but to mechanically mulch them. The conventional farmers also spoke of the indispensable value of innovating and use of technology for farm viability. Phone Apps conveniently tracked and provided access to farm input and output data and other different kinds of vital information, while drones provided useful perspectives on the state of the farm. They believed a successful farmer must also be a good accountant, not just practically competent on the ground.

One of the organic farmers emphasised that besides a healthy environment and a happy whānau, a top aim was ultimately "happy cows" (she mentioned her aspiration to one day supply drinking water for the animals that met human quality standards). The conventional farmers agreed too that self-care was very important for a successful farm. The organic farmers believed these values were achievable together with balanced production levels and farm profits. They further considered it an encouraging sign of organic farmer resilience that once 'new' farmers were still operating years later. Having the farm established in a healthy state for the next generation to take over would also be a sign of success.

5.3. Findings – regenerative farmers

The intention of the interviews of the six regenerative farmers was to identify their observations providing insight into soil quality. However, in the first interview the conversation quickly broadened. Regenerative farmers focus on soil health as a precursor to pasture and then animal health. This analysis is based on those themes.

Two of the six farms had organic certification and a third had lapsed certification as Fonterra has no provision for the separate collection of organic milk from that farm. The fourth farm was Demeter (biodynamic) certified and the fifth had Demeter certification earlier in the farm history, but could, along with the sixth farm, be classified as "biological". Four farmed mostly dairy cows and two farmed drystock.

The soil and soil testing

Erwin Eisenman of Waima Hill Organic Beef, stated that the quality of the topsoil was very poor when he and Ursula arrived on the farm 15 years ago.

> ... planting trees was really hard yakka - you could hardly get a spade into the ground. It had a very shallow topsoil with low fertility.

Erwin has focused on soil quality, enhanced by the application of recent learning about regenerative agriculture. Now it has an excellent soil structure with deep topsoil and a darkening subsoil. This has been independently verified by a Northland Regional Council Land Team staff member. Other interviewees identified better drainage and water retention and generally, an improved soil structure.

Worms are abundant and the Crawford farm has abundant dung beetle that quickly recycle dung back into the soil.

All farmers tested soil. Two used the Albrecht System, sending samples to the United States to the Neil Kinsey lab. A key metric is the calcium, magnesium balance. Others used standard soil tests as required. Evan Smeath observed that sometimes soil tests reveal surprising results and he has learned to be very vigilant to ensure that samples don't include misleading samples, that might for example, include old drain cleanings. Generally, the farmers find, that based on their experience and years of observation, soil test results confirm those observations.

Max Purnell has learned a lot about his mycorrhizal fungi. He has a strain of Trichoderma species that is especially effective, as tested by Lincoln Agritech. The Lincoln labs have isolated the species and provided him petri dishes of Trichoderma culture. When he is ready to use the culture he bulks up the fungi through a staged process and then mixes it with pasture seed to inoculate the seed.

Pasture and grazing behaviour

All of the farmers interviewed advocate pasture diversity. Max Purnell set the context for this.

> Diversity is the key. As we moved out of the dark era of everyone spraying 2,4-D every year to get rid of the thistles and the broadleaf weeds, I have always been fascinated to see what broadleaves get grazed.

Max noted that giant buttercup was a concern in the wider farming community, but he noticed how cows sometimes chose it when self-medicating. Other examples of pasture species used for self-medication were storksbill and plantain. The Gillatts noted fennel as a milk enhancer.

Alistair Crawford identified 27 to 30 pasture species on his farm. "A lot of the old pastures have come back strong; plantain, Yorkshire fog, cocksfoot, lotus major". Erwin Eisenmann reported red and white clover and three types of lotus. Sowing species to broaden diversity can be problematic with mixed results, but diversity successions occur over time in the absence of herbicides. One farmer noted that nitrogen suppresses clover. The diverse pastures respond better to stress and perform better in drought.

Kikuyu is a predominant species in Tai Tokerau and can inhibit pasture diversity, but Erwin Eisenmann noted that it weakens in the winter enabling a foothold for other species.

Observation is a key skill for farming. Three of the farmers commented on grazing patterns. Janette Perrett noted that on occasions stock might be reluctant to go into a fresh paddock, possibly indicating less than ideal pasture. Others observed patterns of animals cycling around or zig-zagging until they found their preferred pasture. Erwin Eisenmann pushes his tight though small breaks to create longer rotations, so the stock eat what they can. The Gillatts observed that young stock prefer the harder feed on the farm perimeter.

Animal health

All farmers observed very good animal health. The use of antibiotics is either very rare or absent. Among the benefits of promoting good soil and pasture health are low somatic cell counts, minimal or no milk fever, staggers, bloat, facial eczema. Animal health remedies include homeopathics, essential oils, and rock marine salt licks.

Healthy animals produce better meat and milk, but there is no easy way of proving or marketing this at present. Alistair Crawford is the sole supplier for Whangarei artisan cheese producer Grinning Gecko.

Learning

One of the farmers attributed the learning process to "one third science, observation and gut feeling". Max Purnell emphasised "making observations over time about what does and doesn't work". He doesn't welcome the input of those with prescriptive advice – "don't arrive with certainty at our gate". Janette Perrett emphasized the importance of life-long learning.

5.4. Findings – soil data

Here is the executive summary from Graham Shepherd's report *Soil, Pasture and Environmental Performance of a Site on an Organic and a Conventional Dairy Farm*. For the full report see Appendix two.

The condition of the soil and the performance of the pasture was moderate and poor for the organic and conventional sites respectively with VSA scores of 19.5 & 16.5 at the organic site and 6.5 & 9 at the conventional site. The soil and pasture scores were also in sync with each other at both the organic and conventional sites, i.e. the performance of the pasture followed the condition of the soil.

All VSA indicators for the soil and pasture scored ≤1 for the conventional site. Only one of the soil indicators of the organic site scored ≤1 (Earthworm numbers) while only Pasture Utilisation scored above 1 (moderate) on the pasture scorecard. It is therefore the condition of the pasture at the organic site and both the soil and pasture at the conventional site that needs attention.

Being first and foremost a management tool, those VSA indicators scoring ≤1 highlight those areas

We are a small internationally acclaimed artisan cheese producer that makes some of New Zealand's finest soft cheese. We source top quality, export standard certified organic, milk from a local farm milking Ayrshire cows. Our cheese is made on the same day it is milked, and because we only use the milk from one herd we have total control over quality from beginning to end.

We pick up the milk early in the morning, as the cows are being milked and it is in our pasteuriser within an hour of leaving the cow.

Our fresh organic milk is batch pasteurised, which is a very gentle method of pasteurisation. We believe the way we treat our milk throughout the process is reflected in the quality of our cheese. We use non-animal rennet and all our cheese is handmade and aged on site.

From the Grinning Gecko website.

that need to be addressed in the first instance. By focusing on and addressing each of the individual soil and plant indicators that are scoring ≤1 (moderate or poorer), the VSA provides a road map forward to improve production, profitability, environmental outcomes and quality of life on the farm.

With the exception of pH and Olsen P, the soil tests of the two sites were roughly similar. The pH of the soil at the conventional site could, however, do with lifting, ideally to 6.4. The amount of phosphorus present is also overly high as indicated by an Olsen P of 42 mg/L and high levels of P in the herbage (0.55%). By comparison, the pH of the soil at the organic site is good while the level of P in the herbage is also high, despite an Olsen P of 23, a level that would be considered by many to be marginal. The results highlight the importance of having a herbage as well as a soil test to be able to gain an insight into the efficiency of nutrient uptake by the plant.

High K levels and low Ca, Mg and Na levels in the herbage at both sites could suggest there may be incidences of grass staggers, milk fever and bloat.

Except for Zn, B and Se, trace elements occur at satisfactory levels in the herbage from the conventional site while Fe, Mn, Zn, B, Co and Se are deficient in the herbage sample from the organic site. The low levels of Fe and Mn in the herbage from the organic site could be due to a suppression effect from the amount of Ca in the soil. No further application of Ca is recommended for some time at the organic site.

While the amount of sulphate-S is low in the soil at both sites, it is efficiently taken up by the plant which has good levels at both sites.

Molybdenum is high in the herbage at the organic site and could suppress the uptake and utilisation of copper. Adding sulphur-90 to the dung effluent and spread as a solid would lock up the Mo allowing Cu to be more efficiently utilised by the cow.

Trace elements are not added to the fertiliser at the conventional site and are applied in the water troughs at the organic site. If they are deficient in the herbage test, it is better to add them to the fertiliser because the body organs and glans of the cow can utilise nutrients more efficiently than if they were administered artificially as a ‘bullet’ for example.

While the infiltration rate of water into the soil was very rapid at both the organic and conventional sites, the infiltration rate was almost five times faster at the organic site. The greater infiltration rate at the organic site compared to the conventional site indicated a better soil structure, porosity and aeration status.

The organic site has 158.1 t C/ha in the upper 1 m of soil whereas the conventional site has 136.2 t C/ha. Compared to the conventional site, the organic site has 21.9, 17.6 and 10.6 more TOC in the upper 100, 60 and 30 cm depths respectively.

Given the benefits that soil C brings to the production, economic and environmental performance of a farm, soil C should be sequestered by adopting carbon farming management practices.

The organic site is potentially carbon neutral where soil C is in a steady state, i.e. it is neither increasing nor decreasing. The conventional site is potentially C negative where the amount of C could decrease.

While both the organic and conventional sites have a moderate potential for nutrient loss into the groundwater and waterways, the organic site has a lower potential for nutrient loss.

The organic site has a low potential to emit GHGs into the atmosphere while the conventional site has a moderate to high potential to emit GHGs.

6. Discussion, next steps and recommendations

6.1. Mahi tahi – working together

Project objective one:

Work with the kaumātua and landowners in the Takahiwai Kāinga to co-create a research plan to identify indigenous ways of managing soil health. (By 'research plan' we mean we will put together a list of questions to ask Māori landowners who are farming).

For the pilot study, the Community Engagement started early with the two kaumātua who are kin relations through a shared Te Parawhau ancestry. At the time of the engagement, Dr Benjamin Pittman was living abroad; nonetheless, the research team met with Dr Mere Kepa. Together, the team walked the ancestral land, at Takahiwai, still farmed by a younger member of the extended family, an interviewee in the study. During the process to create the research questions, the kaumātua/researchers/advisors/participants contributed effectively to the co-designed project. They were consulted when the farms, under study, were selected.

The two farmers are descendants of Māori ancestors, one shares his ancestry with Drs Kepa and Pittman. Both learned to farm from mainstream sources and, then, the organic farmer learned about organic farming from the wider organic community and from available literature. During their individual interviews, there was a clear gender influence on the farmers' focus by their partners who expressed enthusiasm for the animals.

Social order

The kainga grounds Māori and binds them to whakapapa. The young learn from the example of older people working around them and are eased into more complex tasks. The authority of the kaumātua is mostly unquestioned, but to be effective, kaumātua also need to conform to tikanga.

An important underpinning of the social order was religion, with most people attending church. The kaumātua commented that their tupuna found resonance between Christianity and Māori spirituality. Karakia preceded and concluded work and social occasions.

6.2. Regenerative farming

Project objective two:

Utilise existing literature, conversations with Māori and Pākehā landowners and field trials to develop basic soil health data from two participating Takahiwai farms.

Project objective three:

Identify multi-factors and processes that influence soil health on a farm using regenerative methods (e.g. pasture diversity, plant root depth, soil porosity, mycorrhizal associations, grazing intensities, carbon levels, soil microbiome) and compare to a non-regenerative farm.

Obtaining soil data

There was intense and iterative learning in preparing for trials to elicit soil and pasture ecosystem data. The potential for sequestration of CO2 as soil carbon, both for mitigating climate change, and enhancing soil quality was a strong motivator for this project. If soil carbon levels could be accurately and reliably measured, it would support policies and programmes whereby farmers could be recognised for building soil carbon (including, for example, remuneration for positive changes).

Currently, farmers use conventional testing methods to determine soil fertility, carrying capacity and other soil quality indicators. This is a considerable cost and can be mediated by fertiliser companies that then make recommendations for purchases of their product – a conflict of interest scenario undermining test result integrity.

Accessing soil science literature and discussions with Dr Brent Clothier made apparent the complexity of measuring soil carbon. Variables determining soil carbon include soil type, topography, soil moisture (influenced by flood or drought), and pasture composition. Soil carbon is most abundant in the topsoil and reduces with depth.

This reduction can be modelled to enable calculations of carbon for the whole soil profile to be extrapolated from topsoil samples, but this adds another level of variability to carbon calculations.

The Visual Soil Analysis

By contrast, and through consultation with farmer mentor, Max Purnell, the team was introduced to a more cost-effective, user-friendly and equally (if not more) reliable soil monitoring method - the Visual Soil Analysis (VSA).[143] The VSA method also gives the farm owner more control over the collection, access to and use of their soil data. In this way, VSA helps address a concern raised by Mike Taitoko in his presentation to one of the project's hui, that is, the need to protect farmers' data sovereignty.

This principle of autonomy and control, and the desire to reduce the cost of testing for farmers, led to investigating the use of low-cost kits. One was obtained to test soil chemistry and a second kit for soil biology, but these were quickly discounted during testing because results appeared to be highly variable.

During the first six months of the project the value of the VSA became increasingly apparent. This New Zealand authored process has been adopted by the Food and Agricultural Organisation of the United Nations and is used widely across the globe.

The author, Graham Shepherd, reports that people new to VSA are able to achieve very similar scores to him, as they work through the assessment process. This indicates that, as a farm extension tool, farmers can be trained quickly to use the tool. Moreover, the one-off low cost VSA user guide can support a lifetime of learning.

The VSA's title alludes to the importance of visual assessment of "key soil 'state' and plant performance indicators" of soil quality. However, the process also involves touch and smell, thus using three of our senses. Observation is a cornerstone of science, and the VSA helps to integrate soil science and farmer observation.

Graham Shepherd travelled to Tai Tokerau to guide the team through the VSA process on both farms, so the research team got to see first-hand, the value of this tool in action. He also ran a workshop with Northland Regional Council staff who are planning to use the VSA in their land management processes. The VSA has potential as a core tool for supporting transition to regenerative farming.

How do established regenerative farmers evaluate soil quality?

After appreciating the value of the VSA, the research team asked "how do established regenerative farmers evaluate soil quality?" This led to a series of interviews as outlined in the analysis section.

Farmers are continuously learning, principally through observation, and because farming is seasonal, some opportunities to learn through observation may only come annually. The interviewed farmers learn from observing the soil, pasture and animal health. Clues to pasture health come when the farmers observe, for example, stock moving into a fresh paddock. If they are reluctant to enter the paddock, it might be that they sense low pasture quality. Once they get into the paddock they might graze immediately, or may be very selective about the species they want to eat.

The importance of pasture diversity was emphasised by Peter Barrett and Jono Frew when they presented at a project hui. Stock tend to instinctively select species that support their health, so more diverse offerings means an increased chance that the animals will find the plants they need. This contrasts with the practice of eliminating broadleaf pasture and other so-called ‘weed’ species with herbicides. Lying down and chewing their cud is another sign of a well-nourished cow. Alternately, if they are continually eating throughout the day, the pasture might appear adequate, but be minerally deficient.

Figure 14: Pasture diversity and vigour at Linnburn Station

The farmers commented on pasture diversity, with species present providing clues to soil condition and fertility. For example, buttercup tends to grow where soil is compacted, daisies accumulate potassium and plantain accumulate silica. Pasture species succession is also observed. One farmer noted the “old” species, plantain, Yorkshire fog, cocksfoot and *Lotus pedunculatus* coming back strongly on his farm. Another reported that animals found the buttercup and giant buttercup palatable, and while they were regarded by others as a problem weed, he observed them targeted by his stock as a preferred species. Plant species succession follows changes in soil quality. Regenerative farmers note species succession as an indicator of improved or degraded soil dynamics.

Animal health is another indicator. All farmers interviewed reported improved animal well-being as they established better soil and pasture health and diversity over time. These benefits accrued from using more organic or regenerative approaches in conjunction with natural animal health supplements like mineral salt licks and seaweed. They typically report significant reductions in milk fever, staggers, somatic cell counts, empty rates, facial eczema and bloat.

Barbara Gillatt commented that their stock would look for storksbill and eat the flowerhead and leaves. Proving access to a paddock with abundant plantain enabled “wormy” stock to self-medicate and eliminate worms. The medicinal properties of diverse pastures is worthy of further investigation.

Another source of information is cow pats. Ideally, the consistency will resemble pavlovas, rather than liquid, indicating a healthy gut biome.

The farmers also use soil tests. Two use the Albrecht system and send their soil samples to the U.S. for analysis. The cornerstone of the Albrecht system is the balance between magnesium and calcium in the soil. The farmers following this method reported that once the recommended balance was achieved, pasture quality advanced significantly.

Figure 15: “Pavlova” cow pat (image credit Jasmine Purnell)

Not happy with high empty rates in first calving heifers, Evan Smeath changed his farming methods.

Several years ago we were getting high empty rates in our cows and two year old first calving heifers, like 26% in the first calving heifers. So that is just ridiculous, it costs a lot of money to rear them up just to go down the road empty. We thought there must be something wrong so that's when we started doing testing, we tested pastures and the soil, bloods, urines, we did all sorts of testing. We sent them down to Hamilton, we sent them all around the place to get analysed. Between myself, my vet, my farm advisor and my accountant, we actually found out it was high, high potassium levels, so we decided we had to do something about it. We turned that around from 26 down to 2%, and this year only about one and a half percent in the heifers. . . . From then on I said "right that's it, now, I've got to take control of this myself". So we changed our fertiliser programme . . . and got our soils tested in America in the Neil Kinsey lab, running on the Albrecht method and we have never looked back.

As with the other farmers, Evan draws on several sources of information for learning and decision support on the farm. This includes observation and reflection, records, specialist support, soil, and pasture and animal health testing. The one thing regenerative farmers lack is a local community of practice, as neighbouring farms are typically farming conventionally.

A phosphate story

Superphosphate, manufactured by treating phosphate rock with sulphuric acid, has been a mainstay of New Zealand farming. Phosphate is also available as partially acidulated phosphate and as untreated phosphate rock. This brief exploration of the phosphate fertiliser raises questions about its continued use.

The story of the Terra preta soils in the Amazon is well known. Not so well known is how Pre-European Māori used charcoal, gravel and sand to increase the quality of soils in the Waimea plains and other soils around New Zealand. In their 1923 paper in the *The Journal of Polynesian Society*, authors T Rigg and J.A. Bruce were clearly impressed by soil quality and the soils were notably still of superior quality when these soil scientists tested them. The gravel and sand applied improved the soil texture and Bruce and Rigg attributed the very high levels of phosphate to the burning of scrub.

> The source of the enrichment was apparently wood ashes, since the soil is black, owing to the presence of much charcoal. Wood, scrub, or other vegetable matter must have been brought on to the land and there burnt. Tea-tree (Manuka) is suggested as the form of vegetable matter which was employed for this purpose. The ash of tea-tree is rich in phosphates, potash and lime. (Rigg and Bruce, p. 9).[144]

A recently published book by Ewen Campbell identified how a Māori associate reported his father's reaction to the use of superphosphate on the neighbouring farm

> I was with Bob Maru, an ex-World War II Māori Battalion member in Gisborne. In his later years Bob was attempting to reinvigorate the East Coast utilising Māori land. After I had spoken to a group of his colleagues, he came to me with a grin on his face and stated that he had finally worked out what his father had spoken to him about when he was seven years old. He was about eighty at that stage, so he had waited a fair while for the answer. He recounted to me that he and his dad were in the garden while they were applying superphosphate on the neighbouring property. His father commented to Bob that "those white fellas are stealing our "mauri". Mauri is the Māori word for "life force". I had informed the group of how acid fertiliser binds silica to aluminium and therefore the silica loses its electrical production capability and in doing so changes the nutrient delivery system from electrical to soluble so, in effect, as Bob's father observed, the life force is taken (Campbell, pg 97).[145]

From the clues in the text the date of Bob's conversation with his father would be between 1900 and 1920. Superphosphate production began in New Zealand in 1882[146]. After World War Two, returning pilots found work topdressing superphosphate, increasing the spread of hill country farming. New Zealand has accessed its phosphate from Nauru and more recently from Western Sahara with detrimental consequences. About 90% of Nauru is now covered in jagged and exposed petrified coral and runoff into the ocean has impacted on marine life.[147] New Zealand fertiliser companies import about $30 million of phosphate from West Sahara every year. This country was taken over by neighbouring

Morocco in 1975 despite protests from the United Nations. The Moroccans dominate the control of phosphate. In 2019 representatives of the New Zealand Government officials met with a representative of the Western Sahara independence movement and agreed that we should be sourcing our phosphate elsewhere[148].

In interviews for this project, Dr Benjamin Pittman related how his grandfather, Okeroa, refused to have artificial fertilisers on his farm.

Results from the soil tests on Matenga farm revealed Olsen P levels of 23, on the low end of the medium range. This would normally prompt recommendations for the addition of phosphates. But herbage tests revealed high levels of phosphorus (0.49%). This indicates an active microbiome on the Matenga farm that effectively mines phosphate from soil minerals and makes it available to plants.

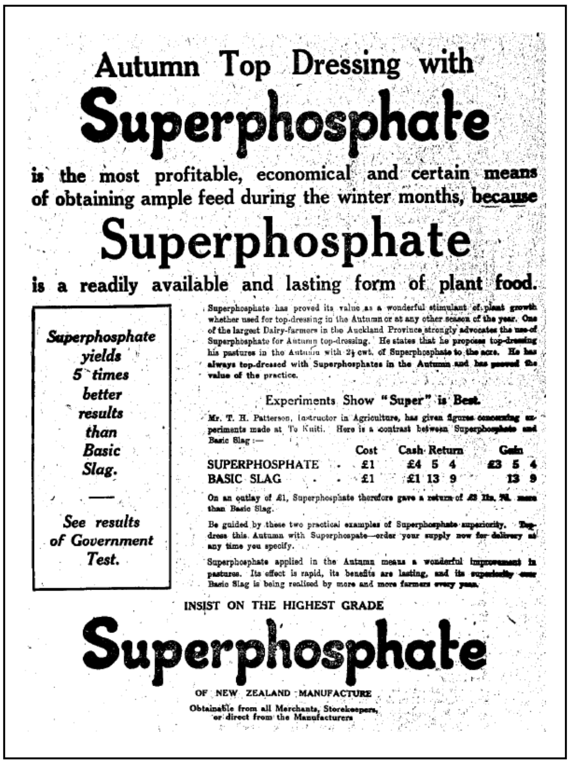


Figure 16: Superphosphate advertisement from the Te Aroha news[149]

Beside perpetuating injustices in countries of origin, phosphate fertilisers do harm here too. They contain cadmium and fluoride. The Ministry of Primary Industries claim that cadmium is within World Health Organisation guidelines. Cadmium is a heavy metal that can harm human and ecosystem health.[150] [151] Phosphate fixes strongly to the clay fraction of soil. In New Zealand "over two hundred million tonnes of sediment are lost . . . into the ocean every year".[152] This is the main pathway for phosphates to pollute our waterways.

When one member of the project team was taught soil science in the late 1970s, he learned that when minerals are taken off the land in produce, they have to be replaced. Forty years on, Australian soil scientist, Christine Jones, told him that what is exported is negligible compared to the store of minerals available in the soil. The microbiome effectively mines these minerals originating from parent material in the age-old process of pedogenesis. In addition to the electrical dimension of mauri referred to above, we can include the life force of the microbiome.

We can excuse those who applied the fertiliser in the past, but now we know more about the soil biome and the work it does in supplying plants with minerals, surely the costs outweigh the benefits. There are alternatives to highly soluble fertilisers. We have a lot to learn and a lot to unlearn. If the voice of Māori had been better respected, perhaps we could have reduced the negative impacts of using soluble fertilisers.

Data about the microbiome

Project objective three included mycorrhizal associations in the data the team would seek. As the project advanced, it became evident that testing for mycorrhiza, for example, would be too expensive and beyond the project's intention. While knowledge of the microbiome is important it is beyond the scope of family farms to access this data as a routine test. As the importance of soil biology becomes more widely acknowledged, this may change.

However, the organic farmers are very aware of the vital role of the microbiome. Practices they use to enhance it include applying molasses, and effluent-soaked bio char to pasture, ideally four times a year. Molasses stimulates bacteria, which in turn feed fungi.

Calm the farm

Another bonus for the project was the launch of the Calm the Farm website.[153] On the second day of the Walter Jehne hui, Mike Taitoko (Ngāti Maniapoto), the Acting CE of Calm the Farm spoke to an audience of approximately 20 Māori farmers and growers. Calm the Farm, with an assemblage of farmers, advisors and investors, plan to kickstart a full-scale transition to regenerative agriculture. Their plans include tracking the performance of regenerative farms with sophisticated data gathering and analytical tools, creating a community of peers, providing financial assistance for those transitioning, and disseminating the positive results that they are already seeing.

Food systems

IPES-FOOD highlight the food systems perspective calling for the transition from industrial food systems to sustainable food systems. Given the focus of this project includes regenerative agriculture, the transition is better expressed as from industrial food systems to regenerative food systems.

Our conversation with kaumātua revealed their lived experience of earlier food systems. They also identified transitions in those systems from their experience and whānau stories. In the second half of the nineteenth century, Māori food production centred on the kainga, powered by the local labour force for peak seasonal demands. These were often on a large scale with co-operative labour from many of the whānau (extended family) having roles to play in the processes of planting, watering, weeding and harvesting. Staples such as kūmara, kānga (sweet corn) and potato were grown in kainga gardens while household gardens grew rīwai/taewa (potatoes), merengi (melons), paukena (pumpkin), kamokamo (marrows) and other foods the whānau fancied. A kaumātua recalled a transition back to smaller gardens in the latter 1960s since there was often no longer the required labour to manage the larger gardens of former times, especially with many away and working in the cities. Kaumātua still at home on the land, maintained their skills and interests with smaller plots of traditional crops as well as experimenting with new crops such as herbs, green peppers, eggplant and onions. Another development was planting rongoā plants such as kawakawa close to the house for easy access and gathering. Going to collect plants in the bush often required much fitness and agility and was beyond many older people.

The early decades of the twentieth century saw the transition away from kainga gardens to household gardens and in the middle decades, the large household garden became the norm at Takahiwai. While there was a shift away from the collective kainga garden, there was still a lot of gifting and exchanging of food with Takahiwai and beyond, including with local Pākehā. The same held true for Waiotu.

After the Second World War, the emergence of the industrial food system accelerates. Kaumātua recall Okeroa Pitman not allowing the use of agrichemicals up to his passing in 1959. But supermarkets and production demands were transforming the food systems in the 1970s.

What emerges is an evolution of the food system to what we have today and how we anticipate that might further evolve. Stages are:

1. Pre-colonial food system, characterised by adaptation of food crops from the tropics and kainga gardens.
2. Adaptive food systems, integrating new European plants and animals into the food system.
3. Kainga food systems, with Māori in survival mode in the face of colonisation.
4. Household food systems.
5. Industrial food systems.
6. Regenerative food systems.

From this perspective, food systems evolve in response to wider environmental changes. With some confidence, we anticipate that the failures of industrial food systems will spur the transition to regenerative food systems.

Using a food system lens we consider food from a wider perspective—production, processing, distribution and retailing and consumption. The food system interacts with the health system as an even wider consideration. We might evaluate the success of a food system through its ability to deliver on the three dimensions of sustainability identified earlier: kaitiakitanga, manaakitanga and oranga.

The kainga and household gardens at Takahiwai worked. They were gentle on the land, sustained on mostly on-property and ocean inputs, leveraging the fertility of cow manure, clover and the harbour. People did not go hungry, and the obesity that is characterised by the industrial diet was mostly absent. Food transcended bodily sustenance as the food system provided social cohesion and a means of teaching children how to work together for the greater good.

6.3. Photography, video and the exhibition

Project objective four:

Work with Te Parawhau taitamariki (young people) and NorthTec students to develop a photographic exhibition at one of the marae kāinga in order to share the knowledge from the project and increase community engagement in it.

As the project developed, it became evident that working with taitamariki of the Takahiwai Kāinga would be the better approach. Two daughters of Māori whānau running the two principal farms involved in the project were interested and available to produce a photographic record. A workshop was run by Marcus Williams, an experienced photographic teacher, and some basic equipment was purchased for the young women. Dr Mere Kēpa organised and facilitated a photographic safari of the district, taking in sites of significance and arranging access to neighbouring farms. Both Calais and Nina assisted with capturing images of different project scenes and activities. After basic training from Marcus, Nina went on to also undertake videography of the second hui involving guest speakers Walter Jehne[154] including editing and pre-distribution finishing.

The Visual Soil Assessment workshop held at both farms was extensively documented as well as aspects of farm life during the 2020 year. Working with Marcus, the two taitamariki have been learning about editing, file preparation, printing, exhibition planning and installation, toward a display of the work at the final hui in mid-November. A final note is that this experience led to opportunities for Nina to provide photographic services to an MBIE-funded "Unlocking Curious Minds" project at Bream Bay College focusing on soil health.

6.4. Bi-lingual narrative

Project objective five:

Produce an evidenced based, bi-lingual narrative around the intersection between Māori approaches to farming and regenerative farming, and the potential of regenerative farming practice to improve soil health.

This report is "evidence-based" and expounds the "intersection between Māori approaches to farming and regenerative farming", but falls short as bi-lingual narrative. The project opened up many opportunities to advance this narrative but the research team did not have the resources available for translation.

However, the team believes the project to be an exemplar of bicultural research that can be further enhanced with a fuller expression of Te Reo. The larger project events have been hosted on marae. Most importantly, the project design and implementation have been co-designed with strong acknowledgement of the role of kaumātua in a guiding role.

The two kaumātua and Catherine Murupaenga-Ikenn will give a presentation on the project at "Kaitiakitanga"; the Māori Research Symposium at Otago Polytechnic. [155]

7. Conclusion, recommendations, further questions and next steps

The team of Māori landowners, scientists, educators, and regulators has collaborated to utilise te reo Māori me ngā tikanga (Māori language and culture) and Western science methodologies to produce scientific evidence and mātauranga Māori that supports and enhances emerging concepts of regenerative farming beliefs and practices. The findings are encouraging; Regenerative agricultural practices are informed by science and also deepen the farmer's appreciation and reverence for the earth, leading them forward to new practice, while reaching back to traditional knowledges.

The team sees conventional agribusiness as a detour from a more appropriate nature-based approach to farming. This leads us to question the cultural assumptions and practices driving the industrial food system. The widespread adoption of regenerative agriculture will accelerate the realisation of the bi-cultural partnership inherent in the Treaty of Waitangi / Te Tiriti o Waitangi through fostering a much greater respect for mātauranga.

An unanticipated outcome from the project has been our developing awareness of the hydrological cycle for the mitigation of and adaption to climate change. We are encouraged that work that enhances and respects the natural world can help us to address this existential crisis.

Further findings and concepts emerging from this project are embedded in the following recommendations and suggested next steps.

Recommendations

These recommendations range from practical next steps for those promoting regenerative agriculture to more aspirational recommendations for the wider community.

1. Strengthen research in Tai Tokerau to support regeneration of the environment, society and economy.

> *Practical steps to achieve this are applications for further research funding, advocacy for policy change, and strengthening national research links through Te Pūkenga and local and central Government, including the Climate Change Commission.*

2. Promote mātauranga Māori as an essential support for regenerative thinking.

> *Rather than using artefacts of te Ao Māori mostly for ceremonial purposes, embedding mātauranga Māori into education curricula, policy discussions and commercial practice will help us address the big challenges we face and diversify our thinking.*

3. Further research the impacts of the hydrological cycle and its implication for land use in Tai Tokerau.

> *Our findings suggest that a better understanding of the hydrological cycle can provide a potent tool for both mitigating and adapting to the climate crisis.*

4. Curate an annotated and well-structured repository of practical material about how to manage land regeneratively, designed to maximise ease of access and reference for farmers, other users of land, educators and policy-makers.

> *The Visual Soil Assessment and brix meters are examples of resources that proved their value as tools for increasing farmers' knowledge of soil. The agribusiness industry and Government agencies are still orientated toward conventional farming. Currently extension support is being provided by peer networks and these can be supported by creating a repository.*

5. Identify support for transition for farmers, especially Māori farmers.

> *In addition to opportunities for engagement identified in recommendation 1, the types of support offered by Calm the Farm are worthy of dissemination or replication in Tai Tokerau. These include technical and financial data, extension services, and financing support.*

6. Create stronger networks between those with interests in the regeneration of landscapes including farmers, those involved in ecosystem regeneration, permaculturalists and regenerative foresters.

> *Our current production landscapes tend to be monocultural. Approximately 50% of Tai Tokerau is pasture – as more farms transition to regenerative farming the community cohesion around a regeneration kaupapa will grow alongside opportunities to diversify.*

7. Create a database of farmers for Tai Tokerau.

> *Farmers benefit from learning from others. Those pursuing a regenerative kaupapa are often isolated from their peers. Recent innovations such as the Red Meat Profit Partnership and the Quorum Sense initiative are demonstrating the value of creating spaces for farmer engagement. It is important to consider if this database is controlled institutionally or is community-led.*

Further questions

Many questions emerged from this project opening up enticing horizons for further investigation.

1. How do we resolve the perceived tension between mātauranga Māori and Western science to better equip ourselves to address the challenges we face?

> *Strategically, organisations use Māori names on documents and espouse the values of mātauranga, but there appear to be unsurfaced biases that still privilege Western science as the arbiter of "truth" and require "evidence-based" decision-making, or delay action by requiring "more evidence". Until we can learn to find the sweet spot between these two ways of knowing, and be aware of the limitations of science as currently practiced, we will struggle to make meaningful progress. Enquiry could start, in the regenerative agriculture context, with discourse analysis, starting with "He Waka Eke Noa" and Fit for a Better World" through to operational discourse in agencies such as MPI.*

2. How do we make land available to young people for the production of food?

> *The housing crisis evident in urban New Zealand is mirrored by the increasing cost of land for food production. Smaller farms are commonly subsumed into larger blocks in the pursuit of productivity, and this creates a devitalisation of rural communities.*

3. We know what regeneration looks like in pastoral farming, but what of other land uses, such as forestry, waterways and oceans?

> *Regenerative agriculture shows much promise in both addressing the climate crisis and healing our land and waterways. The benefits of the regenerative potential in the ancient interaction between ruminants and pasture species is easy to understand, but what of these other environments? We can discern an increasing incidence of destructive wildfires. If our native forests are further degraded, might they be threatened. Tai Tokerau has over 2,000 km of coast and harbour shore – the oceans and waterways are another place for us to contribute to improving the environment and exploring their mitigative potential.*

4. We are beginning to understand what regeneration looks like in the natural world, but what of the economy and our communities?

> *Regenerative agriculture can heal some of the impacts of our extractive land-based activity, but the economic system remains extractive with an increasing gap between the rich and poor. What do regenerative economics look like? How do we enact the concepts of economists such as Kate Raworth?*

5. Is regeneration of the hydrological cycle effective for climate change mitigation and adaption, and if so, how can wider dissemination of its efficacy be achieved, policy influenced and action taken?

> *Current climate mitigation initiatives are confined to CO_2 and related minor greenhouse gases. This includes reduction of fossil fuel emissions and sequestration of carbon. Fortunately, these steps are also important for hydrological cycle regeneration. A wider focus provides greater agency for mitigation, especially relevant to land use.*

Next steps

The developments suggested here are predicated on some design principles:

- Any design must open potential for better engagement between Māori and farmers.
- A takiwa [catchment] is a naturally defined area, based on waterways and includes a variety of landscapes and land uses that are ultimately interdependent.
- Farmers like to learn from other farmers.
- Any projects should be designed to run without external funding, but ready to use whatever funds may become available.
- The kaupapa is based on regenerating landscapes, both wild and farmed, and communicating the importance of landscape regeneration in mitigating and adapting to global warming.

Takiwa projects

These projects are based on takiwa, ideally confined to a geographically small area. This might include 20 to 50 farms or horticulture blocks, one or more marae, a school, and native and plantation forest. Tai Tokerau has many such locations. The locations chosen will have one or more farmers who are farming regeneratively and are passionate about the practice. That farmer can probably identify others in the takiwa who are farming regeneratively or interested in transitioning. There may also be whānau land, marae, schools, and Land Care groups whose people have related aspirations.

Resources will be sought to map the takiwa and its activity and identify the locals engaged in ecosystem work. Ideally this mapping will be done by locals but supported by a regional support centre. Reconnecting Northland's Connectivity Planning process can be used to facilitate the connections made. The regional support centre will also develop and disseminate resources and ideally connect to other regional networks. Emerging national resources, such as the Canterbury-based Facebook Group Quorum Sense and the Māori-led *Calm the Farm* provide further information and practical support.

Examples of Takiwa

Kawakawa River catchment

The Kawakawa River flows from Motatau, alongside Moerewa, past Kawakawa and into the Opua estuary. Gary and Maryanne Hayman's farm is a few kilometres north of Kawakawa. Gary is an enthusiastic promoter of regenerative agriculture and an ideal Takiwa facilitator. He employs a farm worker from a local whānau who are very interested in transitioning to regenerative farming. Karetu Marae is nearby. The takiwa is heavily forested and has significant tourism values, with the historical railway and bike track running through the valley.

Waimamaku River catchment

The Waimamaku River flows towards the West Coast south of the Hokianga Harbour and north of the Waipoua Forest. Rebekah Land and her husband farm a Te Rorora-owned farm. Rebekah has been a very active connection with others interested in regenerative farming and is leading extension visits. The catchment is fed from the iconic Waipoua Forest and the southern hills of the beautiful Hokianga Harbour and includes Te Whakamaharatanga Marae.

Ruakaka River catchment

The Ruakaka river flows from Springfield, through Mata, and into Bream Bay south of Ruakaka Town. The organic farmers have been strong supporters of this project and are organic farmers with over 15 years' experience. The conventional farmers are interested in transition. Dr Mere Kepa is the co-ordinator for the Takahiwai Hills Pest Strategy. Bream Bay College is engaged with a regenerative soil science project and Patu Harakeke Marae is in the Takiwa. Durham Farms, with regenerative beef and dairy is about 10 minutes south on the Ahuroa sub-catchment of the Waipu River catchment.

The value proposition

These projects will be grassroots-led and network-based. They restore the mana of the waterways as vital arteries in the landscape. Ultimately they will force a rethink of the current siloed approach to the delivery of government services. This has potential to mirror the whānau ora approach as a ***whenua ora*** project, reaching into Ministries of Primary Industries, the Environment, Conservation and others. It connects groups the ecosystem regeneration aspirations and can enhance the mana of mātauranga Māori in the wider community, leading to its guidance of regenerative processes. Webs of mutual interest become more apparent. Farmers that don't use agrichemicals create cleaner water to enhance traditional food sources such as tuna [eel]. Reducing the possum population reduces the tuberculosis threat for farmers. Greater community cohesion will present more options for those considering replanting monocultural pine plantations. Any activity that regenerates the ecosystem supports climate change mitigation and adaptation and increases catchment resilience.

Appendix one: Food systems in Aotearoa

Before industrialisation, food was typically consumed close to where it was produced, with surpluses traded as nearby as possible and viable. Industrialisation shaped food production in Aotearoa compounded by a second influence, colonisation. In the twentieth century, consumerism added to radically change our food landscapes to have us "eating other people's landscapes".[156]

Figure 17: Timeline for the forces that shaped our food system

Before the arrival of Europeans, Māori were isolated in Aotearoa and there was therefore no imported food. Neither was food processed beyond cooking, drying or fermenting. Gardens were community enterprises with crops grown including taro, hue (gourds) and kūmara. Helen Leach's book, *1,000 Years of Gardening in New Zealand* documents pre-colonial gardening. It includes a drawing by one of Captain Cook's crew of an East Coast garden with kūmara, yam, taro and gourd [157].

Colonisation

Colonisation caused a decline in Māori population. After Te Tiriti o Waitangi / Treaty of Waitangi were signed in 1840, the population declined to a low of 42,000 in 1892 and took decades to recover [158]. Colonisation continued to impact on food systems through the middle decades of the twentieth century. The Māori renaissance of the late twentieth century laid the foundation for reshaping the food environment, but the forces of industrialisation and consumerism invoked another form of colonisation that dominated food landscapes.

> "Through colonisation this knowledge has been marginalised and is now retained by only a few experts across tribal regions.[...] The specialist traditional knowledge aligned to horticulture and pedology has been relegated to only a few practitioners."(Helen Leach)[159]

Industrial agriculture

New Zealand as a nation is less than 200 years old and our development parallels the growth of industrialisation. When Captain Cook travelled here in 1769, James Watt patented his steam engine – the first powered machine to have a significant impact in commerce. Jeremy Rifkin identifies three industrial revolutions, the first driven by steam, the second by oil, and the third by renewable energy.[160]

In the 1860s the first railways began to connect the country. The famous SS Dunedin was a wind -powered ship, but its steam-driven refrigeration system enabled us to deliver the first shipment of frozen meat to England in 1882. By then, steamships had started to appear too, cutting a month off the long sea journey to England. Steam engines started to have an impact in food production from the 1860s with machines used initially for threshing grain. Henry Ford's production line concept, manifested in freezing works in Aotearoa.

The industrialisation of agriculture accelerated after the Second World War when industrialists sought markets for the increased production capacity in machinery and chemicals. Nitrogen, manufactured for bombs, found a market on farms.[161] Pilots returning from the war found work in aerial topdressing. Canned food, developed for troops, proliferated and supermarkets emerged, accessing food from global supply chains. Tim Lang of The Guardian describes this as the end of farmer control of the food system in the U.K.

> Until the second world war, it was the farmers who were the major players in food. But the end of farmer power began just when they thought they were at their most powerful – in the middle of the twentieth century. After the war, they were given grants and subsidies, but these were merely to stop them collapsing altogether. They were supported but only so long as they restructured: in return for intensification, increasing efficiency and the adoption of labour-saving technologies in the form of agrichemicals, machinery and plant science.[162].

Industrialisation also transformed the demand side of the food system. In New Zealand, with the advent of supermarkets and more sophisticated supply systems, the proportion of locally grown produce has declined, as much produce is sourced out of region. In Northland this trend has disadvantaged local food producers. Returns are not much better than they were 20 years ago in dollar terms, but when inflation adjusted, growers' returns are eroded significantly. Consequently, the number of growers in Tai Tokerau has sharply declined. Up until the late 1930s, most distribution was local.[163]

In 1938 Tom Walder was a private agent and commission buyer for Whangarei retailers making twice weekly trips to Auckland. He joined with

Auckland's Turners & Growers to create subsidiary company Turners & Walder. Auctions began in 1956 according to Ron Corder

> …as the protective regulations to rail were removed and with more relaxation in the regulations to road transport which also coincided with the advent of supermarkets and the demise of the old greengrocer so did business at these depots decline with buyers coming to attend the auction at Whangarei.[164].

Now distribution systems are dominated by the supermarket supply chains, South African company Bidfood and 73% German owned Turners & Growers.

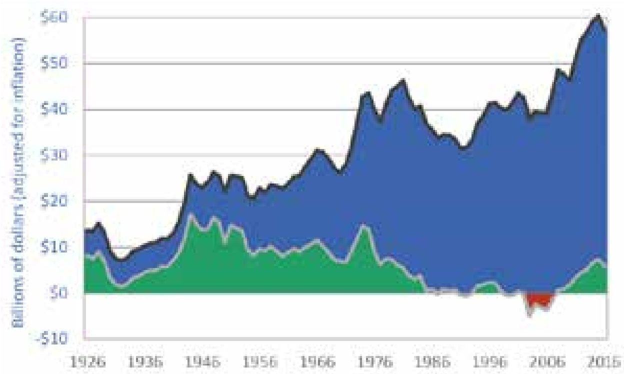


Figure 18: Canadian net farm income and gross revenue, inflation adjusted, net of government payments, 1926–2016[165]

In addition to political influences, commercial interests influence farmers' decision making. Agribusiness services extract a growing proportion of farm revenue. In New Zealand, the trend has been towards larger herds and greater production as farmers work to remain viable. This graph reveals the growing gap between farm revenue and net farm income. While this is based on Canadian data, similar trends are occurring globally. It is notable that the gap began to widen dramatically after World War Two, when markets had to be found for the production capacity of nitrogen, phosphorus and machinery.

In 2019, nearly 40% of U.S. farm income came from subsidies with a projected cost of $US88 billion [166] In India, since 1955, 300,000 farmers and farm workers have killed themselves. This is attributed to climate change and debt.[167].

Consumerism

Consumerism was supercharged after World War Two to further shape the food system. Industrial capacity mushroomed to equip the war effort and all of that enterprise had to find new markets. Marketers aligned production systems with a rethinking of societal design, to optimise market opportunities. The industrial machine was at full steam and needed willing customers. Victor Lebow articulated a new creed of consumerism.

> Our enormously productive economy … demands that we make consumption our way of life, that we convert the buying of goods into rituals, that we seek our spiritual satisfaction, our ego satisfaction in consumption… We need things consumed, burned up, replaced and discarded at an ever-accelerating rate.[168].

The marketers had new tools to shape the developing consumerist culture. Television offered unprecedented access for marketers into family homes. Victor Lebow lauds television's impact as having a captive audience, and a means of indoctrination, with access to the whole family [169] .

At the heart of many of the problems we identify with food is its change of status from something for nourishment to a marketable commodity. The need for industrial food manufacturers to enable food to last on long journeys to market and in warehouses and on shop shelves has necessitated processing. Sugar and salt preserve. Pasteurisation slows down decomposition and dehydration and chemical additives extend shelf life.

The food – health connection

This global-century-long transformation of world's food system has consumed huge resources, but not delivered optimum health outcomes for the majority of the people. Of the 7.3 billion people on the planet in 2015, 795 million were going hungry, two billion suffered from micronutrient deficiencies and 1.9 billion were obese or overweight. Tragically, 50% of the hungry are small-holding farmers.[170].

New Zealand's food system shapes poor food choices.

> Currently takeaways and dairies cluster around schools, particularly in the poorest neighbourhoods. There are more fast food outlets and convenience stores (like dairies, whose sales overwhelmingly comprise pies, soft drinks and sweets) in poor areas generally. Primary schools seem to attract more stores, although secondary schools were surrounded by higher levels of unhealthy food advertisements. The upshot of this is that the average child in Auckland has to walk less than 350 metres from the school gate to the nearest dairy, and under 400 metres to the nearest fast food outlet. Given what we know about the impact of sugary, fatty and salty food on the developing brain, it is hard not to draw a comparison with drug lords targeting the youngest and most vulnerable members of our society to get them hooked. It reminds you of the stated goal of one of the largest cola bottlers in the world, articulated in the 1990s, to ensure that there was cola for sale within 100 metres of every consumer on earth. (Gareth Morgan)[171]

Corporations selling food-like substances have a long and insidious reach. Coca Cola's marketers aspire to make their brand even more ubiquitous. "Through the stories we tell, we will provoke conversations and earn a disproportionate share of popular culture." [172].

The environment influences people's diet. Inuit, for example, eat a lot of Arctic wildlife. From a young age, most of the food children are exposed to in the media is nutritionally deficient. A 2007 study of television advertising in New Zealand found that 66% of food advertisements featured high fat, salt and sugar foods.[173]

Gareth Morgan offers contrasting scenarios of what our food system might look like.

> What can be hard to change is your community; if you live in a neighbourhood bristling with fast food joints, then you are likely to eat it. If, on the other hand, we live in an area with cycle lanes, foot paths, fruit trees growing on grass verges, communal gardens and farmers' markets, then we are more likely to exercise and eat well. These sorts of communities are blossoming all over the country…[174]

Appendix two: Soil, Pasture and Environmental Performance of a Site on an Organic and a Conventional Dairy Farm

An assessment of the soil condition, pasture quality and environmental performance, September 2019

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The original version of this report with the table of contents is available on the Regenerate Aotearoa website.

1. Executive Summary

The condition of the soil and the performance of the pasture was moderate and poor for the organic and conventional sites respectively with VSA scores of 19.5 & 16.5 at the organic site and 6.5 & 9 at the conventional site. The soil and pasture scores were also in sync with each other at both the organic and conventional sites, i.e. the performance of the pasture followed the condition of the soil.

All VSA indicators for the soil and pasture scored ≤1 for the conventional site. Only one of the soil indicators of the organic site scored ≤1 (Earthworms numbers) while only Pasture Utilisation scored above 1 (moderate) on the pasture scorecard. It is therefore the condition of the pasture at the organic site and both the soil and pasture at the conventional site that needs attention.

Being first and foremost a management tool, those VSA indicators scoring ≤1 highlight those areas that need to be addressed in the first instance. By focusing on and addressing each of the individual soil and plant indicators that are scoring ≤1 (moderate or poorer), the VSA provides a road map forward to improve production, profitability, environmental outcomes and quality of life on the farm.

With the exception of pH and Olsen P, the soil tests of the two sites were roughly similar. The pH of the soil at the conventional site could however do with lifting, ideally to 6.4. The amount of phosphorus present is also overly high as indicated by an Olsen P of 42 mg/L and high levels of P in the herbage (0.55%). By comparison, the pH of the soil at the organic site is good while the level of P in the herbage is also high despite an Olsen P of 23, a level that would be considered by many to be marginal. The results highlight the importance of having a herbage as well as a soil test to be able to gain an insight into the efficiency of nutrient uptake by the plant.

High K levels and low Ca, Mg and Na levels in the herbage at both sites could suggest there may be incidences of grass staggers, milk fever and bloat.

Except for Zn, B and Se, trace elements occur at satisfactory levels in the herbage from the conventional site while Fe, Mn, Zn, B, Co and Se are deficient in the herbage sample from the organic site. The low levels of Fe and Mn in the herbage from the organic site could be due to a suppression effect from the amount of Ca in the soil. No further application of Ca is recommended for some time at the organic site.

While the amount of sulphate-S is low in the soil at both sites, it is efficiently taken up by the plant which has good levels at both sites.

Molybdenum is high in the herbage at the organic site and could suppress the uptake and utilisation of copper. Adding sulphur-90 to the dung effluent and spread as a solid would lock up the Mo allowing Cu to be more efficiently utilised by the cow.

Trace elements are not added to the fertiliser at the conventional site and are applied in the water troughs at the organic site. If they are deficient in the herbage test, it is better to add them to the fertiliser because the body organs and glans of the cow can utilise nutrients more efficiently than if they were administered artificially as a ‘bullet’ for example.

While the infiltration rate of water into the soil was very rapid at both the organic and conventional sites, the infiltration rate was almost five times faster at the organic site. The greater infiltration rate at the organic site compared to the conventional site indicated a better soil structure, porosity and aeration status.

The organic site has 158.1 t C/ha in the upper 1 m of soil whereas the conventional site has 136.2 t C/ha. Compared to the conventional site, the organic site has 21.9, 17.6 and 10.6 more TOC in the upper 100, 60 and 30 cm depths respectively.

Given the benefits that soil C brings to the production, economic and environmental performance of a farm, soil C should be sequestered by adopting carbon farming management practices.

The organic site is potentially carbon neutral where soil C is in a steady state, i.e. it is neither increasing nor decreasing. The conventional site is potentially C negative where the amount of C could decrease.

While both the organic and conventional sites have a moderate potential for nutrient loss into the groundwater and waterways, the organic site has a lower potential for nutrient loss.

The organic site has a low potential to emit GHGs into the atmosphere while the conventional site has a moderate to high potential to emit GHGs.

2. Introduction

Two soils were investigated on two different land management systems on the 2nd July 2020 as a part of the Whakaora ngā whenua whāma study:

Utilising mātauranga Māori and Western science to protect and restore the soil on rural farms in Te Tai Tokerau.

One site was selected on an organic dairy farm running 130 cows on 90 hectares, and the other on a conventionally managed dairy farm running 130 cows on 50 hectares. Both sites are located 1.66 km apart at Mata, Whangarei (Fig. 1). They occur on the Waipu silty clay soil, a heavy textured (approx. 38% clay, 57% Silt and 5% sand), poorly drained Gley Soil formed from sedimentary river alluvium.

Figure 1: The organic farm is bottom centre and the conventional farm is top centre

Because the study was a pilot investigation with a limited budget, the soil and pasture properties were assessed at just the one site on the organic and conventional farms. As the study was limited in terms of its spatial coverage and statistical significance, it is not possible to make definitive conclusions. However, many of the measurements and the observations made were able to lay the foundation and justification for a more in-depth, definitive study.

3. Fertiliser regime

3.1 Organic farm

The organic farm applies folia spray applications of effluent from the pond which also has Biochar and Biozest included. The Biochar provides microsites for the soil nutrients and water to reside in while the Biozest not only provides nutrients but acts as a biostimulant, activating the microbes which convert the effluent solids to a liquid. The process also converts the nitrogen in the pond to less volatile nitrogen reducing the volatisation of N into the atmosphere by up to 67%. Shed effluent including dung and urine with Biozest mixed in is also spread on the farm as a solid. In addition, fifty kilograms of fine lime, two litres of molasses and 500 grams of seaweed per hectare are applied at least three to four times a year.

3.2 Conventional farm

The conventional farm applies 370 kg CropMaster, 300 kg of Muriate of Potash, 250 kg Sulphur Super 30 and 50 kg Sulphur 90 per tonne and spread over 50 ha at a spreadrate of 120 kg /ha. The nutrients applied at this rate would therefore be: 7.8 kg N/ha, 11 kg P/ha, 19.8 kg K/ha, 17.8 kg S/ha and 4.8 kg Ca/ha at a cost of approx. $567 per tonne. Six tonnes of this mix are spread annually on the 50 ha.

4. Visual Soil Assessment (VSA)

The VSA provides a quick and immediate method to visually assess the condition of the soil and the performance of the pasture, as determined by well-established principles of soil science and plant agronomy (Shepherd 2009).[1] The scores assigned to the VSA scorecards are also strongly dependent on and governed by farm management practices and as such the method is first and foremost a farm management tool.

Because the soil and the plant VSA scores were quite similar, the condition of the soil was in sync with the performance of the pasture at both sites (19.5 & 16.5 at the organic site and 6.5 & 9 at the conventional site). The two sites were, however, quite different in terms of their individual VSA scores. This would be a reflection of the organic and conventional management practices applied including the form of nutrients applied.

5. VSA Soil Scorecard

Using the abbreviated version of the scorecard for pastoral grazing (Appendix 1A), the Soil Quality Index score was 19.5 for the organic farm (just below a score of 21 required for a ranking of good) and 6.5 for the conventional farm. The topsoil of the organic site was therefore in moderate condition while the conventional site was in poor condition. The role and importance of each individual indicator given on the scorecard is described in blue text at the bottom of each indicator in the VSA.

The following are the individual scores assigned to each of the indicators.

1 *Shepherd, T.G. 2009. Visual Soil Assessment. Volume 1. Field guide for pastoral grazing and cropping on flat to rolling country. 2nd Edition. Horizons Regional Council, Palmerston North.*

5.1 Soil structure

Soil structure was moderately good (with a score of 1.5) at the organic site and moderate at the conventional site with a score of 1.0. This suggested among other things that the organic site was better aerated with better infiltration of water (Section 9.1). The organic site also had more organic carbon than the conventional site (Section 10.1). An organic compound is known to increase the resistance and resilience of a soil to treading damage. The poorer structure of the topsoil at the conventional site compared to the organic site could therefore be a function of extra treading pressures resulting from a higher stocking rate particularly when the soils are wet. The conventional site had a stocking rate of 2.6 cows/ha while the organic site ran 1.4 cows/ha.

In addition to the greater amount of carbon present, the better aerated state of the organic site explains in part the darker colour of the topsoil with a Munsell Soil Colour of 10YR4/3 (dark brown). The topsoil of the less well aerated conventional site with a poorer structure had a greyer Munsell colour of 10YR 4/1 (dark grey).

Further implications of Soil structure are given on pg. 17 of the VSA.

5.2 Number and Colour of Soil Mottles

The number and colour of soil mottles has a score of 1.5 (moderately good) at the organic site and 0 (poor) at the conventional site. The organic site is therefore better drained and aerated and less water saturated during the year than the conventional site. The additional degree of wetness of the conventional site and the resulting soil chemical reduction effect would suggest that the soil would suppress the uptake of N, P, K, S, Zn, Cu and Co. Nitrogen and sulphur would also be reduced to plant unavailable forms. This would indicate that while nutrient loading is not high as seen in Section 3, the N, P, K and S applied to the conventional site would be quite quickly suppressed and unable to generate a good response in grass growth.

The low score at the conventional site would indicate that artificial drainage using for example perforated piping could remove much of the excess water, improving the degree of aeration, nutrient uptake and increase dry matter production. While the conventional site has been artificially drained with Novaflo and mouldboard ploughing, there is a question as to how well the drains were functioning.

Further implications of the Number and Colour of Soil Mottles are discussed on pg 19 of the VSA.

5.3 Soil colour

Soil colour was moderately good at the organic site with a score of 1.5 indicating there was only a slight paling of the colour of the topsoil compared to the colour of the topsoil under a long-term fenceline. The colour of the topsoil at the conventional site had a score of 0.5 (moderately poor) indicating that the soil colour in the field was substantially paler than under the fenceline. While a change in soil colour in the field compared to that under a long-term fence line can potentially indicate a change in the amount of carbon in the soil, the degree of wetness under a pasture would have an overriding influence on the colour of the soil. The degree of wetness would produce grey (reduced) colours as discussed above.

With the decline in the soil structure and aeration affecting the redox potential of the soil, the greyness of the topsoil of the conventional site compared to the organic site could also be a function of extra treading damage resulting from the higher stocking rate at the conventional site compared to the organic site when the soils are wet as considered above.

Further implications of Soil colour are given on pgs 20-21 of the VSA.

5.4 Earthworms (numbers and size)

Very few earthworms were found at both sites with a score of 0. While numbers were well under 15 in the 200 mm cube sample of soil and therefore had a score of 0 (poor), the soils were very wet due to a recent very wet period that followed a prolonged, very severe drought. Such conditions are not conducive to encouraging earthworm numbers. While earthworm numbers also vary spatially, earthworm numbers were assessed on just the one hole which is insufficient to gain an indication of the likely number of earthworms. A minimum of four random locations in a paddock are necessary to be able to better gauge earthworm numbers.

The benefits of having a good earthworm population are given on pg. 23 of the VSA.

5.5 Soil smell

Soil smell was moderately good with a score of 1.5 at the organic site suggesting that the microlife in the soil may be moderately active. The implications of this would include a moderately good translation of the nutrients in the soil to the plant. This would explain in part the high level of P (0.49%) in the herbage sample relative to an Olsen P of 23 mg/L at the organic site (Appendix 2A). The moderately poor score of 0.5 for Soil smell at the conventional site would suggest the microbial biomass and activity was somewhat lower.

In addition to the difference in the degree of wetness between the two sites, the differences in Soil smell could suggest a difference in the amount and type of fertiliser used and the amount of soil C held in the soil. Studies of the DNA and RNA signatures of soil microbes have shown that quick release chemical fertilisers reduce the biomass of microbes in soil. The use of these fertilisers (Section 3) and the lower organic C levels (Section 10.1) at the conventional site would help explain the moderately poor soil smell at the site relative to the organic site.

The implications of Soil smell are discussed on pages 24-25 of the VSA.

5.6 Surface ponding

A score of 2 for Surface ponding at the organic site would indicate water does not accumulate on the surface after one day, something that was confirmed by the farmer. A score of 0.5 for Surface ponding at the conventional site suggested that water accumulated for quite a number of days during wet periods despite the Novaflo present and the mouldboard ploughing every 3-4 years. The widespread occurrence of soil particles on the pasture confirmed significant recent surface ponding. The ponding of water on the surface and the overall wetness of the soil would explain the greyness of the soil, a result of the strongly reducing environment as expressed by the “r” horizon notation assigned to each of the horizons below the A horizon.

The full implications of Surface ponding are discussed on pages 28-29 of the VSA.

5.7 Horizon notation

The above indicators are represented by the horizon notation assigned to the soil horizons at each site (Table 1). Soil horizons with the subscript notation “g” indicate the horizon is mottled with a dominance of orange and grey mottles while horizons with the notation “r” indicates the matrix base colour of the soil is grey and severely reduced due to a higher redox potential with very low oxygen levels. The severely reduced Cr horizon at the organic site occur at 65 cm+ whereas a Br horizon at the conventional site occurred further up the profile at 22 cm from the surface. The increased wetness of the soil in the lower horizons of the conventional site is confirmed by the higher water table and the higher volumetric water content of 47.2 % as against 36.5% at the organic site.

The degree of soil wetness at both sites, but particularly at the conventional site, would suggest that dry matter production gains would occur by the installation of an effective artificial drainage scheme.

Table 1 Horizon notation of the soil at the organic and conventional sites

Organic site		Conventional site	
Horizon notation	Horizon depth (cm)	Horizon notation	Horizon depth (cm)
Ah1	0 – 10	Ah1	0 – 10
Ah2	10 – 21	Ah2	10 – 22
Bwg	21 – 35	Br	22 – 35
Cwg1	35 – 45	Cr1	35 – 55
Cwg2	45 – 65	Cr2	55 – 80+ (watertable at 55 cm)
Cr	65+ (watertable at 70 cm)		

6. VSA Pasture Scorecard

6.1 Pasture quality

Pasture quality was moderate with a score of 1 at the organic site and moderately poor at the conventional site with a score of 0.5. While not great, the species diversity was better at the organic site with approximately 63% kikuyu, 25% ryegrass, 5% dichondria, 3% buttercup, 2% dock, 1% white clover and <1% daisies. The conventional site was almost entirely kikuyu.

A comparative Brix measurement wasn’t possible between sites because of the time difference and weather conditions, i.e. early afternoon was sunny and warm as against the late afternoon at the conventional site which was overcast and cold. There was a significant difference however recorded in the EC (electrical conductivity) of both the soil and the pasture sap between sites. The EC of the soil at the organic site was 280 S/m and the pasture sap was 3300 S/m. The EC of the soil at the conventional site was only 150 S/m and the pasture sap was 2800 S/m. The EC’s suggest the organic site has a greater ionic concentration of nutrients in the soil and pasture than the conventional site. Ideal EC values are 300-500 S/m for the soil and 3000-5000 S/m for the pasture sap. Unlike the Brix, the EC isn’t affected by the time of day or weather conditions. A combination of both the Brix and the EC provide a good indication of the ‘horsepower’ in the pasture to produce milk solids and live weight gain.

The importance of Pasture quality is discussed on pages 35-37 of the VSA.

6.2 Clover nodules

The performance of the clover nodules is moderate at the organic site with a score of 1 and moderately poor at the conventional site with a score of 0.5. While the results indicate a greater fixation of nitrogen by the clover nodules at the organic site, the herbage tests indicate there is a deficiency of Fe, Mn, Zn, Co and Se required to produce sufficient leghaemoglobin for the nodules to be able to fix N from the atmosphere. The conventional site on the other hand has good levels of Fe, Mn and Co and only Zn and Se may be deficient. The only possible explanation to explain this discrepancy is the overriding beneficial effect of the microlife in the soil at the organic site being able to provide the trace element concentrations required. To gain further insight, a clover-only analysis would be required.

The implications of Clover Nodules are discussed on page 39 of the VSA.

6.3 Pasture colour and growth relative to urine patches

The organic site has a moderate score of 1 for Pasture colour and growth relative to urine patches while the conventional site is moderately poor with a score of 0.5. This shows the latter site has a poorer quality pasture with a poorer, yellower growth of pasture between urine patches. This is also reflected in the lower EC values (Section 6.1) and in the herbage test results (see Section 7.2).

The implications of the Pasture Colour and Growth Relative to Urine Patches are discussed on page 43 of the VSA.

6.4 Pasture Utilisation

A moderately good score of 1.5 at the organic site compared to a moderate score of 1 at the conventional site would indicate the pasture is better utilised at the former site. This is to be expected given the higher EC (Section 6.1), the application of nutrients as a foliar spray and being organic, a greater uptake and utilisation of soil nutrients by a more active microbial biomass.

The full implications of the Pasture Utilisation are discussed on page 45 of the VSA.

6.5 Root Length and Root Density

The Root Length and Root Density was moderate with a score of 1 at the organic site and moderately poor with a score of 0.5 at the conventional site. This difference would be in keeping with the better structure and aeration of the soil at the organic site and the fact that it was less wet at depth. The better length and density of the roots at the organic site would also suggest that the pasture was better able to utilise the water and nutrients in the soil and would be more resistant to droughts. It is noteworthy that during the severe drought experienced between December 2019 to May 2020, the organic farm was noticeably greener than the conventional farm. A short but heavy rainfall event did however occur on the organic farm in Jan. 2020.

The implications of the Root Length and Root Density are discussed on page 46 of the VSA.

As mentioned earlier, the VSA is first and foremost a farm management tool, identifying issues that need to be addressed. With this in mind, by looking at and addressing each of the individual soil and plant indicators that are scoring ≤1, the VSA provides a road map forward to improve production, profitability, environmental outcomes and quality of life on the farm.

All the indicators for the soil and pasture scored ≤1 for the conventional farm (Appendix 1A & 1B), highlighting the need for specific farm management practices to raise the scores of both the soil and pasture and therefore the production and economic performance at the site. By contrast, only one of the soil indicators of the organic farm scored ≤1 (Earthworms numbers) and only Pasture Utilisation scored above 1 (moderate) on the pasture scorecard. This points to the need to focus on raising the performance of the pasture at the organic site.

7. Soil and Herbage Tests

7.1 Organic site (Appendix 2A)

While the organic site has good pH, P and Ca levels in the soil with low S levels, the herbage test indicates that P, K and Mo were high, S is medium and N, Ca, Mg, Na, Fe, Mn, Zn, B, Co and Se were low (Appendix 2A). The high levels of P and K and medium levels of S in the herbage can be explained by the efficiency of nutrient uptake from foliar fertilisers and by the presence and activity of P, K and S mineralising microbes because phosphatic, potassic and sulphur fertilisers weren't added to the foliar mix. Adding further P and K would exacerbate their already high levels.

The low levels of Fe and Mn in the herbage could be due to the high Ca levels in the soil suppressing their uptake by the plant.

The low level of N in the herbage is surprising because N is applied as a foliar from the effluent pond. This would suggest that the amount of N in the pond is lower than it should be because much has been volatised into the atmosphere. Raising the pH in the pond to 7.4 could correct this by increasing the microbial activity in the pond and therefore reducing the volatilisation of N. The low N levels in the herbage would also suggest that the microbial drawdown of atmospheric N and the mineralisation of soil N hasn't as yet established itself.

With a high pH of 6.6, a high % Ca base saturation of 75 and very high total Ca levels of 24.9 me/100g in the soil, it's hard to know why there's such a low amount of Ca in the herbage. This could be because Ca (and Mg) is being supressed by the high amount of K. The low levels of Mg, Na, Fe, Mn, and B in the herbage could also be due to the high amounts of Ca in the soil suppressing their uptake. My recommendation would be to delete any further application of the fine lime until such times as the level of the total Ca in the soil comes down to about 12 me/100g and the % Ca base saturation drops to 68–70. If the pH of the effluent pond is <7.4, the fine lime could be redirected to the pond to raise its pH.

Molybdenum is high in the herbage at the organic site and could suppress the uptake and utilisation of copper, inducing a potential Cu deficiency in the cow. Adding sulphur-90 to the dung effluent and spread as a solid would lock up the Mo allowing Cu to be utilised by the cow.

Selenium, a critically important trace element is low in the herbage with just 0.04 mg/100g. Dairy cows being a heavy weight animal require 0.1-0.15 mg/kg of Se. Trace elements are most efficiently utilised by the animal through the body organs and glans so a source of Se (and other trace elements) should be included as a foliar spray or in the solid dung application. Rather than meeting the trace element requirements of stock by adding the nutrients to the water troughs, add the trace elements to the fertiliser because the clover nodules and the soil microbes also require them.

While iodine is almost always low in the soil and herbage throughout NZ, it's a good option to add liquid stock iodine to the water trough six weeks before mating because like Se, iodine is a major fertility element.

The level of crude protein in the herbage only needs to be 20 % DM so at 24.9, the level is high enough. The amount of digestible organic matter in the dry matter (DOMD) needs to be about 75% so 74.3 % is good. While the common information portrayed will say that the metabolisable energy (ME) of 11.9 MJ/kgDM is good, ME as reported is a nonsense because it is simply a reiteration of the DOMD, reducing the high figure of 74.3 to a lower figure by multiplying DOMD by a constant (0.16); i.e. 74.3 x 0.16 = 11.9. In reality, there is more to assessing the energy in dry matter than DOMD and a constant.

The Grass Staggers Index (K/Ca+Mg) and the Bloat Index (K/Na ratio) are high because of the high levels of K in the herbage relative to Mg/Ca and Na respectively. While the K value is high, I doubt if the cows show much in the way of hypomagnesaemia and/or bloat. If grass staggers are apparent, simply resolving the Ca issue will address the grass staggers problem. Adding salt to the fertiliser mix and spray on as a foliar will resolve a bloat issue. In addition, the Na will raise the palatability of the pasture.

The Ca/P ratio is slightly on the low side because of the high P levels in the herbage but again it is doubtful that many cows would show signs of milk fever. If they do, resolving the Ca issue will solve this. The potential for milk fever is also indicated by the high DCAD Index (K+Na) – (S+Cl) of 334 me/kg. Apart from addressing the K and Na issues discussed above, adding S will help resolve the issue.

7.2 Conventional site (Appendix 2B)

Despite having high levels of Ca (14.1 me/100g) in the soil and a Ca %BS of 66, the conventional site has a pH of only 6.1. While Sulphur Super 30 contains a small amount of Ca (16%), the Ca is not associated with carbonate and therefore cannot lift pH. A lime product, particularly one that has Mg in it such as dolomite would be a good product to apply because it will help maintain Mg levels while lifting pH. The Mg will help to balance the application of Ca.

While the level of Ca and Mg in the soil is good, their uptake by the plant is poor. Again, like the organic site, the amount of Ca is low in the herbage possibly because of the low amount of Ca applied in the fertiliser and it being suppressed by the high levels of K in the herbage. The fertilisers applied do not contain any Mg.

While the amount of P in the soil is high with an Olsen P of 42 mg/L, the amount of P in the herbage is extremely high (almost off scale) suggesting that a phosphatic fertiliser doesn't need to be applied for some time.

The high levels of P and K in the herbage are due partly to the ready uptake of these elements from their soluble, quick release forms of fertiliser. CropMaster, Sulphur Super 30 and Muriate of Potash fertilisers containing P and K were applied just 4-6 weeks earlier.

Like the organic site, while the amount of sulphate-S in the soil is low, it is quite efficiently taken up by the plant which has good levels.

The amount of N in the herbage is marginal, a result possibly of the low amount of N applied in the fertiliser (7.8 kg N/ha), the highly soluble (and very leachable) form of the mineral N applied, and the poorly aerated state of the soil.

The amount of Fe, Mn, Mo and Co is good in the herbage, while Zn, B and Se is low; Cu is marginal. As mentioned above, trace elements are most efficiently utilised by the organs and glans of the animal and because the soil and plants (such as clover nodules) also require trace elements, they are most effectively applied to the soil rather than applied as injections, bullets, or in the water troughs. Sometimes for immediate effect, injections are a preferred and necessary option.

The greater amount of Fe, Mn and Co in the herbage from the conventional relative to the organic site could be due to the presence of the soil particles adhering to the pasture at the conventional site as a result of recent surface ponding.

The crude protein level of 26.6 % DM is higher than the 20% considered to be more than adequate and could suggest the cows may scour a bit. The amount of digestible organic matter in the dry matter (DOMD) of 75.8 % is good and converts to an ME of 12.1 MJ/kgDM by multiplying the DOMD by 0.16 (see above).

The Grass Staggers Index (K/Ca+Mg) and the Bloat Index (K/Na ratio) are high because of the high levels of K in the herbage relative to the levels of Ca/Mg and Na respectively. Some of the cows may show signs of hypomagnesaemia and/or bloat. If grass staggers are apparent, simply resolving the Ca issue by liming with preferably a form of Mg such as dolomite will address the potential of a grass staggers problem. Adding salt to the fertiliser mix will also resolve a potential bloat issue. Because salt is hydrophilic (water adsorbing), it needs to be mixed and applied immediately (on the same day) otherwise it should be applied separately. As mentioned above, the addition of Na will also raise the palatability of the pasture.

The Ca/P ratio is on the low side because of the high P levels and low Ca in the herbage. As a result, some of the cows may show signs of milk fever. If they do, resolving the Ca issue will solve this. The potential for milk fever is also indicated by the high DCAD Index (K+Na) – (S+Cl) of 372 me/kg. Apart from addressing the K and Na issues discussed above, adding more S will help lower the DCAD figure resolving the issue of possible milk fever.

A biological soil test of both the organic and conventional sites would shed a lot of useful information that would help explain and clarify the herbage test results.

8. Soil Infiltration

8.1 Infiltration rates

While the infiltration rate of water into the soil was very rapid at both sites, infiltration rates were almost five times faster at the organic site (a mean of 7700 mls/hr; standard deviation of 180 mm/hr) than the conventional site (a mean of 1600 mls/hr; standard deviation of 210 mm/hr). The greater infiltration rate of the organic site compared to the conventional site indicated a better soil structure, porosity and aeration status, a conclusion also derived from the VSA, the implications of which are discussed in Sections 5 & 6.

Fig. 2. Measuring the infiltration rate of water at the organic site using a double ring infiltrometer

8.2 Measurement of infiltration rates

The infiltration rate of water into the soil was measured at one location only at the organic and conventional sites using a double ring infiltrometer and applying Darcy's Law (Fig. 2). The purpose of an inner and outer ring is to create a one-dimensional flow of water through the inner ring where the second bigger outer ring helps control the vertical flow of water from the inner ring. The inner ring was 150 mm in diameter and the outer ring 300 mm. Both rings were 200 mm deep. Water was first poured into the outer ring and then using a falling head of water, 1760 mls of water was poured into the inner ring and the time required for it to disappear was recorded. The time required for 1060 mls of water to disappear in the inner ring at the conventional site was also recorded. The measurements were repeated until the flow rate came to an approximate equilibrium and the mean of the last four readings calculated.

A meniscus created by the surface tension of water at the tip of an inverted nail pushed into the top of the soil signalled when the water had disappeared. Both rings were gently pushed 10 mm into the ground, minimising any disturbance as much as possible. This was achieved because the soils were very moist and quite soft.

9. Soil Organic Carbon

9.1 Levels of total organic C

Total organic carbon levels (TOC) at the organic and conventional sites are given in Tables 2 & 3 respectively based on one site only. The organic site had 158.1 t TOC/ha in the upper 100 cm of soil while the conventional site had 136.2 T TOC/ha. Compared to the conventional site, the organic site has 21.9, 17.6 and 10.6 more TOC in the upper 100, 60 and 30 cm depths respectively.

Table 2. Total Organic Carbon in the upper 1m of soil at the Organic Site

Horizon	Horizon thickness (cm)	Dry bulk density (g/cm3)	Total organic C(g/100g)	Tonnes TOC/ha
Ah1	0 – 10	0.88	4.9	43.1
Ah2	10 – 21	1.12	2.6	32.0
Bwg	21 – 35	1.21	1.52	25.8
Cwg1	35 – 45	1.16	1.17	13.6
Cwg2	45 – 65	1.24	0.7	17.4
Cr	65 – 100	1.29	0.58	26.2
Total				**158.1**

Tonnes organic C/ha in the upper 60 cm = 127.5
Tonnes organic C/ha in the upper 30 cm = 91.7

Table 3. Total Organic Carbon in the upper 1m of soil at the Conventional Site

Horizon	Horizon thickness (cm)	Dry bulk density (g/cm3)	Total organic C(g/100g)	Tonnes TOC/ha
Ah1	0 – 10	1.04	4.0	41.6
Ah2	10 – 22	1.30	1.7	26.5
Br	22 – 35	1.29	1.24	20.8
Cr1	35 – 55	1.30	0.68	17.8
Cr2	55 – 100	1.31	0.50	29.5
Total				**136.2**

Tonnes organic C/ha in the upper 60 cm = 109.9
Tonnes organic C/ha in the upper 30 cm = 81.1

9.2 Measuring total organic C

TOC was determined by taking a soil sample from the entire thickness of each horizon and sent to the laboratory for analysis. The dry bulk density (DBD) was measured by taking a representative core (of known volume) from each horizon and the sample sent to the laboratory for analysis. Because of the nature of the errors associated with taking the DBD samples, the amount of C present could not be cited beyond one decimal point.

Using the data in Tables 2 & 3, the mount of TOC present at each site is also calculated in the upper 30 cm (the Kyoto Protocol requirement) and 60 cm. Because the lower depth of 65-100 cm could not be sampled because of the watertable, the DBD and the percentage of TOC were founded on an educated guess based on the data of the horizons above and experience. The amount of TOC present to 100 cm is therefore an assessment but it would not be too far from actual levels. The estimated values are given in blue in Table 2 & 3.

Because the TOC measurements haven't been made before, it is not possible to determine whether soil C has been sequestered under one management system compared to another or to be able to calculate possible carbon credits. The measurements do, however, provide a baseline against which any further measurements in the future can be compared. The potential for C sequestration at each site is however discussed further in Section 11.1 below.

9.3 Sequestering soil carbon

It is readily apparent from Tables 2 & 3 how much TOC is unaccounted for if the amount of TOC is only measured down to 30 or 60 cm depth. Disregarding the 60-100 cm depth is significant because in so doing, there is no way of assessing the potential sequestration of TOC that can occur by implementing carbon farming management practices including the introduction of deep rooting pasture species and cover crops. Carbon farming management practices include:

promoting the draw-down of the CO2 (containing C) in the atmosphere by encouraging the photosynthetic capacity and photosynthetic rate of plants by:

- increasing the amount of dry matter produced (the solar panels) including the sowing of cover crops
  - ensuring good species diversity with a deep root system
  - avoiding bare ground with no photosynthesising plants
  - ensuring good soil fertility
  - promoting the drought resistance of the soil
  - promoting the moisture uptake and moisture use efficiency of the plant
  - maintaining good pasture residual levels
  - avoiding over-grazing
  - minimising soil disturbance
- ensuring good soil biological properties.

9.4 Carbon credits

Carbon credits are an attempt to mitigate the growth in concentration of greenhouse gases (GHGs) where carbon credits can be sold as a means of lowering the carbon footprint of, for example, a farming enterprise. By putting a price on greenhouse gases, the Emissions Trading Scheme (ETS) encourages landowners to establish and manage a farm in a way that increases carbon storage. One carbon credit is equal to one tonne of carbon dioxide, or in some markets, carbon dioxide equivalent gases. A carbon credit traded at NZD33.55/tonne of CO2 on the 23rd July 2020.

While sequestering a significant amount of soil C over much of the area of the farm can mean a substantial financial return, the real benefit of sequestering C in the soil comes from all the advantages of building soil C mentioned below.

9.5 The significance of soil C

Soil carbon can be considered the holy grail of the farm because of the improved soil quality, productive, economic and environmental performance it brings. The significance of this becomes apparent when the benefits of soil C are seen. These include:

- C, H, O are the basis of all life
- C provides the building blocks for all the cell material of all organisms
- provides an important food resource for soil organisms
- is an important source and major reservoir of plant nutrients. Its decline reduces the fertility and nutrient-supplying potential of the soil
- is able to hold on to nutrients making them less leachable
- plays a key role in maintaining the cation exchange and buffering capacity of the soil including the buildup of heavy metals such as Cd, Pb, As
- provides a source of energy for fungi (being a heterotroph) and promotes dry matter production
- regulates most biological, chemical and physical processes in soil, collectively determining soil health
- helps develop and stabilise soil structure
- cushions the impact of wheel traffic and stock treading increasing the resistance and

resilience of the soil to structural degradation
- promotes infiltration, the movement and retention of water
- reduces the potential for wind and water erosion
- indicates whether the soil is functioning as a carbon 'sink' or as a source of greenhouse gases
- organic matter acts as a major reservoir of soil carbon
- sequestering sufficient soil C can completely offset all environmental emissions, not just agricultural emissions. The sequestration of carbon can therefore have a significant beneficial impact on the environment and climate change.

Because of the significance of soil carbon to a farm, every effort needs to be made and management practices put in place to increase the amount of organic C present in the soil. Accordingly, in addition to farming plants and animals, land users need to be carbon farmers.

10. Environmental aspects of each site

The Environmental Scorecards in the VSA provide a rapid and cost-effective assessment of the potential of a site to sequester soil C, emit nutrients in the groundwater and waterways, and emit greenhouse gases into the environments. The scores in **blue** and **red** are from the organic and conventional sites respectively.

10.1 The potential for Carbon Sequestration

While the amount of soil C has been measured establishing a baseline figure (Tables 2 & 3), the condition of the soil, the performance of the pasture and the amount and form of fertiliser applied described on pgs 56–58 of the VSA provides an indication of the potential of the soil at both sites to sequester soil C. The scorecard (Appendix 3A) suggests that the organic site is potentially C neutral with a score of **21**. Soil C is therefore in a steady state where it is neither increasing nor decreasing. A score of **13** at the conventional site (Appendix 3A) suggests that the soil is potentially C negative where the amount of C could decrease. The greater amount of soil C measured at the organic site (Table 2) compared to the conventional site (Table 3) is in keeping with the results on the scorecard.

10.2 The potential for Nutrient Loss into the Groundwater and Waterways

Given the condition of the soil, the performance of the pasture, the amount and form of nutrients applied, the stocking rate and the rainfall described on pgs 52–54 of the VSA and on the scorecard (Appendix 3B), both the organic and conventional sites have a moderate potential for nutrient loss into the groundwater and waterways. While the conventional site has a score of 22, the score of 29 at the organic site suggests it is approaching having a low potential for nutrient loss. This is in keeping with the higher amount of total organic C measured at the organic site (Tables 2 & 3).

10.3 The potential for Greenhouse Gas Emissions

Based on the condition of the soil, the performance of the pasture, the amount and form of N applied and the stocking rate described on pgs 60–62 of the VSA and on the scorecard (Appendix 3C), the organic site has a low potential to emit GHGs into the atmosphere with a score of 27.5. The conventional site has a moderate to high potential to emit GHGs with a score of 14.5.

11. Future direction

While the current study concludes that there are a number of significant differences between the soil, pasture and environmental performance of the organic and conventional dairy farms, given the limitations of interpreting the data at just the one site only on each farm, the study needs to widen its scope. The study could be expanded to include a number of sites on the organic and conventional farm (at least four) and the investigation extended to look at other organic and conventional farms.

It would be useful for any future direction to include an assessment of certain key performance indicators (KPI's) including economic indicators such as farm working expenses, return on capital, dollars generated per hectare, cost of producing a kg of milk solids, and indicators such as kg milk solids/ha/yr, milk solids per cow/yr, vet costs/cow/yr, pasture conversion efficiency (kg DM/kg MS), percent empties etc.

Appendix 1A VSA Soil Scorecards

Organic dairy farm

SCORE CARD

VISUAL INDICATORS TO ASSESS SOIL QUALITY UNDER PASTORAL GRAZING ON FLAT TO ROLLING COUNTRY (Abbreviated version)

SOIL INDICATORS

Land owner: Organic farm
Land use: Dairying
Site location: Pump paddock
GPS ref: 35°51'33.3"S 174°22'54.3"E
Sample depth:
Topsoil depth:
Soil type: Waipu silty clay
Soil classification: Gley Soil
Drainage class (p. 19): Poorly drained
Date: 2/7/20

Textural group (upper 1m): ☐ Sandy ☐ Coarse loamy ☐ Fine loamy ☐ Coarse silty ☐ Fine silty ☑ Clayey ☐ Peaty
Moisture condition: ☐ Dry ☐ Slightly moist ☐ Moist ☑ Very moist ☐ Wet
Seasonal weather conditions: ☑ Dry & ☑ Wet ☐ Cold ☐ Warm ☐ Average

Visual Indicators of Soil Quality	Visual Score (VS) 0 = Poor condition 1 = Moderate condition 2 = Good condition	Weighting	VS Ranking
Soil structure (p. 17)	1.5	×3	4.5
Number and colour of soil mottles (p. 19)	1.5	×2	3
Soil colour (p. 20)	1.5	×2	3
Earthworms (Number =) (p.22) (Average size =)	0	×3	0
Soil smell (p.24)	1.5	×2	3
Surface ponding (p. 28)	2	×3	6
SOIL QUALITY INDEX (Sum of VS rankings)			19.5

Soil Quality Assessment	Soil Quality index
Poor	< 12
Moderate	12–21
Good	> 21

If your soil quality assessment is moderate or poor, guidelines for sustainable management are given in Volume 2, Part One of the first edition of the VSA.

Conventional dairy farm

SCORE CARD

VISUAL INDICATORS TO ASSESS SOIL QUALITY UNDER PASTORAL GRAZING ON FLAT TO ROLLING COUNTRY (Abbreviated version)

SOIL INDICATORS

Land owner: Conventional farm
Land use: Dairying
Site location: Paddock 6
GPS ref: 35°50'43.0"S 174°23'19.9"E
Sample depth:
Topsoil depth:
Soil type: Waipu silty clay
Soil classification: Gley Soil
Drainage class (p. 19): Poorly drained
Date: 2/7/20

Textural group (upper 1m): ☐ Sandy ☐ Coarse loamy ☐ Fine loamy ☐ Coarse silty ☐ Fine silty ☑ Clayey ☐ Peaty
Moisture condition: ☐ Dry ☐ Slightly moist ☐ Moist ☑ Very moist ☐ Wet
Seasonal weather conditions: ☑ Dry & ☑ Wet ☐ Cold ☐ Warm ☐ Average

Visual Indicators of Soil Quality	Visual Score (VS) 0 = Poor condition 1 = Moderate condition 2 = Good condition	Weighting	VS Ranking
Soil structure (p. 17)	1	×3	3
Number and colour of soil mottles (p. 19)	0	×2	0
Soil colour (p. 20)	0.5	×2	1
Earthworms (Number =) (p.22) (Average size =)	0	×3	0
Soil smell (p.24)	0.5	×2	1
Surface ponding (p. 28)	0.5	×3	1.5
SOIL QUALITY INDEX (Sum of VS rankings)			6.5

Soil Quality Assessment	Soil Quality index
Poor	< 12
Moderate	12–21
Good	> 21

If your soil quality assessment is moderate or poor, guidelines for sustainable management are given in Volume 2, Part One of the first edition of the VSA.

Appendix 1B VSA Plant Scorecards

Organic dairy farm

SCORE CARD

VISUAL INDICATORS TO ASSESS PLANT PERFORMANCE UNDER PASTORAL GRAZING ON FLAT TO ROLLING COUNTRY (Abbreviated version)

PLANT INDICATORS

Visual Indicators of Plant Performance	Visual Score (VS) 0 = Poor condition 1 = Moderate condition 2 = Good condition	Weighting	VS Ranking
Pasture quality (Brix =) (p. 34)	1	× 3	3
Clover nodules (p. 38)	1	× 3	3
Pasture colour and growth relative to urine patches (p. 43)	1	× 3	3
Pasture utilisation (p. 45)	1.5	× 3	4.5
Root length and root density (p. 46)	1	× 3	3
PLANT PERFORMANCE INDEX (Sum of VS Rankings)			16.5

Plant Performance Assessment	Plant Performance Index
Poor	< 12
Moderate	12 – 21
Good	> 21

SUMMARY

Comparison of soil and plant scores		Do the soil and plant scores differ? If so, why?
SOIL INDICATORS	Plant indicators	

NOTES:

Total available water holding capacity:

Conventional dairy farm

SCORE CARD

VISUAL INDICATORS TO ASSESS PLANT PERFORMANCE UNDER PASTORAL GRAZING ON FLAT TO ROLLING COUNTRY (Abbreviated version)

PLANT INDICATORS

Visual Indicators of Plant Performance	Visual Score (VS) 0 = Poor condition 1 = Moderate condition 2 = Good condition	Weighting	VS Ranking
Pasture quality (Brix =) (p. 34)	0.5	× 3	1.5
Clover nodules (p. 38)	0.5	× 3	1.5
Pasture colour and growth relative to urine patches (p. 43)	0.5	× 3	1.5
Pasture utilisation (p. 45)	1	× 3	3
Root length and root density (p. 46)	0.5	× 3	1.5
PLANT PERFORMANCE INDEX (Sum of VS Rankings)			9

Plant Performance Assessment	Plant Performance Index
Poor	< 12
Moderate	12 – 21
Good	> 21

SUMMARY

Comparison of soil and plant scores		Do the soil and plant scores differ? If so, why?
SOIL INDICATORS	Plant indicators	

NOTES:

A Brix assessment was not done because it was too late in the day and had become quite cold and heavily overcast

Total available water holding capacity:

Appendix 2A Soil and Herbage tests of the Organic Site

Hill Laboratories
TRIED, TESTED AND TRUSTED

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

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Certificate of Analysis

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shvpv1

Client:	NorthTec	**Lab No:**	2398329
Address:	Private Bag 9019 Whangarei Mail Centre Whangarei 0148	**Date Received:**	08-Jul-2020
		Date Reported:	20-Jul-2020
		Quote No:	105989
		Order No:	1109940
		Client Reference:	
Phone:	09 470 3830	**Submitted By:**	Peter Bruce-Iri

Sample Name: Organic Ah1 — **Lab Number:** 2398329.1
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH	pH Units	6.6	5.8 - 6.2
Olsen Phosphorus	mg/L	23	20 - 30
Potassium	me/100g	0.43	0.40 - 0.60
Calcium	me/100g	24.9	4.0 - 10.0
Magnesium	me/100g	2.89	1.00 - 1.60
Sodium	me/100g	0.30	0.20 - 0.50
CEC	me/100g	33	12 - 25
Total Base Saturation	%	86	50 - 85
Volume Weight	g/mL	0.84	0.60 - 1.00
Sulphate Sulphur	mg/kg	5	10 - 12
Total Organic Carbon*	g/100g dry wt	4.9	

Base Saturation %	K 1.3	Ca 75	Mg 8.7	Na 0.9
MAF Units	K 7	Ca 26	Mg 55	Na 12

Sample Name: Organic MPast — **Lab Number:** 2400011.1
Sample Type: Mixed Pasture (P1)

Analysis		Level Found	Medium Range
Nitrogen*	%	3.8	4.0 - 5.0
Nitrogen*	%DM	4.0	
Phosphorus	%	0.49	0.38 - 0.45
Potassium	%	3.8	2.5 - 3.0
Sulphur	%	0.36	0.30 - 0.40
Calcium	%	0.49	0.60 - 1.00
Magnesium	%	0.20	0.20 - 0.30
Sodium	%	0.141	0.150 - 0.300
Iron	mg/kg	93	100 - 250
Manganese	mg/kg	47	60 - 150
Zinc	mg/kg	29	30 - 50
Copper	mg/kg	10	10 - 12
Boron	mg/kg	4	
Molybdenum	mg/kg	1.42	0.50 - 1.2
Cobalt	mg/kg	0.06	0.10 - 0.20
Selenium	mg/kg	0.04	0.05 - 0.15
Chloride*	%	1.70	0.30 - 2.4
Crude Protein*	%DM	24.8	20.0 - 30.0
Digestibility of Organic Matter in Dry Matter (DOMD)*	%	74.3	65.0 - 80.0
Metabolisable Energy*	MJ/kgDM	11.9	9.0 - 12.0

OMD in-vivo*	%DM	83.8	
Grass Staggers Index*	me	2.4	(<1.8 recommended, >2.2 increased risk)
K/Na Ratio*		27	(<10 recommended, >20 increased risk)
Ca/P Ratio*		1.0	(>1.5 recommended, <1.2 increased risk)
DCAD*	me/kg	334	(<200 recommended, >200 increased risk)

Appendix 2B Soil and Herbage tests of the Conventional Site

Hill Laboratories
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Hamilton 3240 New Zealand

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E mail@hill-labs.co.nz
W www.hill-laboratories.com

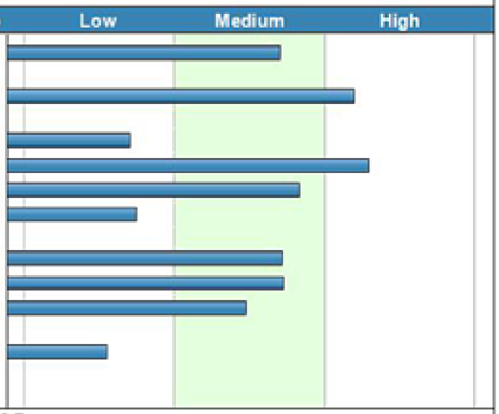
Certificate of Analysis

Client:	NorthTec	**Lab No:**	2398329
Address:	Private Bag 9019 Whangarei Mail Centre Whangarei 0148	**Date Received:**	08-Jul-2020
		Date Reported:	20-Jul-2020
		Quote No:	105989
		Order No:	1109940
		Client Reference:	
Phone:	09 470 3830	**Submitted By:**	Peter Bruce-Iri

shvpv1

Sample Name: Conventional Ah1 **Lab Number:** 2398329.11
Sample Type: SOIL Mixed Pasture (S1)

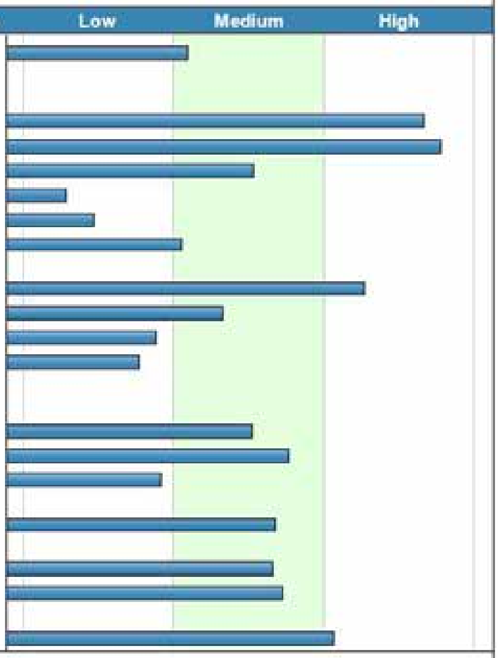
Analysis		Level Found	Medium Range
pH	pH Units	6.1	5.8 - 6.2
Olsen Phosphorus	mg/L	42	20 - 30
Potassium	me/100g	0.33	0.40 - 0.60
Calcium	me/100g	14.1	4.0 - 10.0
Magnesium	me/100g	1.50	1.00 - 1.60
Sodium	me/100g	0.15	0.20 - 0.50
CEC	me/100g	21	12 - 25
Total Base Saturation	%	76	50 - 85
Volume Weight	g/mL	0.79	0.60 - 1.00
Sulphate Sulphur	mg/kg	6	10 - 12
Total Organic Carbon*	g/100g dry wt	4.0	



	K	Ca	Mg	Na
Base Saturation %	K 1.5	Ca 66	Mg 7.0	Na 0.7
MAF Units	K 5	Ca 14	Mg 27	Na 5

Sample Name: Conventional MPast **Lab Number:** 2400011.2
Sample Type: Mixed Pasture (P1)

Analysis		Level Found	Medium Range
Nitrogen*	%	4.1	4.0 - 5.0
Nitrogen*	%DM	4.3	
Phosphorus	%	0.55	0.38 - 0.45
Potassium	%	3.9	2.5 - 3.0
Sulphur	%	0.35	0.30 - 0.40
Calcium	%	0.38	0.60 - 1.00
Magnesium	%	0.17	0.20 - 0.30
Sodium	%	0.159	0.150 - 0.300
Iron	mg/kg	398	100 - 250
Manganese	mg/kg	90	60 - 150
Zinc	mg/kg	29	30 - 50
Copper	mg/kg	9	10 - 12
Boron	mg/kg	3	
Molybdenum	mg/kg	0.87	0.50 - 1.2
Cobalt	mg/kg	0.18	0.10 - 0.20
Selenium	mg/kg	0.05	0.05 - 0.15
Chloride*	%	1.72	0.30 - 2.4
Crude Protein*	%DM	26.6	20.0 - 30.0
Digestibility of Organic Matter in Dry Matter (DOMD)*	%	75.8	65.0 - 80.0
Metabolisable Energy*	MJ/kgDM	12.1	9.0 - 12.0



OMD in-vivo*	%DM	86.0	
Grass Staggers Index*	me	3.0	(<1.8 recommended, >2.2 increased risk)
K/Na Ratio*		25	(<10 recommended, >20 increased risk)
Ca/P Ratio*		0.7	(>1.5 recommended, <1.2 increased risk)
DCAD*	me/kg	372	(<200 recommended, >200 increased risk)

Appendix 3A Visual Indicators to Assess the Potential for Carbon Sequestration

SCORE CARD

VISUAL INDICATORS TO ASSESS THE POTENTIAL FOR CARBON SEQUESTRATION UNDER PASTORAL GRAZING

SOIL & PLANT INDICATORS

Land owner: Land use: Dairying Date: 2/7/20

Site location: Pump Pdk & Pdk 6 GPS ref:

Soil type: Waipu silty clay Soil classification: Gley Soil

Drainage class (p. 19): Poorly drained Topsoil Depth:

Textural group: (upper 1m) ☐ Sandy ☐ Coarse Loamy ☐ Fine Loamy ☐ Coarse silty ☐ Fine silty ☑ Clayey ☐ Peaty

Visual Indicators of Soil Carbon Sequestration	Visual Score (VS) Organic	Visual Score (VS) Conven	Weighting	VS Ranking Organic	VS Ranking Conven
Textural group (p. 16) (Scoring protocol is given below[1])	2	2	x 2	4	4
Clay mineralogy (p. 56) (Scoring protocol is given below[2])	0	0	x 2	0	0
Soil colour (p. 20)	1.5	0.5	x 1	1.5	0.5
Earthworms (p. 22) (Number = ≤15) (Average size = Med.)	0	0	x 3	0	0
Potential rooting depth (mm) (p. 26)	1	0.5	x 3	3	1.5
Root length and root density (p. 46) 50 & 35 cm.	1	0.5	x 3	3	1.5
Pasture growth (p. 42)	0.5	0	x 3	1.5	0
Pasture colour & growth relative to urine patches (p. 43)	1	0.5	x 2	2	1
Amount and form of fertiliser and N applied (Scoring protocol is given below[3])	2	1.5	x 3	6	4.5
SOIL CARBON INDEX (Sum of VS rankings)				21	13

Soil Carbon Assessment	Soil Carbon Index
Soil is potentially carbon negative	< 16 ✓
Soil is potentially carbon neutral	16–30 ✓
Soil is potentially carbon positive	> 30

1 Textural group (Figure 1b, p. 16): VS = 2 for Clayey; VS = 1.5 for Fine loamy and Fine silty; VS = 1.0 for Coarse silty and Peaty (virgin land); VS = 0.5 for Coarse loamy; VS = 0 for Sandy and Peaty (developed land). Strictly speaking, peaty soils cannot be defined as a textural group; however, they are closely aligned to, and have a huge effect on, soil texture..

2 Clay mineralogy: VS = 2 if the soil is dominated by Fe & Al hydroxides and amorphous alumino-silica clay minerals with an anion storage capacity (ASC or P-retention) of > 85%; VS = 1 if the soil has moderate levels of Fe & Al hydroxides and amorphous alumino-silica clay minerals with an ASC of 60–75%; VS = 0 if the soil has little or no Fe & Al hydroxides and amorphous alumino-silica clay minerals; ASC is < 45%.

3 Amount and form of fertiliser and N applied: VS = 2 if 'smart' conditioner fertilisers are used, and N is applied as a foliar spray or in a carbon-friendly form in low amounts; or ≤ 30 kg N/ha/yr is applied as urea or in other non-carbon friendly forms of highly soluble, salt-based nitrogenous fertilisers; VS = 1 if moderate amounts of highly soluble, non-biologically friendly salt-based phosphatic & potassic fertilisers are used, and 60–90 kg N/ha/yr is applied as urea or in other forms of highly soluble, salt-based nitrogenous fertilisers; VS = 0 if high amounts of highly soluble, non-biologically friendly salt-based phosphatic & potassic fertilisers are used, and > 120 kg N/ha/yr is applied as urea or in other forms of highly soluble, salt-based nitrogenous fertilisers.

NB: A soil is carbon positive if there is a measurable increase in topsoil depth since the last assessment

Appendix 3B Visual Indicators to Assess the Potential for Nutrient Loss into the Groundwater and Waterways

SCORE CARD

VISUAL INDICATORS TO ASSESS THE POTENTIAL FOR NUTRIENT LOSS INTO THE GROUNDWATER & WATERWAYS UNDER PASTORAL GRAZING

SOIL & PLANT INDICATORS

Land owner: [redacted] Land use: Dairying Site: Pump Pdk&Pdk 6 Date: 2/7/20

Visual Indicators of Nutrient Loss	Visual Score (VS) Organic	Visual Score (VS) Conven	Weighting	VS Ranking Organic	VS Ranking Conven
Textural group (p. 16) (Scoring protocol is given below[1])	2	2	× 3	6	6
Soil structure (p. 17) (Scoring protocol is given below[2])	0.5	1	× 2	1	2
Potential rooting depth (mm) (p. 26)	1	0.5	× 3	3	1.5
Root length & root density (p. 46)	1	0.5	× 3	3	1.5
Pasture quality (p. 34)	1	0.5	× 3	3	1.5
Pasture colour & growth relative to urine patches (p. 43)	1	0.5	× 2	2	1
Amount and form of fertiliser and N applied (Scoring protocol is given below[3])	2	1.5	× 3	6	4.5
Stocking rate (Scoring protocol is given below[4])	2	1.5	× 2	4	3
Rainfall (mean annual) (Scoring protocol is given below[5])	0.5	0.5	× 2	1	1
NUTRIENT LOSS INDEX (Sum of VS rankings)				29	22

Nutrient Loss Assessment	Nutrient Loss Index
High potential for nutrient loss	< 17
Moderate potential for nutrient loss	17–32 ✓ ✓
Low potential for nutrient loss	> 32

1 **Textural group**
VS = 2 for Clayey; **VS = 1.5** for Fine silty; **VS = 1.0** for Fine loamy; **VS = 0.5** for Coarse silty; **VS = 0** for Coarse loamy & Sandy. If the soil has a humic or peaty textural qualifier (e.g. humic silty clay, peaty silt loam), add 0.5 or 1.0 respectively to the VS score. Note: VS scores cannot exceed a value of 2.

2 **Soil structure – Is the land most susceptible to a) leaching, or b) runoff?**
a) Land susceptible to leaching – Flat land with little or no runoff (overland flow)
VS = 2 for Poor soil structure; **VS = 1.5** for Moderately poor soil structure; **VS = 1.0** for Moderate soil structure; **VS = 0.5** for Moderately good soil structure; **VS = 0** for Good soil structure.
b) Land susceptible to runoff – Gently undulating to rolling land
VS = 2 for good soil structure; **VS = 1.5** for Moderately good soil structure; **VS = 1.0** for Moderate soil structure; **VS = 0.5** for Moderately poor soil structure; **VS = 0** for Poor soil structure

3 **Amount and form of fertiliser and N applied**
VS = 2 if using liquid foliar sprays or low water-soluble, salt-based fertilisers in low to moderate amounts. If using highly soluble, granular forms of N and fertiliser, < 15 kg P/ha/yr and/or ≤ 30 kg N/ha/yr are applied; **VS = 1.0** if using moderately water-soluble fertilisers in moderate amounts, or applying 25–35 kg P/ha/yr and/or 60–90 kg N/ha/yr using highly soluble, salt-based and nitrogenous fertilisers; **VS = 0** if using highly water-soluble, salt-based and granular nitrogenous fertilisers in high amounts where > 45 kg P/ha/yr and/or > 120 kg N/ha/yr are applied.

4 **Stocking rate** – kg liveweight (LW) per ha
VS = 2 if the LW is ≤ 1000 kg (≤ 2 cows*)/ha; **VS = 1.5** if the LW is 1250 kg (2.5 cows)/ha; **VS = 1** if the LW is 1500 kg (3 cows)/ha; **VS = 0.5** if the LW is 1750 kg (3.5 cows)/ha; **VS = 0** if the LW is ≥ 2000 kg (≥ 4 cows)/ha. [* assuming a cow of 500 kg liveweight]

5 **Rainfall** (mean annual)
VS = 2 if RF < 600mm; **VS = 1.5** if RF 600–900mm; **VS = 1** if RF 900–1200mm; **VS = 0.5** if RF 1200–1500mm; **VS = 0** if RF > 1500mm.

Appendix 3C Visual Indicators to Assess the Potential for Greenhouse Gas Emissions

SCORE CARD

VISUAL INDICATORS TO ASSESS THE POTENTIAL FOR GREENHOUSE GAS EMISSIONS UNDER PASTORAL GRAZING

SOIL & PLANT INDICATORS

Land owner: [redacted] Land use: Dairying Date: 2/7/20

Site location: Pump Pdk & Pdk 6 GPS ref:

Soil type: Waipu silty clay Soil classification: Gley Soil

Drainage class (p. 19): Poorly drained Topsoil depth:

Textural group: (upper 1m) ☐ Sandy ☐ Coarse Loamy ☐ Fine Loamy ☐ Coarse silty ☐ Fine silty ☑ Clayey ☐ Peaty

Visual Indicators of GHG Emissions	Visual Score (VS) Organic	Visual Score (VS) Conven	Weighting	VS Ranking Organic	VS Ranking Conven
Textural group (p. 16) (Scoring protocol is given below[1])	2	2	× 2	4	4
Soil porosity (p. 18)	1.5	1	× 3	4.5	3
Number and colour of soil mottles (p. 19)	1.5	0	× 3	4.5	0
Soil Colour (p. 20)	1.5	0.5	× 1	1.5	0.5
Pasture quality (p. 34)	1	0.5	× 2	2	1
Pasture growth (p. 42)	0.5	0	× 2	1	0
Pasture colour & growth relative to urine patches (p. 43)	1	0	× 2	2	0
Amount and form of N applied (p. 62) (Scoring protocol is given below[2])	2	1.5	× 2	4	3
Stocking rate (Scoring protocol is given below[3])	2	1.5	× 2	4	3
GHG EMISSION INDEX (Sum of VS rankings)				27.5	14.5

GHG Emission Assessment	GHG Emission Index
High potential for GHG emissions	< 14
Moderate potential for GHG emissions	14–26
Low potential for GHG emissions	> 26

1 Textural group (Figure 1b, p. 16):
VS = 2 for Sandy and Coarse loamy; VS = 1.5 for Coarse silty; VS = 1.0 for Fine loamy; VS = 0.5 for Fine silty; VS = 0 for Clayey and Peaty. Strictly speaking, peaty soils cannot be defined as a textural group; however they are closely aligned to, and have a huge effect on, soil texture.

2 Amount and form of N applied:
VS = 2 if N is applied as a foliar spray or in controlled release and bio-friendly forms of fertiliser in low amounts; or ≤ 30 kg N ha/yr is applied as urea or in highly soluble, salt-based nitrogenous fertilisers
VS = 1 if 60–90 kg N/ha/yr is applied as urea or in highly soluble, salt-based nitrogenous fertilisers
VS = 0 if > 120 kg N/ha/yr is applied as urea or in highly soluble, salt-based nitrogenous fertilisers

3 Stocking rate – kg liveweight (LW) per ha:
VS = 2 if the LW is ≤ 1000 kg (≤ 2 cows*)/ha; VS = 1.5 if the LW is 1250 kg (2.5 cows)/ha; VS = 1 if the LW is 1500 kg (3 cows)/ha; VS = 0.5 if the LW is 1750 kg (3.5 cows)/ha; VS = 0 if the LW is ≥ 2000 kg (≥ 4 cows)/ha.
[* assuming a cow of 500 kg liveweight]

Research team biographies

Dr Benjamin Pittman

Benjamin (Ngāpuhi: Ngāti Hao – Te Popoto; Te Parawhau; Ngāti Hau), was one of the first graduates with a BFA from Elam School of Fine Arts (University of Auckland, New Zealand) in 1971. He graduated MFA with First Class Honours in 1977. As well as being one of the first graduates, he was the very first graduate of Māori descent with both degrees. Completing teacher training in 1971, and pursuing a career as an art educator in New Zealand (1971-79) Benjamin complete further masters and doctoral degrees in Australia, has worked and lived in Australia, Hawaii and France and has exhibited work in New Zealand, Australia, USA, France, UK, Japan, Germany, Italy and Canada.

Benjamin draws inspiration for his art for the natural world and this is reflected in his community work for social and environmental justice and his support for this project. He is the Chair of Creative Northland and deeply involved in a number of Māori organisations including chairing Te Pouwhenua o Tiakiriri Kūkupa Trust Board, Te Parawhau ki Tai and is Secretary of the Wairau Māori Art Gallery Charitable Trust.

Dr Mere Kepa

Dr Mere Kepa is a Research Fellow of the University of Auckland. In health research, Dr Mere Kepa has a lengthy tradition of fostering International links with Indigenous Peoples ageing successfully, and critically thinking about a future in an Aotearoa New Zealand where cultural diversity and innovation are keenly valued. Since retiring from a full time research role and returning to Takahiwai, Mere has remained actively involved in research, and community activism including her role as Lead Convener, Pest Strategy, for the Takahiwai Hills and Forest.

Mere's grounding in both mātauranga Māori and the academic world have enabled her indispensable contribution to this project.

Marcus Williams

Marcus is an Associate Professor Creative Industries and Director Research and Enterprise at Unitec Institute of Technology. Appointed in 2014, he has led Unitec to a position of strength in applied research over the last five years. As an example, he advocated and facilitated key appointments which led to the creation of Ngā Wai a te Tūī, the Unitec kaupapa Māori research centre which officially opened in 2019. As another, with Unitec being ranked the top ITP (Institutes of Technology and Polytechnics) in the 2018 Performance Based Research Fund (PBRF) portfolio assessment, he has been invited by Minister Salesi to serve on the PBRF review panel. Unitec is successful in managing large research projects, holding MBIE, National Science Challenge and HRC research funded contracts for example.

Marcus holds a Masters of Fine Arts from RMIT University and a Bachelor of Photography from the University of Auckland. In his personal research, he is interested in creative practice as an agent of social change and has led several highly collaborative, transdisciplinary projects with multiple complex outputs, two of which are outlined below in order to demonstrate his experience in leading and delivering on large, multi-stakeholder projects.

Marcus is also a climate change champion and has facilitated the establishment of regenerative agriculture projects. He made this project possible and has contributed to a project design that draws together mātauranga Māori, agriculture science and practice and the arts.

Research team biographies

Graham Shepherd

Graham is a soil scientist and agricultural consultant running his independent agricultural and fertiliser advisory company BioAgriNomics. He is the author of Visual Soil Analysis which has been widely adopted in New Zealand and internationally. The Food and Agricultural Organisation of the United Nations contracted Graham to produce an edition for their use. He established the company in part to help bring clarity to the mixed messages often given to the farming community. Graham specialises in linking soil conditioning, plant nutrition, animal health and farm productivity with 'smart fertilisers' and smart farm management practices. This includes the development of good soil physical, chemical and biological properties to promote crop and pasture production, pasture quality and stock performance. The natural capital of the farm is maximised to improve farm productivity, food quality and environmental outcomes. Graham focuses closely on the biological condition (the engine room) of the soil and economic performance of the farm.

Catherine Murupaenga-Ikenn

Catherine (Ngāti Kuri and Te Rarawa; BI/B.Soc.Sci, LLM) has a background in Government policy and law. In the new the millennium, she returned home to work for her people, focusing on areas such as Treaty claims settlements, environmental protection and climate change. Since being awarded a United Nations Indigenous Human Rights Fellowship in 2005, Catherine maintained her keen interest in human rights protection. A strong advocate for the (now established) Bachelor of Applied Management's Māori Enterprise Major at NorthTec, she left teaching to serve as a Senior Indigenous and Minorities Human Rights Fellow with the UN Office of the High Commissioner for Human Rights Pacific Regional Office.

Peter Bruce-Iri

Peter Bruce-Iri was born and raised at Te Kōpuru. He holds a Masters in Management and a National Diploma in Horticulture. Peter has had a passion for organic production and the environment for all his adult life. His current research is about regenerative food systems and climate change.

Peter was a founding director of Local Food Northland in 2016 and in 2017 was the lead convenor for the Local Food Northland Conference and then the Tai Tokerau Climate Change Action Conference in 2018. Peter is a founding trustee of the Climate Change Tai Tokerau Northland Trust, one of the outcome of the conference. Peter has established a network of regenerative farmers and works to promote regenerative agriculture and support the development of a community of learning. A recent research output is an article on the climate crisis and change processes. Peter recognises that engagement is essential to achieving change.

A veteran educator, Peter has led programme development and accreditation initiatives, including the recent Māori Enterprise Major for NorthTec's business degree. Peter is an associate member of the Ngāti Pū hapū, through marriage to Huria Bruce-Iri.

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Whakaora ngā whenua whāma

Utilising mātauranga Māori and Western science to protect and restore the soil on rural farms in Te Tai Tokerau.