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## Exploring indigenous Māori soil health concepts in Aotearoa-New Zealand

Garth Harmsworth<sup>1</sup> (Te Arawa, Ngāti Tūwharetoa, Ngāti Raukawa)

<sup>1</sup>Manaaki Whenua – Landcare Research NZ Ltd,  
Private Bag 11 052, Palmerston North 4442, New Zealand

E-mail: [HarmsworthG@LandcareResearch.co.nz](mailto:HarmsworthG@LandcareResearch.co.nz)

**ABSTRACT.** A Government funded science project “soil health and resilience: oneone ora, tangata ora” (2016–2021) was carried out to support the development of a longer-term and more comprehensive view of soil health and resilience within Aotearoa-New Zealand and to develop an integrated soil health framework that can be used by a wide range of end-users. As part of this research programme we conducted work with a wide variety of indigenous Māori groups and organisations to understand the range of perspectives, values, central concepts, and knowledge of soils and soil health. This indigenous research has run in parallel to a science led theme of work. We provide a summary of findings, to help elevate the importance of land and soils for indigenous peoples, to build research capability and capacity with (and within) indigenous groups, and to articulate and explain indigenous soils knowledge, values, and concepts to a variety of end-user groups including, tribal groups (e.g. iwi/hapū) and Māori organisations themselves, and outwardly to non-indigenous researchers, central and local government, business, industry, land managers, and land owners. Our goal is to show the importance of Māori knowledge in research, planning, and policy, and to improve discussions on the management of land and soils in future.

**Key words:** indigenous Māori, values, land, soils, soil health, indigenous knowledge, transdisciplinarity

## INTRODUCTION AND BACKGROUND

Te toto o te tangata he kai, te oranga o te tangata, he whenua, he oneone  
While food provides the blood in our veins, our health is drawn from the land and soils

Soils are being degraded and destroyed globally at an alarming rate (MEA 2005; Koch et al. 2012, 2013; Global soil partnership 2012; UN 2015; FAO 2015, 2017; OECD 2017; Field et al. 2017; Baritz et al. 2018; IPCC 2019a,b). This ranges from destruction and removal of soil for urban-built environments, settlement, and infrastructure under increasing local populations, highly modified landscapes, desertification, salinisation, high rates of erosion from steep land and cropping land, destruction of natural habitats and large-scale biodiversity loss, loss of forest soils and habitats, to degradation of agricultural soils through unsustainable intensive land use management practices. The degradation of agricultural soils includes rapid declines in soil carbon and fertility, loss of soil biology and microbes, increased soil compaction, increasing salinity and acidification, sea level rise and flooding, and increased rates of soil erosion from cropping and desertification. On top of this is an alarming increase in contaminated sites worldwide. Loss of soil and soil degradation is often expressed as a move towards poor soil condition, declining soil quality, declining soil health. This decline goes hand in hand with a burgeoning global human population of now around 8 billion, projected to be ~10 billion by

2100, creating enormous pressures on our fragile environments, planetary ecosystems, and resources.

A large number of land and soil issues are reported in Aotearoa-New Zealand (A-NZ). Extensive soils monitoring (e.g. soil carbon, physical-chemical, nutrients), especially since the 1990s, is being carried out regionally by local Government and science researchers. These findings are often aggregated and summarised at the national level in state of environment reports (PCE 2016, 2019; MfE & StatsNZ 2018, 2019, 2021, 2022). These reports show a large number of soil issues ranging from large-scale erosion (e.g. mass movement) in mountainous and hill country, flooding and deposition on lowlands and floodplains, declining soil health under intensive agriculture, soil fertility issues, nutrient load issues under intensive land use and management (e.g. dairying, cropping), to increasing water quality issues associated with intensive agriculture and urbanisation, rapid loss of highly productive agricultural soils, especially under urban development and increasing land fragmentation (MPI & MfE 2019, 2020), and increasing local land/soil contamination issues. A-NZ was extensively deforested in the mid-late 1800s to the early 1900s and converted to extensive grassland with only 23% of the country now covered in indigenous forest, mainly in mountainous terrain. This extensive transformation of the natural landscape of A-NZ – intrinsically linked to centuries of indigenous Māori cultural values, tribal landmarks, and communal land status – followed a largely colonial vision based on European values, where multiple introduced new land uses with exotic vegetation cover, settlement patterns, individual ownership title and property boundaries, roads and infrastructure, replaced extensive indigenous ecosystems and habitats. Most floodplain, lowland, and rolling-hill country areas (around 50% of A-NZ) are now in large-scale pastoral farming systems with cropping and horticulture on the best soils. Production forestry (e.g. *Pinus Radiata*) covers ~8% of the country generally on poorer and hillier soils. Māori land title and customary ownership now only represent around 1.4 million ha or 5% of the total A-NZ land area.

An increasing array of work globally is trying to understand the range of values associated with nature (Diaz et al. 2018; Ellis et al. 2019; Chan et al. 2012, 2016, 2018, PBL 2018; Pereira et al. 2020; Lundquist et al. 2021) with some specific focus on the importance of soils (Shumei 2015; Stronge et al. 2020, 2022; Friedrichsen et al. 2021; Kannemeyer et al. 2022). In terms of values, soils are not rated highly and often forgotten as an essential building block of natural capital, ecosystem services, culture, life, food, fibre, well-being, and human indigenous values. Particular focus has been on soils as an essential food base (Schreefel et al. 2020) and from an indigenous perspective (TWKO 2011 Hutchings 2015; Hutchings & Smith 2020; Hutchings et al. 2012). In A-NZ there has generally been poor understanding of indigenous knowledge, values, and concepts, especially to support research, planning, and policy. Indigenous rights in A-NZ are recognised and enshrined under the Treaty of Waitangi, a legal document signed in 1840 between the British monarchy (the Crown) and indigenous Māori at the tribal level (iwi/hapū). The Treaty, through its framework and principles (participation, partnership, protection of customary rights), has gained prominence in most forms of A-NZ legislation and policy, and many Treaty settlements are redefining resource management (e.g. co-governance arrangements, indigenous rights explored) and influencing national planning and policy through various acts of legislation (e.g., Treaty of Waitangi Act 1975, Waikato River Settlement Act 2010, Te Urewera Act 2014, Whanganui River Claims Settlement 2017, Ruru 2018) often resulting in co-design of national policy and governance frameworks, and the widespread incorporation of indigenous frameworks, concepts and language.

## A GOVERNMENT FUNDED SOIL HEALTH PROGRAMME

A Government funded science research programme *Soil health and resilience: oneone ora, tangata ora* (C09X1613, 2016–2021) was developed to explore concepts of soil health and resilience. It used two main research streams: one science oriented and one indigenous led. A third research stream was used to bring the science findings and indigenous knowledge and values together, incorporating social science research on societal pluralistic values (Booth et al. 2019; Kannemeyer et al. 2022) into an integrated framework (Lauder et al. 2018; Stronge et al. 2020) to better define soil health to inform policy, planning, and management practice and achieve stated outcomes such as healthy soils and healthy ecosystems, and identify links between soils and human well-being (Stronge et al. 2020, 2022). The indigenous research part of the programme documented indigenous knowledge of soils, explored Māori values and Māori concepts of soil health, and developed a framework for indicators (Harmsworth 2018a,b,c,d 2019, 2020a; Hutchings 2020; Hutchings & Smith 2018, 2020a,b; Hutchings et al. 2018; Roskrige 2020). The programme worked across a diverse range of Māori groups in A-NZ: from those more commercially (production) focussed groups such as agribusiness and the industry sector (e.g. horticulture, dairying, sheep and beef farming) to those at the more traditional cultural and spiritual end of the spectrum, typically local Māori communities, local landowners and gardeners, traditional knowledge experts, a Māori organics collective (e.g. Te Waka Kai Ora), iwi/hapū (tribes), and marae (social and cultural centres throughout A-NZ). At the agribusiness/industry end, Māori groups were generally more comfortable with, and reliant on, mainstream science and soil health definitions and indicators for assessing soil health and land productivity. At the cultural-customary end, groups wanted more holistic integrated concepts largely framed on Māori belief systems, concepts, knowledge, and values. At conclusion, most groups wanted a complementary mix of land assessment, evaluation, and monitoring approaches that embraced indigenous knowledge and values next to science. At the more traditional knowledge end of the spectrum, we utilised frameworks and concepts from traditional knowledge experts, iwi/hapū (tribes) the Māori organics movement, landowners and local gardeners, Māori schools (kura), and marae groups, especially those with gardens and horticultural training. Key findings and interviews from this work were documented in the book “Te Mahi Oneone” Hutchings & Smith 2020.

### Science definition of soil health

Much scientific literature has described terms such as soil quality (e.g. Andrews et al. 2002; Arshad et al. 1996; Carter et al. 1997; Davidson 2000; Doran 1994; Doran & Jones 1996; Doran & Parkin 1996; Sparling & Schipper 2002, 2004; Mackay et al. 2013; Bünemann et al. 2018), soil condition as used in soil security (Koch et al. 2013; McBratney et al. 2014, 2017a, 2019; Montanarella & Panagos 2021) and soil health (Doran & Safley 1997; Doran 2002; Doran & Zeiss 2000; Moebius-Clune et al. 2016; Kibblewhite 2018; Slater 2018; Rinot et al. 2019; Ng & Zhang 2019; Lehmann et al. 2020). There have been several recent reviews of soil quality and soil health that discuss this evolution (see for example Bünemann et al. 2018; Kibblewhite 2018; Rinot et al. 2019) through to holistic indices for assessing soil health (Rinot et al. 2019; Lehmann et al. 2020). Although individual definitions of soil health differ, they generally divide soils into three primary components: physical, chemical, and biological. However, the diversity and variability in soil types, properties, and qualities (both spatially and temporally, e.g., Stockdale et al. 2019) mean that finding biochemical and physical indicators that can be used practically to provide meaningful information to support soil management decisions is difficult (Lehmann et al. 2015; Kibblewhite 2018; Slater 2018). Soil health was a term initially

used to understand the biological component (Doran & Safley 1997; Lehmann et al. 2015, 2020) of soils along with development of indicators (Doran & Zeiss 2000; van Bruggen & Semenov 2000) that could express more information about biological or microbial diversity (e.g. including microorganisms, bacteria, and genetics, e.g. Neal et al. 2020). The ecological functioning of soils and the effects of degradation on soil ecology have become an increasing focus for soil science (McNiell & Winiwarter 2004; Haygarth & Ritz 2009; Robinson et al. 2012). More recently, many authors have stressed understanding soils and soil health from an economic perspective (Bowman et al. 2016; Stevens 2019), supporting natural capital and ecosystem services (Dominati 2013; Dominati et al. 2010, 2016; Samarasinghe et al. 2013a, b, McBratney et al. 2017b; Lehmann et al. 2020), regenerative agriculture (Schon et al. 2013), and contributing to international sustainable development goals (Keestra et al. 2016, 2018; Bouma 2019, 2020) and links to human health and well-being (Steffan et al. 2018; Stronge et al. 2020; Friedrichsen et al. 2021).

Defining whether a soil is of high or low or good or bad quality, whether it is healthy or unhealthy, rests on the perceived suitability of the soil for its intended end use, function or purpose (Sparling & Schipper 2004). A further consideration is the degree of modification a soil requires to be suited to its intended use (Cornforth 1998), which encompasses the notion of fitness for future use. McBratney et al. (2014) stated, “There is little value in talking about the health of any given soil, unless there is an understanding of how healthy it can actually be”.

A-NZ has been formally monitoring soil health since the late 1990s (Sparling & Schipper 2002, 2004; Sparling et al. 2001, 2008; Lilburne et al. 2004; Stevenson et al. 2020; MfE and StatsNZ 2018, 2021; Statistics New Zealand Environmental Reporting Series) and was influenced by early work, such as the publication by The Soil Science Society of America (SSSA) of ‘Defining Soil Quality for a Sustainable Environment’ (Doran 1994). This document illustrated the state of dynamic soil properties that could be quantitatively measured and described, thereby providing a foundation for land assessment where the quality or health of the soil system could be assessed and reported. In A-NZ the selection of soil indicators followed a rigorous process of choosing a minimum data set that could provide a balance of production versus environmental needs. Seven measures were selected to provide information on organic reserves, fertility, acidity, and physical status of our soils (i.e. total C, total N, pH, Olsen P, mineralisable N, bulk density, and macroporosity). Each indicator is measured against target or optimal ranges for a number of key land uses, e.g., pastoral grassland (drystock/sheep/beef v dairy), cropping, forestry, horticulture, and native forest (Sparling et al. 2008), and collectively they give an indication of soil health status and can detect any subtle changes. Although the system attempts to balance agronomic and environmental concerns, the emphasis (as elsewhere in the world) is on the biochemical and physical aspects of soil over social or cultural dimensions (Lauder et al. 2018; Booth et al. 2019).

In this study we started with the overarching definition: “soil health is the continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals and humans” (Natural Resources Conservation Service – USDA-NRCS 2012; Moebius-Clune et al. 2016; Bowman et al. 2016; Lehmann et al. 2020). We agreed that soil health invokes the idea that soil is an ecosystem full of life and needs to be carefully managed to regain and maintain its ability to function optimally. As our project progressed our understanding of soil health became much deeper and more holistic, based on the human and social dimension, human pluralistic values, and links to well-being, including values and concepts from an indigenous Māori perspective.

## RESULTS AND FINDINGS

### Māori beliefs

Māori knowledge (mātauranga Māori) of soils and concepts of soil health is shaped by a Te Ao Māori world view and belief system (Best 1924; Buck 1950; Marsden 1988; Barlow 1993; Mead 2003; Timoti et al. 2017). This goes back to the time of creation, the origins of space and time, the earth, the sky, the land and water, through centuries of traditional knowledge, customs, and practice. The belief system often starts with the nothingness, the void (Te Kore), moves through the night and darkness (Te Pō), to the origins of a world as we know it, with the primordial parents Papatūānuku (earth mother) and Ranginui (sky father) separated by one of their progeny to form the world of light (wheiao, Te ao mārama). In traditional knowledge, there were around a total of 70 departmental Atua (gods, deities) who presided over every domain of the earth and biosphere. In this world of light an intimate bond developed between humans and ecosystems, moving between spiritual and physical worlds. Knowledge was created in the world by one deity ascending to the 12<sup>th</sup> heaven and bringing the knowledge back in three kete (baskets) for humans to use wisely. Knowledge was revered. In terms of the environment, landscape and soils, this understanding of knowledge, concepts, and wisdom starts with a deep understanding of Māori language (te reo Māori), a key that unlocks knowledge for use in a modern world. Many words, concepts, and terms are used to describe the environment in every sense stressing reciprocal links between human beings and nature (Harmsworth & Awatere 2013; Morris 2020; Proctor & Harmsworth 2020). Most Māori introduce themselves through pepeha (a statement of connection between place and people), linking themselves to the mountains, rivers, lakes, and sea from which they draw their identity and place in the world. An example of this bond is ‘*Ko te whenua, nga wai me te tangata, Kotahi tonu*’ which means the land, the waters, and people are one and the same (Ngāhuia Lena from Boasa-Dean & Bryce-Hare 2020).

Ancestral stories and traditional knowledge reiterate a strong connection between indigenous Māori and soils, and place Māori – through whakapapa (ancestral lineage) – inside – as part of ecosystems – rather than outside or on top of the soil ecosystem. The complete life cycle, starting with birth and ending in death, was frequently acknowledged. The first woman, Hineahu-one (the female element) was said to have been created from soil (a red clay from a specific location) (Harmsworth 2020a). In terms of death, narratives include, e.g. when the demigod Māui failed to convince Hine-nui-te-pō, goddess of the underworld, to let humans die like the moon (die and return) she told him, ‘*Me matemate-a-one*’ (let humans die and become like soil) (Harmsworth 2020a). Māori connection to the environment is often expressed through traditional proverbs and sayings (whakataukī, whakatauākī) such as *Ka mau tonu ngā tāonga tapu o ngā matua tupuna, koinei ngā tāonga i tuku iho, nā te Ātua*/ Hold fast to the treasures of the ancestors, for they are the treasures that have been handed down to us by God.

### Māori key concepts

Indigenous Māori have been observing and interacting with their environment for centuries. The traditional Māori worldview acknowledged a natural order to the universe, a dynamic system built around the living and the non-living, and the central belief was that all parts of the environment were interconnected and interdependent through the domains of ngā atua or departmental gods. Within this system, mauri (life force, life principle, vitality, essence) is a key concept used to explain the inherent qualities or energy of a resource or system to sustain life and well-being. If the mauri is weak, the resource is degraded or contaminated; if the mauri

is strong, the system remains resilient and healthy. Traditionally, Māori believed that small shifts in the mauri or life force of any part of the environment, for example, through use or misuse, would cause shifts in the mauri of immediately related components, which could eventually affect the whole system. All activities and relationships with the environment were governed by mythology, religion, and Māori values (Best 1924, Buck 1950). Within this framework, spiritual qualities guided resource use through an elaborate system of tikanga (customary practice, values, ethics), kawa (local protocols, rules and process), and ritenga (custom, regulation, likeness), with goals to sustain and enhance the well-being of people, communities, and natural resources (Harmsworth & Awatere 2013). In terms of soil health, indigenous Māori typically strive to understand the whole system, its interconnections and interdependencies, in order to distinguish what is healthy, what is not healthy. The need to understand values and find balance and permanence in the system is always emphasised (Barlow 1993; Marsden 1988; Harmsworth & Awatere 2013).

### **Māori knowledge – mātauranga Māori**

Māori have a long history of understanding the importance of soils, describing and differentiating soils, often highlighting the best soils for certain crops, land qualities, best land, poor land, the characteristics of a soil, cultural soil resources, practice and use. Over 100 traditional indigenous Māori names exist for soil (Table 1); and most parts of the landscape are described in detail (Best 1925; Williams 1975, Harmsworth 2002; Harmsworth & Roskrige 2014a,b; Boasa-Dean & Bryce-Hare 2020; Roskrige 2020; Harmsworth 2020b; Morris 2020; Harmsworth & Taura 2022), with many descriptors (e.g. for degrees of wetness, stoniness, depth, texture, colour, etc.). Although most of the soil names have originated at a local level, many are now used and understood generically at a national level (Table 1).

**Table 1. Selected examples of Māori soil names**

<b>Māori soil names and English description</b>	<b>Māori soil names and English description</b>
Oneone – general name for soil	Kenepuru – sandy silt, alluvial
Onemātua – typically loam, fertile soil of silt and sand containing humus	Parahua – silt
Whenua taepu - loam	One-pārakiwai – silt
Onemata – dark fertile soil	Paru, paruparu – mud, dark mud
One pū – rich soil, consisting of clay, sand and decayed organic material	Kere was used as a prefix for many types of clay, including:
One paraumu – very dark fertile soil, friable, humus	Keretū, onekeretū, keremātua, kerewhenua
Onetakataka – a friable soil	Keretū, Keretā – heavy clay
Onewawata – a lumpy soil	Kere whenua – yellow clay
Pūngorongoru – a light, loose soil (soft spongy)	Kerepi, Kerepehi – sod, clod
One haruru – light but good soil, sand and loam	Kōtore, pākeho – white clay
Onekōkopu – gravel or very gravelly soil	Uku – unctuous clay, white or bluish clay
One-pū – sand	Uku whenua – plastic clay (old traditional name)
One hunga – sea sand, sandy beach, sometimes mixed with mud	Ūkui – wash, wipe away
	Rei – Peat

Onetai, taipū, onetaipū – sandy soil, sand dune One tea – light sandy soil, white soil, sandy volcanic material Pungapunga (also purupuru) – pumice soils Pungarehu – ashes	Onekopuru – An organic soil found in wet situations
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Māori have always had some understanding and reference to what constitutes good quality land, poor quality land, whether fertile, infertile, healthy, or unhealthy. Many Māori terms were used for fertile land versus poorer quality or exhausted land and soils (Table 2).

**Table 2. Māori terms (examples) for good quality land versus poorer land and soils**

<b>Māori names and English description</b>	<b>Māori names and English description</b>
Haumako – to be fertile, rich, productive Whai hua – fertile Mōmona – rich fertile land, in good condition Whakamōmona – enrich, make fertile Opīhi, pīhi – the place of good growth, plants springing up Makurutanga – abundance, fertility Tāmata – a new cultivated site Whakapara, whakaparapara – burning woody remains for incorporation as ash; adding compost Pātohe – an abandoned cultivation site or fallow site Ngakinga – garden plots, cultivation Maara kai – gardens	Titōhea, hūiki, tohetea; hahore – land barren or exhausted through cultivation Pākihi – to be dried up, barren land Koraha – infertile, barren land Akeake – poor land, infertile land Pūtutu – stunted, barren land Tuakau – sterile land, wasteland, barren land Pākeka – land exhausted through cultivation Whenua pākeka – poor land Pūwhenua, taekai, pāhoahoa – exhausted lands, barren, infertile (cf. sterile) Tuakau – inferior lands, waste lands, bog Hahore – barren land, desolate, infertile, unproductive land Kīrea – land exhausted by frequent cropping Rake – bare or barren ground (whakarake – to make bare)

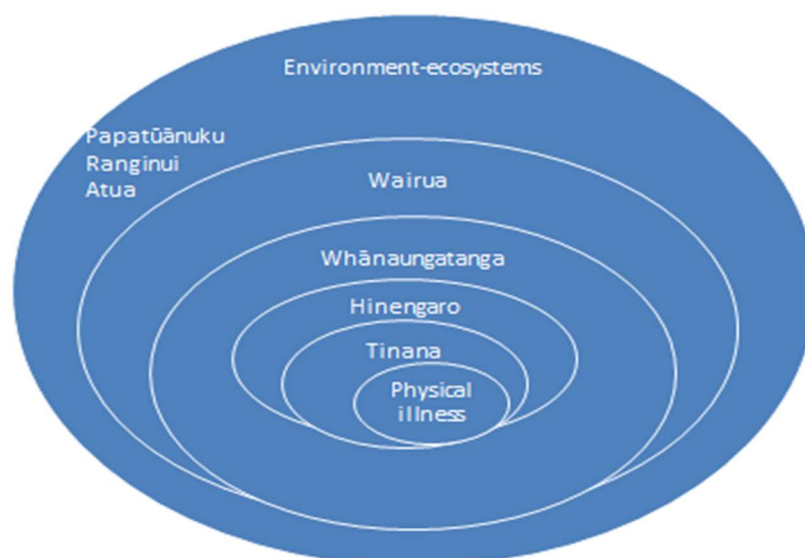
### **Māori well-being and health**

Māori frameworks and concept models tend to locate Māori at the centre of ecosystems (Fig. 1) and regard a healthy soil as one “capable of supporting, maintaining, and enhancing life and well-being” through “maintaining and enhancing the mana, mauri and wairua” of its essential intrinsic qualities and related components. Connections between environmental health and human well-being are significant (Durie 1994; Harmsworth 2014, 2018d, 2020a; Bruce-Iri et al. 2020; Boasa-Dean & Bryce-Hare 2020; Stronge et al. 2020); cultural and spiritual values are inextricably linked to the natural environment and provide the basis for sustainability (Toitū whenua, te ao turoa, whakapūmautanga, taonga tuku iho).

Fundamental to Māori well-being (oranga, hauora, whaiora, toiora) are cultural and spiritual identity and sustenance (Durie 1994, 1999, 2003) based on whakapapa (ancestral lineage), family and social relationships, and integral connections between individuals, whānau (family), and the environment (e.g. landscapes, ecosystems). Environmental models and frameworks of health (Harmsworth & Awatere 2013; Awatere & Harmsworth 2014; Harmsworth 2020a) are



often based on Māori health concepts and models (Durie 1994, 1999, 2003; Boasa-Dean & Bryce-Hare 2020) of tinana (the physical body or material state), hinengaro (the mental state or condition), whanaungatanga (the associated or family state of relationships) and wairua (the spiritual dimension), or matawairua (Boasa-Dean & Bryce-Hare 2020) (Fig. 1). Lack of access to cultural resources, alienation from land and resources, and the declining condition or quality of land or soil resources (e.g. degradation) can all greatly impact on human health and well-being with an overall decline in cultural, social, and spiritual well-being.



**Figure 1. Links between human health well-being and the environment/ecosystems fit within Māori creation stories and belief systems of Papatūānuku (the earth mother), Ranginui (the sky father), and atua domains (gods, deities).**

### Interviews and case studies

From many forums, case studies, workshops/wānanga, hui, and face-to-face interviews, a very small sample of the wealth of information and knowledge given through interviews and conversations was documented to become important excerpts/statements for the soil health programme (e.g. Boasa-Dean & Bryce-Hare 2020; Coffin & Coffin 2019; Coffin 2020; Hutchings & Smith 2018; Hutchings et al. 2018; Harmsworth 2018a,b 2019; Hutchings 2020; Hutchings & Smith 2020b; Roskrige 2020) and helped shape our conceptual thinking, providing a knowledge base. Selected examples, stressing the links between health/well-being, land and soils (Hutchings & Smith 2020), are given below:

“Furthermore, Māori are connected to their lands through Hine-ahu-one (goddess of soil), created by Tāne who sought the female element. Our name as tangata whenua (people of the land) is derived from the creation and whakapapa (ancestry) of these tupuna (ancestors)” (HW 2017).

“We are soil, we come from soil, we live on soil, we will return to the soil; this signifies its central importance to us and demonstrates our deep relationship with and belonging to Papatūānuku” (JH).

“What is missing around the kaitiaki of our soils is the deep understanding of the whakapapa of our soils” (HW 2017). “Through whakapapa Māori have an inextricable relationship to the land and natural resources” (NR). “It is almost impossible to speak of the soil, of your whenua tīpuna, of your papakāinga and one tapu without providing an insight into her whakapapa and personality” (TBD & RNBH on Ngāhuia Lena).

“Whakapapa defines what a healthy soil is, it comes from our whakapapa, we define ourselves from our pepeha, our land. So whatever happens to the soil happens to me; when we are disconnected from our soil, our land, it also affects our physical, spiritual, and mental health....The indicators and measures of soil health can be seen in the place names, the geographical whakapapa” (HW 2017).

“Papa Oranga ki a mātou – soils are so important to me because they exemplify my health, my well-being, who I am – ko wai ahau, nō hea ahau, tōku whakapapa me ngā tikanga e pā ana ki tōku mana arā ka puta ko te kōrero mana whenua” (MP 2017).

“For soil health you should use ‘papa oranga he aha ai? kia whakatōhia te mana o Papatūānuku ki roto i te whenua’, so I respect soil, it has mana more than that it has a mauri” (MP 2017).

“Soil health: “the optimal state and condition of soils to support an intended land use and sustained productivity level, and to ensure the optimal soil resource is in place for future generations” (Blair Waipara, land development manager, Te Tumu Paeroa).

“It is particularly important to enhance the mauri of the soil by enhancing its fertility, structure and biological activity” (Te Waka Kai Ora 2011).

“She would often say ‘he ngakingaki kaari kē taku mahi nātemea he matenui au ki ōku pākeke’, meaning I till (work) these gardens because of the great love I have for my parents and grandparents whose hands worked these soils before me (TBD & RNBH). The soil is said to be the puku or digestive system of Papatūānuku (earth mother)” (TBD & RNBH). “The water is the life blood of the whenua, and the whenua is the life blood of humanity” (TBD & RNBH).

“Ngāti Kahu is reconnecting with its long tradition of gardening. Kaumātua and whānau members are sharing stories and inspiring a new generation to learn more about soil and gardening (AC) (Coffin & Coffin 2019; Coffin 2020). Kahu was widely known as a good provider of kai for his people – from hunting, gathering, and cultivation – and these qualities gained him the leadership of the hapū (AC) (Coffin & Coffin 2019; Coffin 2020).

“Capable of supporting, maintaining, and enhancing life and well-being” (from the soil health programme workshop 2018).

“In all cases, healthy soils sustain healthy people” (research programme wānanga 2018).

### **Māori values**

Māori values (Barlow 1993; Mead 2003; Ataria et al. 2019) guide behaviour, responsibility, and action. Values and concepts translate to practices and actions to maintain or enhance the soil resource. Māori have developed comprehensive resource management practices over centuries to manage, sustain, improve, and enhance natural resources, more recently taking on

board science, food technology, innovation, in combination with more traditional approaches and practices based on mātauranga Māori (Māori knowledge and values) (e.g. Raskin 2009; Harmsworth & McDowall 2011; Hutchings et al. 2017; Māori land online, Whenuaviz on-line tool, Tupunz on-line tool, Māori maps, Mauri whenua ora tool, Whenua Life Values on-line tool, Kohuratia; Reid et al. 2021). Important Māori concepts include kaitiakitanga (environmental guardianship, caretaker-ship, e.g. Hutchings et al. 2017), an active exercise of giving benefit to the resource, including reciprocity (tau utu utu, giving back what you take, e.g. Harmsworth & Awatere 2013; Reid et al. 2021). Strong links are given in this environmental guardianship to have authority (mana, rangatiratanga) to make wise decisions for sustaining natural resources. Many of these traditional approaches in distinct geographic (local) areas are based on tikanga, kawa, and ritenga. Ritenga can include tapu (restricted or closed access to a resource or sacred site), rahui (temporary restriction), and noa (open access and permitted activity) (e.g. Barlow 1993; Ataria et al. 2016). A number of core values and principles for understanding what constitutes a healthy soil from a Te Ao Māori perspective (Table 3) were identified during the soil health programme (Hutchings et al. 2018; Hutchings 2020; Harmsworth 2020a).

**Table 3. Core indigenous values/principles integral to understanding soil health**

Māori core values/principles	Description
Whakapapa	Recognising the ancestral links or lineage of the soil originating from the Māori belief system (Papatūānuku and Ranginui, Te Ao Marama, and Atua (gods, deities, domains)) and links to tangata whenua (e.g. whānau/hapū/iwi). Strengthens understanding of inter-dependencies and inter-connections between ecosystems, plants, animals, and humans.
Mana	Power, prestige, and authority. Giving respect to the soil resource, elevating the importance and prestige of soils, thereby giving them mana. Also the mana, authority, and responsibilities of human beings to care for, govern, protect, and manage the soil resource in accordance with local tikanga and kawa (customs and values). Recognises the Treaty of Waitangi – Te Tiriti o Waitangi – as an over-arching framework to reinforce this mana.
Mauri	Life force or energy, vitality and continued capacity of a soil to sustain/support healthy living ecosystems, including the basis or support for human well-being, e.g. a well-functioning soil ecosystem has the capacity to maintain inter-connections between the physical, chemical, biological components of soil, plants, animals, microbes, and people and restore balance in the system to sustain health and well-being.
Wairua	The spiritual dimension/soul/connection to soil and land – helps provide the glue to maintain and strengthen mana and mauri to achieve a healthy soil and human well-being, through spiritual endeavour and practice.
Taonga tuku iho	Soil is a treasure passed down through the generations and has an ancestral lineage and connection. Soil health can be maintained by building inter-generational capacity to care for the soil resource through kaitiakitanga (e.g. values driven guardianship to give wise-land use options that sustain soil health and well-being).
Maramataka	Based on the Māori lunar calendar, climate, weather, and seasonal variations, guiding cultivation, and planting and harvesting activities

Māra kai/Māhinga kai	Ability of soil to provide healthy food (kai) for sustenance and well-being.
Oranga, waiora, toiora	Ability of a soil to provide and ensure health and well-being of whenua (land), plants, animals and humans A well-functioning soil free of harmful pollutants, contaminants, pathogens, and toxicity.
Tau utuutu	Giving back what you take, an active exercise of benefit to the resource (e.g. soil) through environmental guardianship (kaitiakitanga), shown through careful management and practice.
Kaitiakitanga	Cultural and environmental guardianship, as a responsibility, to protect and manage the environment embracing all the values above.

### Soil management practices

Practices to sustain and enhance the soil resource typically draw on a blend of traditional, historic, and modern Māori knowledge, alongside science-based approaches (Bruce-Iri et al. 2021; Roskrige 2020, 2021). Values often guide best management practice and activities in the field and on the ground. A range of publications on Māori agriculture, gardening and horticulture have explained and shaped soil management practice from the earliest (Best 1925) to the recent more specialised methods, for example, crop production and traditional foods (Roskrige 2011, 2012). Mātauranga Māori and science together have resulted in publications specialised on pests and disease of traditional Māori crops such as potato (taewa) and kumara (Roskrige et al. 2012) and those providing a resource base for the establishment and management of māra kai/local gardens (Roskrige 2021). All these have provided a wealth of information about the management of soils to promote soil health and healthy food, especially building on oral knowledge passed through generations and families (whānau) and tribes (iwi/hapū). Hua Parakore (Te Waka Kai Ora 2011; Hutchings 2015; Hutchings and Smith 2020b) is one example of a Māori led approach, where the Māori values, philosophy and verification system is used as a key knowledge source for soil management and practice based on Te ao Māori. Within hua parakore practices and actions are devised and implemented to reach a pure or uncontaminated state, for example, to sustain and enhance the mauri of the soil, maintain and enhance the mana and wairua of the soil, improve fertility, maintain structure and texture to achieve balanced soil health, improve texture, add sand, gravel, stones, pH, improve drainage, air and porosity, maintain wetness and moisture levels, maintain or increase organic matter and carbon, increase humic levels, encourage worms and microbes, redistribute and recycle nutrients, add natural fertilisers, etc., to bring balance and vitality back to the soil. Practices can include for example (Table 4).

**Table 4. Indigenous Māori practices for maintaining and enhancing soil health**

<b>Examples of soil management practices based on Māori values and knowledge (mātauranga Māori) and science to achieve Māori aspirations</b>
<ul style="list-style-type: none"> <li>• Growing and maintaining a healthy functioning soil, nurturing the soil and its foods</li> <li>• Retiring land from production, giving it a spell to rest or recover and build up fertility/nutrients and structure</li> <li>• Mulching soil, using natural compost (e.g. organic waste (non-human), using animal manure and waste, seaweeds, food scraps, straw, grass clippings, compost, plant remains</li> <li>• Use minimum tillage, retire overused (exhausted, degraded) areas, resting land (whenua), using rotation practices to sustain soil health</li> </ul>

- Maintain or increase organic matter and carbon, increase humic levels, encourage worms and microbes, redistribute and recycle nutrients, add natural fertilisers, nutrients to find a balance, maintain pH and fertility, nitrogen levels, etc.
- Improving texture, adding sand, gravel, stones, to improve drainage, air and porosity, stability, maintain wetness and soil moisture levels
- Suppressing invasive and exotic weeds
- Reducing and eliminating pesticide and artificial fertiliser use
- Using and regulating seed stock, protecting indigenous seed stock
- Promoting indigenous biodiversity within productive and ecological farming systems, diversification, regenerative agriculture, cultural landscapes (e.g. protecting cultural sites, selection of crops, native forest planting, riparian planting, wetland restoration)
- Increasing plant and soil biodiversity, plant species diversity (away from monocultures)
- Reducing soil erosion (e.g. cropping techniques, retiring steep hill sides)
- Using the maramataka (Māori lunar calendar, e.g. seasons, months) to guide all practices e.g., cultivation and planting times, harvest
- Using shade and cover when required
- Embedding wairua and customary values into all practices (e.g. maintaining the spiritual component, use of prayers or karakia, use of local customary protocols)

### **Māori soil indicators**

In the last 20–30 years, a large number of publications have cited indigenous-led environmental monitoring approaches, with international reviews (e.g. Thompson et al. 2020) and much activity in A-NZ (Harmsworth 2002; Tipa & Tierney 2006; Harmsworth et al. 2011, 2016; Lyver et al. 2017, 2018; Reid 2018a,b; Reid et al. 2013; Rainforth & Harmsworth 2019). In terms of monitoring soils, international soil studies have increasingly emphasised the need for an improved understanding of the soil biology and the importance of the soil biota and fauna to provide a fuller picture of soil health (e.g. Doran & Safley 1997; Doran & Zeiss 2000; Lehmann et al. 2015; Neal et al. 2020; Schon et al. 2021). The use of farmer knowledge as a basis to improve soil health monitoring (Testen et al. 2018) – in particular the use of farmer knowledge of soil fauna – has also been promoted (e.g. Pauli et al. 2016; Lobry de Bruyn 2016). Fewer examples are given explaining the need for using indigenous soil knowledge to underpin the monitoring of soils, for soil management or sustainable agriculture (e.g. Handayani et al. 2010), and fewer still are specific to Māori knowledge and values in A-NZ, with the majority of Māori studies of soils still documented in traditional and historic manuscripts such as Best (1925), or those from archaeological studies (e.g. Furey 2006). Scarcely any projects have discussed the need for developing indigenous knowledge-based indicators for land or soil monitoring. In terms of contemporary requirements, the notable works of Peters (2006) and Bruce-Iri et al. (2020) have explored Māori and iwi/hapū values at the land block farm level. Many indigenous-led studies have used indigenous knowledge to frame and understand connections between land, soils, and food security (Raskin 2009; Roskrugge 2011, 2012; Roskrugge et al. 2012; Hutchings 2015; Reid & Rout 2016; Howard et al. 2020), with a consistent theme stressing the important connection between food, soil, and Māori well-being (Hutchings 2015; Bruce-Iri et al. 2020; Harmsworth 2020; Howard et al. 2020). In terms of Māori soil indicators and soil health assessment, there has been widespread interest in adapting the visual soil assessment method (Shepherd 2000; Shepherd et al. 2000a,b; Shepherd & Janssen 2000) alongside more indigenous knowledge-based and kaupapa Māori led approaches (Harmsworth 2018; Bruce-Iri et al. 2020). This is largely attributed to the pragmatism of the

visualisation approach, and its close affinity with describing and assessing the life forms in soil, using observation, and describing periodic change. All these studies provide useful guidance for the future development of indigenous frameworks, methods, and indicators for land and soils.

Whatever indicators are used to assess condition or soil health, we should be aiming at a more complete picture of soil condition and soil health for decision-making, and, in the long term, to achieve sustainable land management and soil security (Reid 2018b; de Bruyn et al. 2017, 2019). As stated by many authors “there should also be indicators that can be embraced and understood by wider society as well as scientists” (McBratney et al. 2014), where soil health can be viewed through a broader set of indicators, including those based on indigenous knowledge (Harmsworth 2017; Hutchings et al. 2018; Rout et al. 2019). Some early development of soil health indicators based on Māori concepts and knowledge has been carried out (Bruce-Iri et al. 2020; Harmsworth 2018a,b,c, 2019, 2020a,b). Much of this combines Māori knowledge (mātauranga Māori) and western science to help plan, protect, and manage soils across Aotearoa.

Māori have traditionally referred to indicators as “tohu”, tūtohu, or “tohotohu” which means signposts in the environment or markers of change, to guide, instruct, and advise (Harmsworth 2017). Many core Māori values and traditional knowledge practice provide a basis for soil indicator development, including those values from the Hua Parakore framework (Hutchings 2015; Hutchings et al. 2018), such as: knowing and describing the soil based on a te ao Māori worldview; the soils location and cultural activities and uses associated with them; their location within the landform; connecting people to land and soil (knowing its whakapapa-ancestry/links); knowing the local descriptive indigenous names (Māori soil names/ngā kupu, ngā ingoa see Table 1) and describing and knowing soil texture, soil colour, soil fertility and wetness (Table 2). Other factors may be important such as the quantity and health of microbes and organic matter (e.g. soil carbon), the number of earthworms, e.g. worm counts per unit area or volume of soil, and other culturally important biota/fauna and flora (taonga). Other essential Te ao Māori indicators include assessing the mauri (life essence, vitality, life-supporting capacity), generally an assessment made up of a broad set of attributes of the total soil ecosystem including degree of connectivity and care between humans and soil; the mana (elevated status of the soil resource) usually based on values and decision-making for good soil management (e.g. actions of benefit to the soil); using the maramataka (Māori lunar calendar) to measure change through the year, where maramataka-based indicators are derived locally from specific iwi/hapū Māori tribes within regions or catchments to assess distinct seasonal changes in climate, cultivation, and harvest; through to describing soil condition change throughout the year by season and month. Once this Māori knowledge is in place, then it can be used alongside science indicators (i.e. physical, chemical, biological). A complementarity framework was developed to show how indigenous Māori soil indicators could be used alongside science-based indicators and less technical (e.g., farmer knowledge, citizen science) indicators to provide an enriched picture of soil health reflecting broader societal or pluralistic values (Table 5).

**Table 5. Using kaupapa Māori assessment tools and indicators next to science: Complementary assessment tools and indicators can be used together, for assessing soils and soil health**

Kaupapa Māori soil assessments/indicators	Farm, community-technical & non-technical assessments	Science based – including professional scientific, technical assessments, and science based (statistical) sampling strategies
<p>Kaupapa Māori based Mātauranga Māori knowledge based Based on Māori concepts and values</p> <p><i>Approaches (e.g.):</i> Hua parakore (Māori organics) Kaitiaki assessments (pastoral, cropping, gardening, etc) Farm KPIs Customary environmental indicators e.g., mahinga kai, mauri Cultural impact assessments Iwi/hapū/marae monitoring of contaminated sites</p> <p>Require in-depth Māori knowledge and understanding of particular environments and issues. Understanding of Māori values, goals, and aspirations. Kaupapa Māori approaches can include science and technical assessments.</p> <p>Examples:</p> <ul style="list-style-type: none"> <li>• Māori concepts, principles, and values</li> <li>• Kaupapa or mātauranga Māori based assessments and indicators</li> <li>• Traditional stories, narratives</li> <li>• Cultural heritage sites</li> <li>• Food, gardening and harvest practices (maara kai, mahinga kai)</li> <li>• Maramataka (lunar calendars)</li> <li>• Soil management guidelines, best practice</li> </ul>	<p><i>Examples:</i></p> <ul style="list-style-type: none"> <li>• Can be subjective</li> <li>• Visual soil assessment (VSA)</li> <li>• Farm assessment</li> <li>• Farm indicators</li> <li>• Community based indicators (e.g., collectives)</li> </ul> <p>Can be subjective and practically based. Cost effective, relatively simple and short duration assessments linked to land management, soil management, farm operations, cropping, orchards, market gardens, hill country, etc.</p> <ul style="list-style-type: none"> <li>• Farmer, grower, orchardist, industry</li> <li>• Community values</li> <li>• Technical and non-technical assessments</li> <li>• School assessment programmes (soils and gardens)</li> </ul> <p>VSA pastoral, soil management guidelines, cropping, pastoral grazing, hill country</p> <p><i>Indicators:</i></p> <ul style="list-style-type: none"> <li>• Soil structure and consistence</li> <li>• Soil porosity</li> <li>• Soil colour</li> <li>• Earthworm counts</li> <li>• Compaction–tillage pan, clod development</li> </ul>	<p>Scientific soil quality and soil health approaches: e.g., objective, measure ‘soil quality’ or a ‘soil health target range’ for each land-use</p> <p><i>Example indicators measured –</i></p> <p>Organic reserves</p> <ul style="list-style-type: none"> <li>• Total carbon</li> <li>• Total nitrogen</li> <li>• Mineralisable nitrogen</li> </ul> <p>Fertility</p> <ul style="list-style-type: none"> <li>• Olsen phosphorus</li> </ul> <p>Acidity</p> <ul style="list-style-type: none"> <li>• pH</li> </ul> <p>Physical status</p> <ul style="list-style-type: none"> <li>• Bulk density</li> <li>• Macroporosity</li> </ul> <p>Trace elements Contaminated soils</p> <p>Use science-based sampling strategy</p> <p>Science methods Laboratory analysis</p> <p>Require higher levels of technical input and skill, robust sampling strategies, analyses, and interpretation, can be expensive and time-consuming.</p>

<ul style="list-style-type: none"> <li>• Land management, whenua, kaitiakitanga</li> </ul> <p>Can include culturally based assessments for soil health and soil quality</p>	<ul style="list-style-type: none"> <li>• Soil erosion</li> <li>• Organic matter</li> <li>• Plant indicators</li> </ul>	
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## DISCUSSION

An increasing array of work globally is trying to understand the range of values associated with the environment and nature (e.g. Chan et al. 2012, 2016, 2018; Diaz et al. 2018; Ellis et al. 2019; Pereira et al. 2020). From these have come a number of specific studies to link human values to soils, and to soil health and well-being in particular (Stronge et al 2020; Friedrichsen et al 2021). The understanding of a wider set of pluralistic values, is seen as fundamental to understanding our links with nature, and accordingly how we prioritise our values to act.

Te Ao Māori (worldview) belief systems, Māori concepts and knowledge, and Māori traditions and practices have provided a solid basis for understanding and defining human health and well-being, ecosystem health, and soil health. This worldview places Māori within the biosphere, natural ecosystems, and soil ecosystems (Fig. 1) and helps explain links and connections. It also explains a continuum of knowledge from the ancient to the traditional, historical, and contemporary, where core Māori values and principles have been derived from Māori knowledge.

By fusing many of the Māori concepts and values, alongside science concepts and definitions, the soil health research programme developed a working definition for the duration of the research: "...The capacity of a soil as a living ecosystem to sustain and support all forms of life (to sustain microbes, plants, animals, humans and complex interconnections), through the maintenance of te mauri and mana, to strengthen and enhance whakapapa, taonga tuku iho, oranga, wairua, and whai rawa".

## CONCLUSIONS

This research study has explored indigenous Māori concepts and values to be applied to improving the health of ecosystems and soil. Māori concepts, values, and principles are used to understand Māori perspectives of soil health, providing the foundation for the development of Te Ao Māori decision-making frameworks, tools and indicators. The research backgrounds the connection Māori have with their natural, spiritual, and physical environment as a basis for the goals and practices they wish to apply and implement to sustain and enhance soil resources through careful and wise land management. The research shows the importance of including Māori knowledge and values in research, planning, and policy, to improve discussions on the sustainable management of land and soils. This work has reaffirmed the importance of strengthening the understanding of traditional and local knowledge alongside modern science. The work has supported a broader and more holistic definition of soil health to include reciprocity between the environment and human beings and to elevate the importance of nature, above humans.

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kaumātua, kuia, scholars) in different parts of A-NZ, and much is scarcely recorded in written form. The authors have worked extensively with scholars, collectives, iwi, hapū, and marae groups throughout A-NZ to discuss land management, soils, and soil health. We thank all those people who have contributed their knowledge and ideas to this paper in this present research, and from past and related projects.

## Glossary

Ao	World, earth, cloud
Aotearoa	Māori name for New Zealand, land/world (ao) of the long (roa) white (tea) cloud (ao)
Atua	God, deity, power and strength, immortal
Hapū	Pregnant, sub-tribe
Hui	Meeting
Ingoa	Name or term
Iwi	Tribe, bones
Kaitiakitanga	The ethos of sustainable resource management, environmental guardianship
Karakia	Prayer, ritual or sacred chants, often connects the spiritual world to the physical
Kaumātua	Elderly male, one respected with knowledge and wisdom
Kaupapa Māori	Led by Māori, use of Māori methods, to address specific Māori issues, desires, and needs
Kawa	Ceremony, local protocols, rules, process
Kuia	Elderly female, one respected with knowledge and wisdom
Kūmara	Sweet potato, thought to be originally from South America, traditional and modern Māori potato cultivars and varieties, family: <i>Convolvulaceae</i>
Māra kai	Gardens, cultivation, cropping land
Mahinga kai	Food growing and gathering area, area of cultural resources for collection or harvest
Manaaki	Host, provide hospitality
Manaakitanga	Reciprocal and unqualified acts of giving, caring, and hospitality
Mana whenua	Rights of self-governance, rights to authority over traditional tribal land and resources
Mana	Prestige, power, authority
Māori	Ordinary, us as distinct from them
Maramataka	The Māori lunar calendar, based on phases of the moon and stars, 12-13 months
Mātauranga Māori	Māori knowledge and philosophy
Mauri	Energy, vitality, essence, life force, life giving qualities, sustaining life force or spirit
Ngā kupu	Māori words, terms (ngā is plural)
Oneone	Soil
Papa-tū-ā-nuku	Earth mother
Parakore	Pure, uncontaminated state, with no impurities
Pepeha	Connection to place, recitations linking people to place, their connection to mountains, rivers, forests, lakes, coasts, etc.
Polynesia	The large ocean and island area north of New Zealand, place of origin, islands in the southern Pacific Ocean

Ranginui	Sky father
Ritenga	Custom, regulation, likeness
Taewa (or rīwai)	Sweet potato ( <i>Solanum tuberosum</i> ), many varieties and colours
Taiao	The natural world, nature
Taonga	Treasure, precious resource, treasured or important places, objects, and species, culturally significant biota
Taonga tuku iho	Treasured possessions sustained or passed through generations, intergenerational guardianship
Tapu	Sacredness, restriction, forbidden
Te ao Māori	Indigenous Māori world-view
Te ao Pākehā	Pākehā or mainly European/western world-view
Te reo Māori	Māori language, voice
Te ao mārama	The creation of light, world of light, the biosphere
Te ao turoa	Sustainable world, long standing
Te oranga o te taiao	Healthy sustainable environment, make the environment healthy
Tikanga	Customary practice, protocols, ethics, values
Tino rangatiratanga	Self-determination, independence, away from dependency
Tohunga	Knowledge expert, specialist, priest
Treaty of Waitangi (Tiriti o Waitangi)	Treaty of good faith to uphold indigenous rights signed between the British monarchy and its representatives (The Crown or British Government) and Māori and tribal representatives in 1840
Wāhi tapu	Sacred site
Wāhi taonga	Cultural heritage site, place of treasures
Wairua	The spiritual dimension to life, spiritual practice
Wānanga	Advanced learning, workshop, interactive meeting to gain knowledge and understanding
Whai rawa	To build prosperity and wealth, and meet needs, through nature's assets
Whakataukī	Māori proverb, saying, statement of wisdom or advice (originator not known, anonymous)
Whakatauākī	Māori proverb, saying, statement of wisdom or advice (originator known)
Whakakoha	The act of giving
Whakapapa	Ancestral lineage, ancestral connections, genealogical relationships
Whānau	Family, extended family (incl. cousins, twice, thrice over, etc.)
Whanaungatanga	Family connections and family relationships
Whakapūmau	Permanent, constant, sustainable, enduring
Wheiao	Transition to light, from dark to light
Whenua	Land, placenta

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