Manaaki Whenua
Landcare Research

Soil health and resilience: oneone ora, tangata ora

Stakeholder survey report

February 2019

Soil health and resilience: oneone ora, tangata ora – Stakeholder survey report

Contract Report: LC3334

Pamela Booth, Electra Kalaugher, Bryan Stevenson, Garth Harmsworth, and Robyn Kannemeyer

Manaaki Whenua – Landcare Research

Reviewed by:
Geoff Kaine
Senior Economics Researcher
Manaaki Whenua – Landcare Research

Approved for release by:
Chris Phillips
Portfolio Leader – Soils & Landscape
Manaaki Whenua – Landcare Research

Contents

List of Figures

Summary

Project and Client

The ongoing capacity of soil ecosystems to maintain the services they provide is fundamental to our economic, cultural, social, and environmental well-being. We estimate that in economic terms, around 17% of New Zealand's GDP depends directly on our soils, but the importance of soil to our social, cultural, and long-term environmental well-being is less well understood.

The MBIE-funded project Soil health and resilience: Oneone ora, tangata ora aims to support the development of a longer term and more comprehensive view of soil health and resilience. The project also seeks to develop an integrated soil health framework that can be used by a wide range of end-users, from primary industry, landowners, iwi/hapū, to central and local government. This survey informs the soil health and resilience project.

Objectives and Method

We conducted an online survey with stakeholders from the agricultural sector. We sought input from a wide range of soil professionals, land owners and other end-users. The survey objectives were to provide:

- a baseline understanding of the different ways people understand soil health and value soil as a resource,
- information on which aspects of soil health are currently being monitored, and where gaps are perceived, and
- a network of interested parties who would like to keep in touch with progress in the project.

Results

A total of 235 respondents completed the survey. They were predominately male (64%) between the ages of 40 and 60 (53.8%), self-identify as NZ European/Pākehā/New Zealander (78.6%), from the North Island (79.3%), and a farmer/grower/producer/ landowner (40%) in drystock (57.4%) farming. Respondents identified as: NZ European/Pākehā/New Zealander (78.6%), Māori (14.8%), European (9%), Asian (2%), and Pacific Islander (1%). They were primarily from Auckland (23.2%) or Waikato (18.2%) in the North Island and Southland (7.1%) or Canterbury (5.6%) in the South Island. Participants included farmers/growers/producers/landowners/home gardeners (42%), researchers (30%), consultants (26%), policy makers/planners (23%), and Māori representatives (10%).

A variety of ways were used by respondents to define soil health. There was a recurring emphasis on the importance of soil to support life, humans, and production, and on the interactions between physical, chemical, and biological properties. The respondents' soil health definitions are grouped into: Bio-physical properties; What can I see and identify; Soil's ability to produce and support life; and the holistic or mauri view.

There were 124 respondents who thought there were gaps in our current understanding and assessment of soil health and resilience. These insights identified five themes: 1) Education and communication of current knowledge; 2) Societal values of soil health; 3) Monitoring, assessment and modelling; 4) Bio-physical processes and dynamics; 5) Policy and Planning.

A series of questions were asked about how respondents manage and monitor soil health. Overall, 89% of respondents indicated they monitored soil health or quality as part of their work or on their land. A very high proportion of farmers reported they managed and monitored soil health. However, across the different types of farm categories the proportion of farmers/landowners who monitored soil health was not significantly different. A variety of monitoring techniques are used by farmers to monitor the health of their soil and these include: changing stocking rates or using lighter stock (31%), rotating stock around paddocks (15%), standing off stock during wet times (21%), and cropping (15%). Many also reported they followed biological/holistic/organic methods of farming (31%) and used soil tests (30%) to determine type, timing, and application rates of fertilisers (7%). The aspects of soil health that respondents believe should be monitored parallel the gaps in understanding and assessment of soil health.

To better understand how people value soil as a resource, survey respondents were asked how much they agreed with a range of statements about soil health and the importance of soil health in the provision of a range of services. There was support for changes in how society views soil health, and a need to understand people's attitudes and opinions toward the different dimensions of soil health. In this survey, respondents agreed that soil health is very important to New Zealand's economy, environment, and society but that soil health is currently undervalued in New Zealand policy. From a personal and cultural perspective, soil health is also important to respondents.

With regards to ecosystem services, respondents thought that soil health is very important for the provision of food, fibre, and fuel. Overall, most respondents thought that soil health is important for the provision of water regulation, water purification/waste treatment, climate regulation, natural hazards, or supporting biological services.

Conclusions

This survey will contribute to the development of an integrated soil health framework that can be used by a wide range of end-users, from primary industry, landowners, iwi/hapū, to central and local government. An adaptive approach to stakeholder involvement is an important aspect of this project. While we have identified a key set of initial stakeholders, we anticipate that this list will evolve and grow throughout the life of the project.

Finally, this survey has identified a range of perceived gaps in our efforts to monitor and understand soil health. The results of this survey will contribute both to the development of a shared understanding of soil health among stakeholders, and to the further development of the overall project.

1 Introduction

The ongoing capacity of soil ecosystems to maintain the services they provide is fundamental to our economic, cultural, social, and environmental well-being. We estimate that in economic terms, around 17% of New Zealand's GDP depends directly on our soils, but the importance of soil to our social, cultural, and long-term environmental well-being is less well understood. Current measures of soil health focus on short-term "dynamic" soil characteristics, such as pH and soil nutrients, that may be inadequate to assess long-term changes to soil health and resilience. Also, current measures in Aotearoa-New Zealand do not recognise cultural perspectives, such as Mātauranga Māori, which should be considered when defining and assessing soil health in our multicultural and pluralistic society.

The MBIE-funded project Soil health and resilience: Oneone ora, tangata ora aims to support the development of a longer term and more comprehensive view of soil health and resilience. The project will also seek to develop an integrated soil health framework that can be used by a wide range of end-users, from primary industry, landowners, iwi/hapū, to central and local government.

The three overall objectives of the project are to:

1 test long-term land-use sequences on different soils to gauge the effects of land-use intensification on soil properties to better define soil resilience

2 develop concepts of soil health from a Māori perspective

3 create a more integrative framework that incorporates cultural value systems and Mātauranga Māori, new scientific knowledge and policy needs for soil health.

To support these project objectives, we conducted a survey in June 2017, seeking input from a wide range of soil professionals, land owners and other end-users. The survey objectives were to provide:

- a baseline understanding of the different ways people understand soil health and value soil as a resource,
- information on which aspects of soil health are currently being monitored, and where gaps are perceived, and
- a network of interested parties who would like to keep in touch with progress in the project.

These survey objectives feed into the larger soil health and resilience project in two ways. First, because there are currently different initiatives for land and soil, and different concepts of soil health, we considered what would be required for an integrated framework to make a useful contribution to the national soil health programme. Second, there is a need for a broader understanding of New Zealand's soil health to increase both the productivity and sustainability of soils and how soil health changes under different management. Objectives 1 and 2 will contribute to the development of such a framework.

To be effective, the framework would need to be adopted by policy makers and managers of the land. This would require understanding the issues from the perspective of different sectors and stakeholders, and tailoring the concepts and indicators to their needs and worldview. An indicator of success would be indicators and soil health concepts adopted by Māori landowners/businesses. Objective 3 will contribute both to broadening the network of interested parties and to assessing the diverse perspectives of these various stakeholder groups.

2 Methods

2.1 Survey methods

The survey was conducted online using the program Survey Monkey. This program allowed for adaptive logic within the survey to show relevant questions based on previous answers. There were 15 questions, including demographics. As a result of the adaptive logic, respondents saw between 11 and 15 questions. All questions were optional.

The survey questions were developed and reviewed in consultation with internal and external personnel with relevant expertise to achieve the stated objectives. Informal feedback on the questions was also sought from stakeholders from different sectors. The survey questions are provided in Appendix 1.

Survey recruitment followed the 'snowball' approach. The initial survey invitation was sent to approximately 100 stakeholders and relevant contacts identified by the project team as having a focus on the agricultural sector. These invitees were further invited to forward the survey to relevant contacts. The survey was open during June 2017.

2.2 Analysis methods

Survey data were processed and analysed using the statistical program Stata (http://www.stata.com) and the qualitative analysis software NVIVO©. Open-ended questions were coded and analysed using NVIVO. Analysis is descriptive as no statistical tests were run for any question.

3 Results

3.1 Survey respondent demographics

A total of 235 respondents carried out the survey. Respondents were predominately male (64%) between the ages of 40 and 60 (53.8%), self-identify as NZ European/Pākehā/New Zealander (78.6%), from the North Island (79.3%), and a farmer/grower/producer/ landowner (40%) in drystock (57.4%) farming.

One third (33.5%) of the respondents were female. No respondents were under the age of 20, 29.4% were between 20 and 40 years old, and 16.8% were over 60 years old.

Respondents could choose more than one ethnicity, and identified as: NZ European/Pākehā/New Zealander (78.6%), Māori (14.8%), European (9%), Asian (2%), Pacific Islander (1%), and other ethnicity (4.5%). Respondents were primarily from Auckland (23%) or Waikato (18%) in the North Island and Southland (7%) or Canterbury (6%) in the South Island (Fig. 1).

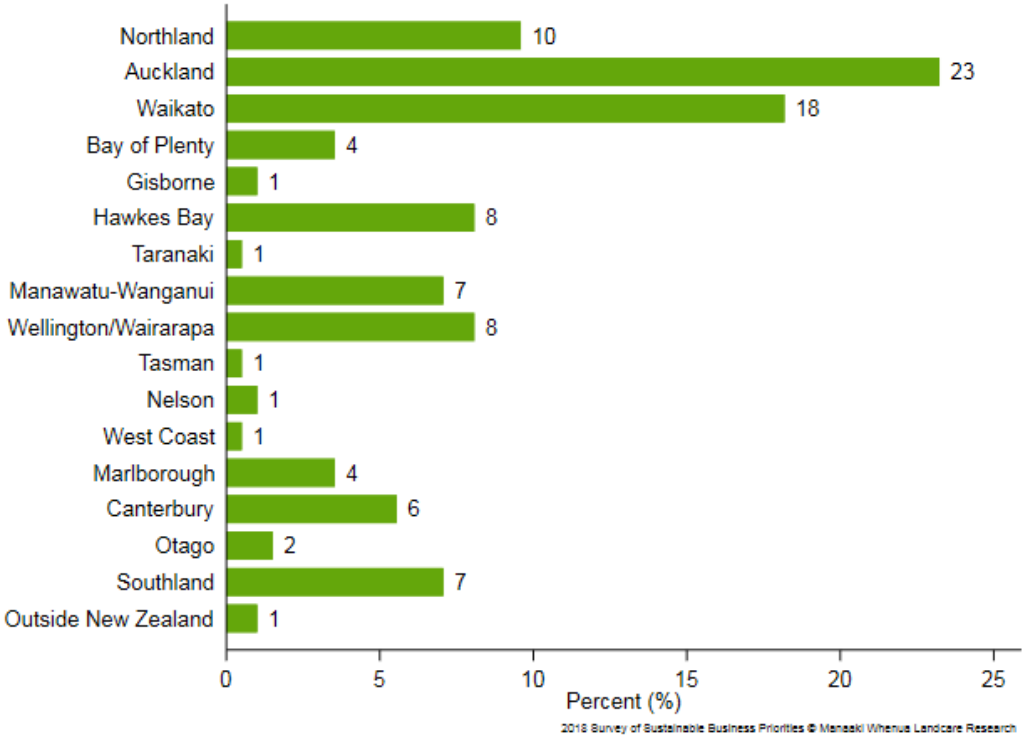

Figure 1. Regions of respondents
(n=196 responses).

Respondents could choose from any number of the nine occupations listed in the survey. The occupations were aggregated into six groups (Fig. 2). The largest group (42%) is composed of farmers, growers, producers, and/or landowners, and home gardeners. The researcher group (30%) contains soil researchers, other researchers, and students. The consultant group (26%) was composed of primary sector support, community organisers, soil consultants, and agricultural consultants/extension. The policy maker/planner (23%), Māori representative (10%), and other groups (6%) are unchanged from the original survey options.

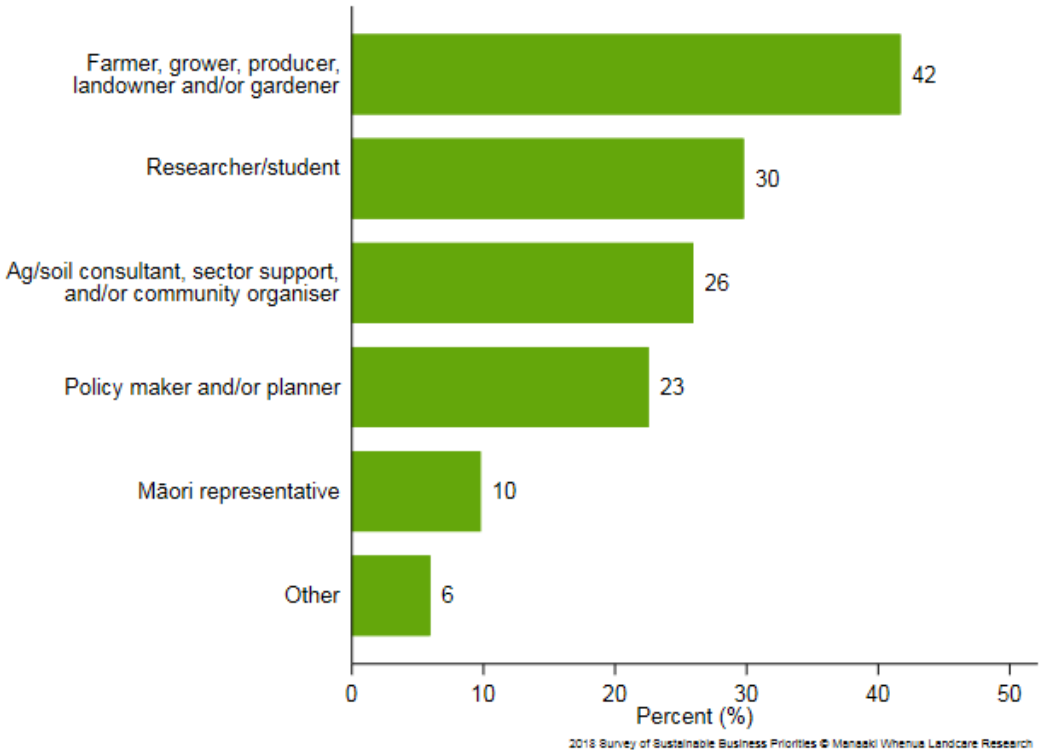

Figure 2. Occupation of respondent
(n= 235 responses. Respondents could choose more than one occupation. The top three occupation groups were aggregated post-survey).

Farmers, growers, producers, and/or landowners were asked in broad terms to define the type of farm they own/farm. The majority of farmers, etc. were in drystock (57%), followed by dairy (27%), horticulture (17%), cropping (13%), lifestyle block (9%), and other (15%) (Fig. 3). Respondents could choose more than one farm type.

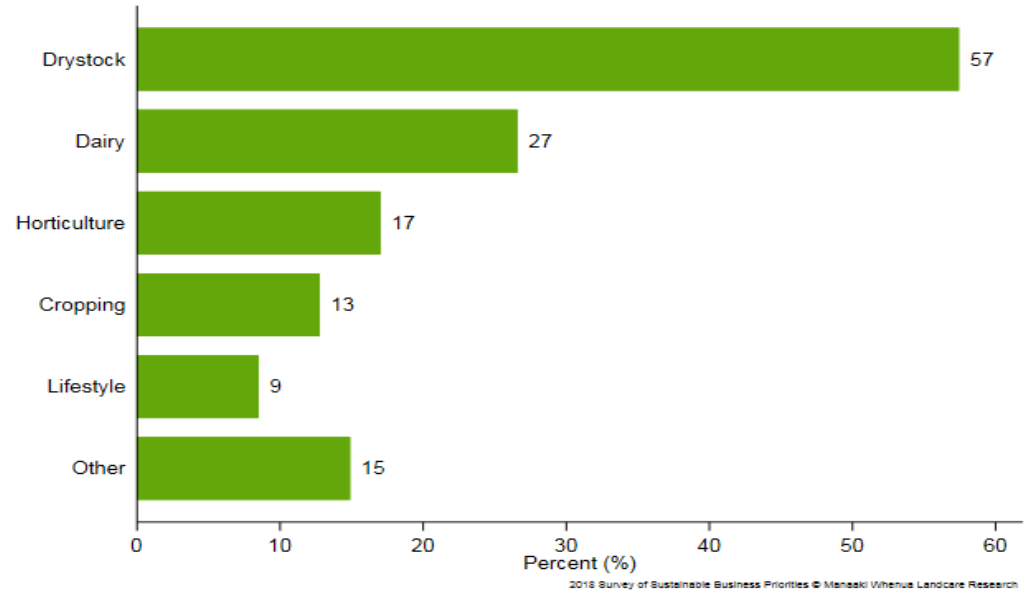

Figure 3. Types of farms
(n=196 responses. Respondents could choose more than one farm type).

3.2 Definitions of soil health

To better understand what respondents thought about soil health and how they valued soil as a resource (Objective 1), respondents were asked, "How do you define soil health?" and "Do you think there are any gaps in our current understanding and assessment of soil health?". Both questions were open-ended and were coded into themes during the analysis.

3.2.1 How do you define soil health?

A variety of ways were used by respondents to define soil health, e.g. using the concept of mauri as a living organism, or whole context view. There was a recurring emphasis on the importance of soil to support life, humans and production, and on the interactions between physical, chemical, and biological properties (Fig. 4).

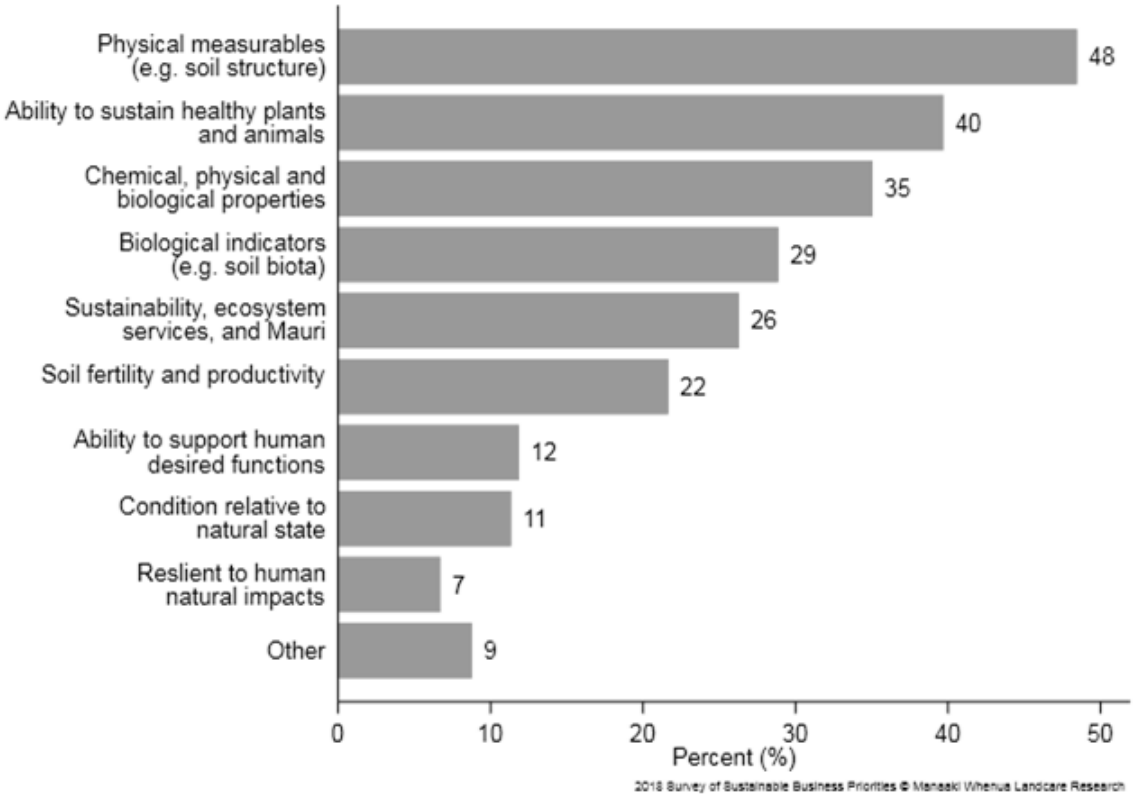

Figure 4 How do you define soil health?
(n= 194 responses. This question was optional and groups were coded during analysis from the open-ended responses. Responses could be coded as more than one option).

The respondents' soil health definitions are grouped into:

- Bio-physical properties
- What can I see and identify?
- Soil's ability to produce and support life
- Holistic or mauri view

Bio-physical properties

Some respondents answered the question in terms of the bio-physical properties of soil and soil harmony. This view included whether the soil can sustain itself and be productive, the soil's physical properties, e.g. erodibility, biological properties, and chemical properties, e.g. nutrient balance, stability and the soil's functional biota. A sample of the quotes showing the range and complexity of definitions is given below:

> *Lots of bugs n worms and stuff.*
>
> *Healthy soil is aerated, full of hummus, microbes, worms.*
>
> *High levels of humates and organic matter. Macro and micro elements on the right level. Good level of biological activity.*
>
> *Soil health is the overall condition of soil, taking into account physical, biological and chemical properties. It is different to soil quality which is a soil's fit for purpose.*
>
> *Soil structure and chemistry that provides for structural stability, appropriate conditions for water entry (infiltration) and storage root growth to maximum depth determined by plant phenotype and seasonal growth conditions (temperature, day length, water availability) and growing season length, capture of nutrients by plant growth and the existence of beneficial organisms rather than root pathogens…*
>
> *1) Is the soil staying put? 2) Is the soil in a steady state in terms of stocks and services e.g. soil structure, aerobic condition, fertility, organic matter content? 3) Is the topsoil mineralising rather than immobilised if on a farm? 4) Is the soil able to continue to sustain the current land use type and land use intensity and what other alternatives are there?*

What can I see and identify?

Respondents also defined soil health in terms of what is identifiable and visual. They described soil health in terms of measurable, soil physical properties, e.g. soil structure; the relationship between soil's biological, chemical, and physical properties; the soil's productivity; and fertility relative to its natural biologic, chemical, and physical state. A few respondents also mentioned defining soil health in relation to various tests including the VSA – Visual soil assessment. Representative quotes are given below:

> *Rich, culpable, bug and worm laden, thriving ecosystem of wairua.*
>
> *Well aerated soil, preferably dark top soil, with abundant worms. [It has] bread crumb structure [and is] not blocky or powdery.*
>
> *VSA (Visual soil assessment) monitoring system… and aim for a dark humus topsoil with good structure, good drainage, good earth worm counts and healthy, diverse pasture sward.*

Soil's ability to produce and support life

Some respondents defined soil health in terms of the soil's ability to produce and support life. This included supporting the living organisms within the soil, e.g. worms, the soils ability to produce healthy plants and animals, and the soil's ability to support desired anthropogenic functions, e.g. primary production. A few respondents also mentioned that healthy soil does not pose a threat to the health and well-being of plants, animals, and humans. See below for a sample of the definitions.

> *A healthy soil for primary productivity is free draining, fertile… reflected in an abundant worm population.*
>
> *Capable of growing nutritious plants.*
>
> *The ability of soil to maintain and grow plants at optimal or near optimal rates for climatic conditions.*
>
> *The chemical, physical and biological condition of the soil as it relates to supporting the dependent ecosystems growing within and dependent on the soil.*
>
> *Where the soil has balanced nutrients and microbes, and minimal toxins, enabling strong and thriving invertebrate ecosystems.*
>
> *Soil health is the soil's ability to complete essential biological functions to sustain/promote plant and animal health/productivity and/or maintain/enhance air and water quality.*
>
> *The key parameters of soil health are defined by its use – the parameters are the physical and chemical properties of soil and the level of these required for its use determines the health or otherwise. Soil health includes soil structure, micro-organism content, mineral and nutrient content.*

Holistic or mauri view

Within the concept that heathy soil produces and supports life are the ideas of sustainability, ecosystem services, mauri, and resilience. These ideas represent taking a holistic or 'whole context' view that healthy soil is productive, supports biota and human uses, is resilient to human and natural impacts, supports the ecosystem and provisions of ecosystem services, and should be treated as any other living, breathing organism. Representative quotes include:

> *A community of organisms and elements that maintain and enhance the mauri of living organisms through symbiosis.*
>
> *If Papatuanuku is maemae (withered or dehydrated) then so too will be the people.*
>
> *It is the skin of Papatuanuku that allows life to breather and prosper. The mauri of our soil will need to be protected and replenished in order for the many things it sustains to remain healthy and abundant.*

The ability for soil to provide ecosystem services for both natural/indigenous ecosystems and modified/anthropogenic ecosystems.

The capability of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health. Soils is a living, dynamic, resilient system that provides multiple ecosystem services.

3.2.2 Gaps in current understanding and assessment of soil health

To broaden our understanding and assessment of soil health, respondents were asked in Question 12 "Do you think there are any gaps in our current understanding and assessment of soil health?" A small percentage (10.4%) of respondents were unsure if there were gaps, primarily because they felt they were not familiar enough with current working knowledge about soil health to make an educated assessment. Less than 2% of respondents did not identify any gaps. Five broad themes were identified by the 124 respondents (88.2%) who thought there were gaps. The themes identify gaps in both understanding and assessment of soil health in the relationship between and among land use, land practices, ecosystem services, and societal values. Respondents also identified gaps in how we currently measure, and analyse soil health; map and model soil data; understand bio-physical processes and dynamics; and inform policy and planning decisions. The themes identified are:

1 Education and communication of current knowledge

2 Societal values of soil health

3 Monitoring, assessment and modelling

4 Bio-physical processes and dynamics

5 Policy and planning

In the first theme, Education and communication of current knowledge, respondents commented on a lack of education/public awareness of soil health. They suggest it is difficult to maintain the status quo of current knowledge, practices, and policies and that there is a need for a centralised source of New Zealand and international information, e.g. one respondent wrote "*What do we do with what we know?*" The spread of misinformation or pseudo-science was a concern. There was also a call for educating landowners/managers about vegetation cover, water infiltration, organic matter measurements, soil structure, and management techniques for sequestering carbon.

Social, environmental, economic and cultural values associated with soil health are highlighted in the second theme – Societal values of soil health. From a cultural perspective, some respondents wanted a more holistic, Mātauranga Māori view of our relationship to and with the land and the implementation of concepts such as mauri in the soil health framework. Economic values identified by respondents related to the valuation of land and the current rezoning of land from rural to urban. From environmental and social perspectives, there may be differing priorities for land owners and trade-offs between soil health and productivity, while others point to an unwillingness for change. One respondent suggested that "*the true value of 'elite' soil for food production e.g. food*

security, total employment [was] at risk of urbanisation." Other issues raised from a societal viewpoint related to regulating cultural and social services of soil; evaluating soil for all ecosystem services and exploring the value of open green spaces for food production.

Respondents also identified gaps in how we currently monitor, assess, and analyse soil health and quality (Theme 3). These gaps in metrics and assessment methods reflect a general sense that to change policy and land use practices for the better, our current knowledge of soil health needs to expand and improve. This could be done by increasing and standardising current assessment methods so that changes could be tracked spatially and temporally, reducing the financial and time costs to get a quick-and-easy assessment of soil health. There is a need for simple and cheap soil health measurement indicators which include micro-organisms. One respondent highlighted the need to measure the loss of soil to waterways and the resultant impacts. Respondents also requested soil mapping data and erosion models.

Theme four highlights the gaps in bio-physical processes and dynamics. There is a need to better understand physical processes such as attenuation, compaction, sedimentation, and trajectories of degradation (i.e. gradual, linear or rapid crash) over time. An improved understanding of the bioavailability of contaminants and the effects of heavy metals was identified as important. Gaps in soil biology or ecology include micro-organism triggers, the pairing of plant and animal genetics that pressure soil less, and the restoration of soil health and function as part of ecological restoration. Respondents thought we needed a more accurate picture of land use practices such as optimising fertilisers for different soils or the effects of excessive fertilisers and animal waste on soil dynamics. Finally, there is a gap in knowledge of the contribution of meso- and micro-fauna, bacteria, fungi, and viruses to soil health and their stressors, as well as a gap in information about nutrient balances in a soil's natural state.

Many respondents were concerned that our current ways of viewing and regulating the land cause increased stress on soils, which leads to declining crop productivity and ecosystem services, lost productive land, erosion, pugging, and other deteriorating soil health indicators. Theme five identifies ways in which policy and planning could be used to address these stresses. There is a need for changes to current policy to better reflect soil health knowledge; for policy decision makers to be more informed and aware of soil health stresses; and for a "*coherent national scale reporting as a tier 1 indicator*". Better spatial assessment and planning to identify land use pressures, e.g. urban encroachment, and the spatial resolution of soils are needed, along with an understanding of what soils have been lost.

3.3 Managing and monitoring soil health

To better understand how soil health is currently being monitored and the possible gaps in monitoring and management (Objective 2), respondents were asked a series of questions. All respondents were asked Question 6, while only farmers, growers, producers, and/or landowners were asked Questions 4, 7, 8 and 9.

- Do you monitor soil quality or soil health as part of your work, or on your own land? (Question 6)
- Do you actively manage soil quality or soil health on your farm? If so, please comment on your approach (Open ended, Question 4)
- Which aspects of soil quality and/or health do you monitor? (Question 7)
- Are there other aspects of soil health you feel are important to monitor? (Open ended, Question 8)
- Have you observed or measured any long term or significant changes to the soils you work with? (Open ended, Question 9)

The open-ended questions were coded into themes during the analysis. Questions 8 and 9 are answered under section 3.3.2 Gaps in monitoring and 3.3.3 long-term or significant changes in soil health respectively.

3.3.1 Current management and/or monitoring of soil health

Overall, 89% of respondents indicated they monitored soil health or quality as part of their work or on their land (Q6). Farming respondents were asked to supply detailed information on their soil management and soil monitoring (Q4). A very high proportion of farmers reported they managed and monitored soil health (see Fig. 5). The proportion of farmers/landowners who monitored soil health was not significantly different across the farm categories. The same was the case for monitoring soil health.

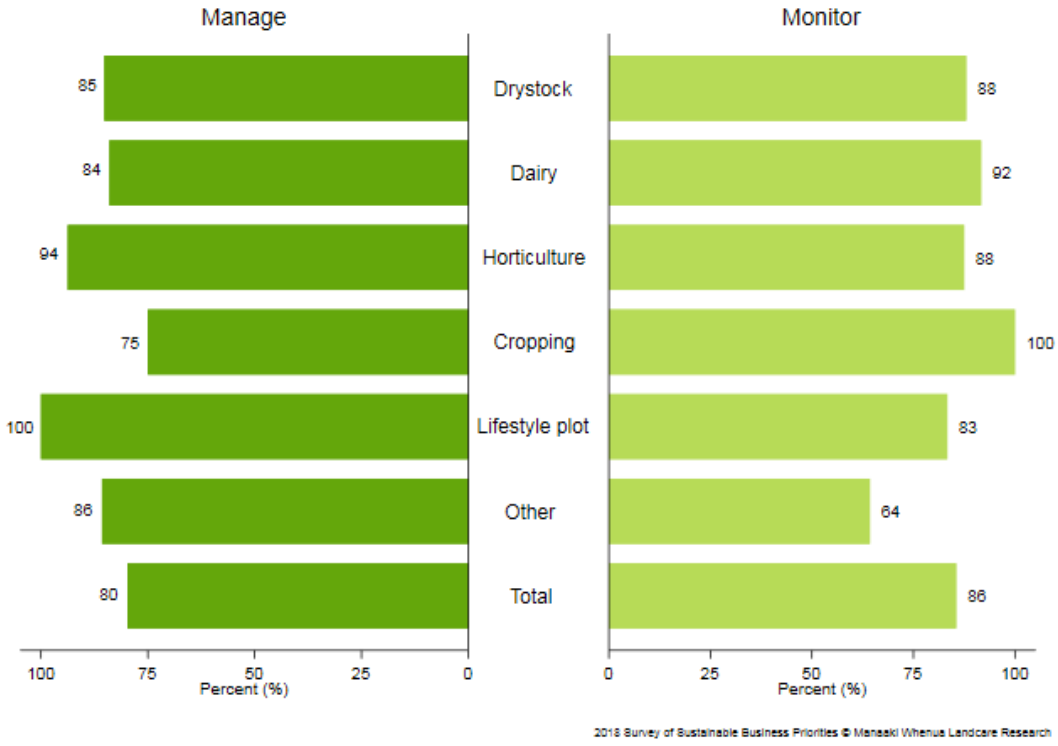

Figure 5. Do you manage and/or monitor soil quality and/or health on your farm?
Note: Results are from 94 farmers/growers/producers/landowners. Respondents could choose more than one farm type. Total shows the unweighted distribution. These questions were optional and responses were coded during analysis from the open-ended responses.

Farming respondents' answers to questions about their monitoring of soil health indicated that they manage soil health and quality on their farm using a combination of management practices. These practices included changing stocking rates or using lighter stock (31%), rotating stock around paddocks (15%), standing off stock during wet times (21%), and cropping, e.g. mixed and rotational crops (15%). Many also reported they followed biological/holistic/organic methods of farming (31%) such as avoiding herbicides, pesticides, and artificial fertilisers, and using organic fertilisers, compost, and growing green manure crops. They also use soil tests (30%) to determine type, timing, and application rate of fertilisers (7%)

Figure 6 shows the main aspects of soil quality or soil health that are monitored by the respondents (Q7). The majority of respondents (79%) used basic soil tests e.g. pH, Olsen P, Cation exchange capacity, etc. to monitor soil health, while organic matter (53%), trace elements (49%), worm count (49%), rooting depth/penetration (45%), available nitrogen and sulphur (40%) also being used by many respondents as indicators of soil health.

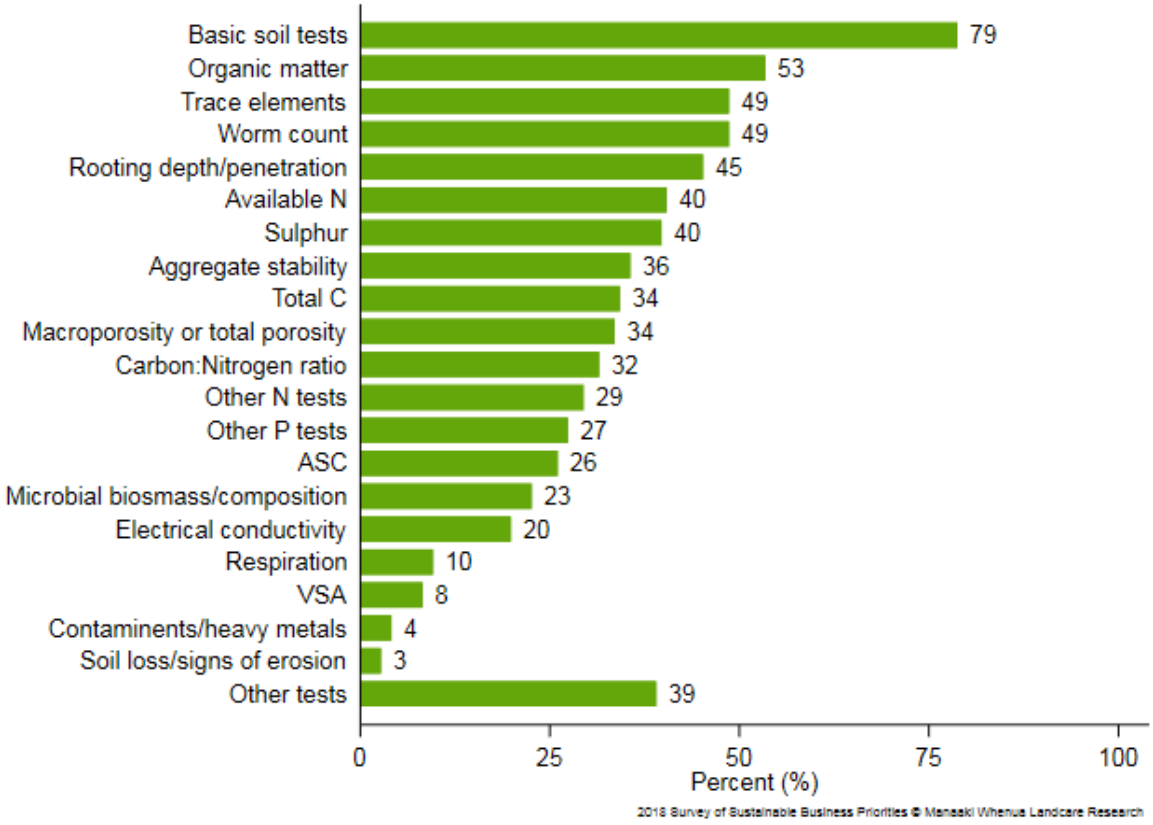

Figure 6. Which aspects of soil quality and/or health do you monitor?
Note: Results are from 146 respondents who said they monitor soil quality or soil health. Respondents could choose more than one test/aspect. (ASC – phosphate retention, VSA – Visual soil assessment)

3.3.2 Gaps in monitoring

In addition to providing other tests or soil quality aspects that respondents currently monitor, respondents were also given the opportunity to describe aspects of soil health and quality that they believe should be monitored in general. Many of the specific responses are categorised by the previous list of tests and monitoring aspects in Section 3.3.1. Additionally, the aspects of soil health that respondents believe should be monitored parallel the gaps in understanding and assessment of soil health discussed in Section 3.2.2.

As previously discussed, there are gaps in what is 'measured' and how often that measurement is taken. Respondents believed Carbon, organic matter, Carbon to Nitrogen (C: N) ratio, total Carbon, and total Nitrogen should be better monitored. One respondent suggested the need to further develop the N indicator, e.g. nitrogen isotopes 15N, host water extractable Nitrogen (HWN), C: N, and HWC: HWN. Monitoring or measuring various enzyme assays, such as beta-glucosidase, uranium, fluoride, P retention, and ASC was also suggested. Respondents also suggested that insufficient attention was being given to contaminants in the soil, highlighting the need for baseline testing for pollutants such as heavy metals, pesticide residues, industrial pollutants, herbicides, pesticides, rodenticides, molluscicides, fungicides, etc. These contaminants included emerging organic contaminants, pharmaceuticals, and other agricultural chemicals.

Measuring biological aspects of soil health such as soil microbiology (fungus, bacteria, etc.) as well as pests in the soil was a recurring theme. Several respondents highlighted the connection between soil structure and soil biology, in particular, the effect of compaction, for example on the activity of insects and other biota. Insect presence/damage, the presence of beneficial insects, disease incidence/pressure, and the time taken for dung to decompose were suggested as biological indicators of soil health. However, the difficulty of measuring these aspects of soil health was acknowledged.

Measures of soil structure were repeatedly noted under this question, with particular emphasis on compaction and associated measures such as permeability, drainage, water-holding capacity, pugging, topsoil (and horizon) depth, and rooting depth. Other aspects of soil structure that should be monitored include erosion, water runoff, nutrient runoff, and crusting of the soil.

A number of suggestions emphasised measuring the carbon content and depth/quality of organic material with reference to active carbon and humus levels. Reference was also made to structural parameters that can be directly linked to soil functions, e.g. air and water fluxes as well as water infiltration rates as a reflection of biological elements fungal macro-ped and bacterial micro-ped formation.

The importance of practical, visual assessment approaches suitable for use on farms was repeatedly emphasised:

> *We need relevant soil physical and biological tests which are not greatly complex or expensive to undertake but which are 'calibrated' to meaningful outcomes for soil health and function.*

For me visual in the field signs, such as grass growth rates/health, soil composition, root depth, worm numbers are quick and useful.

It would be good to be able to monitor soil biology species present with a spectrometer or something immediate so you could get results in the paddock.

It would be valuable to link our indicators more directly to the functional aspects of soil quality, particularly those relating to nutrient cycling, either by monitoring microbial activity directly, or by understanding and characterising the physical and chemical conditions under which those processes operate

Several respondents mentioned the value of using Graham Shepherd's Visual Soil Assessment (VSA) approach. Practical/farm level analysis included:

- Morphologic features, thickness and colour of topsoil, compaction/loose erodible material, redoximorphic features
- Soil temperature and moisture
- Soil smell
- Worm counts
- Infiltration testing
- Visible aggregate on root surfaces
- Increase in area, number and/or percentage of bare patches in paddocks
- Extent of pugging, compaction, amount and type of sediment collecting in low points or flowing out in creeks in heavy rainstorms, and inception of tunnel gully, gully head, soil slip and earthflow erosion and sediment loss in vulnerable areas (wet or erodible or fragile soils).

Visually assessing pasture health and species present (including weed species) was considered an indicator of overall fertility and potential nutrient deficiency. The ability of the soil to grow multiple species of grass or a particular tree or crop was considered a possible measure of pasture health. Other measures of pasture health mentioned included hand-held infra-red analysis, brix, and mineral content, secondary metabolite content delivered from the soil (to agricultural produce), and the nutrient density of the produce manifested in flavour, smell, storability and crop disease resistance.

Respondents also further emphasised the need to understand those broad-scale impacts and spatial factors of soil health such as disturbance, fragmentation and loss of productive soils, and the different types of land use associated with soil type, e.g. the extensive planting of radiata pine. In addition, soil security and understanding the history of land use, and the effects of long-term changes, e.g. loss of native biodiversity and the degree of modification from natural pre-human soils to the present day, are important.

Finally, there was a recurring emphasis on the need to monitor soils as part of the living ecosystem to which they belong. In particular, there is a need to understand the soil's ability to renew, the integrity of soils in relation to taonga species, the health of animals and/or plants dependent on the soil, and the value of ecosystem services provided by soils beyond monetary value, stocks and processes such as energetic flows. Soil needs to be

understood as part of our "*social fabric*", i.e. the relationships between soil health and biological, social, and cultural processes. There is a need to relate soil measurement targets to actual changes in soil services, and land use change to changes in soil services.

3.3.3 Long-term or significant changes in soil health

In Question 9, we asked respondents for observations of long-term or significant changes to the soils with which they worked. Responses were first coded into a yes/no format, and then the direction of observed change was coded into the following categories: "improving", "both improving and declining", "declining", and "did not specify the direction of change". Overall, 47% of respondents answered the question (*n*=91). Of those who responded, 82% said they have observed and/or measured long term changes; 7.2% said they have not observed any long-term changes; and 10.8% did not feel they had sufficient data to make an accurate assessment of long term trends in soil health.

The majority of respondents who had observed a long-term change believed that soil health was improving (65%). Only 12% of respondents believed that soil health was declining. Approximately 17% were unable to make a judgement. There were no significant differences across occupations or regions in perceptions of long-term changes in soil health.

Those who did not specify a direction of change referred to previous studies/projects, available literature, the long-term monitoring site at Ballantrae, and the monitoring programmes of regional councils. Many also suggested the need for better and longer term data to make more informed assessments of the specific direction of changes to soil:

> *Greater Wellington has monitored our SOE sites for 17 years, including the period Landcare Research undertook the work. We need to fund a regional or national analysis via the Land Monitoring Forum, quite possibly in collaboration with Landcare Research. We need the science/statistical analyses undertaken before conclusions are made on trends.*
>
> *20 years SQM, 14 years trace elements. The main soil quality concerns in the Waikato region detected by soil quality monitoring are surface compaction, high or excessive nutrient concentrations, and loss of soil organic matter and these three issues are interconnected. Since 2007, Cd accumulation has stabilised except for Horticulture, which is still increasing, but Cd is still added so where does it go? Total F has accumulated in arable and pasture; As has accumulated in pasture; Cu has decreased, Zn in arable and pasture has increased.*
>
> *Several long-term projects have shown long-term changes in soil properties, depending on land use, etc. One example is development of organic matter following land modification by humping and hollowing on the West Coast of the South Island.*

The majority of respondents referred to long term improvements in soil structure, quality and productivity due to management, or a decline in soil structure and quality due to land use and/or management factors. In particular, respondents thought that pasture

productivity (23%), topsoil and root depth (16%), water storage/drainage (12%), compaction and soil structure (10%), and resilience to shocks, e.g. drought (9%) have improved over time. Other respondents, however, thought that soil structure and integrity (13%), nutrients and trace elements (8%), compaction, erodibility, and soil stability (including slips) (11%), soil fertility and productivity (4%), and root depth and organic matter (2%) were in decline.

Some respondents had been monitoring soils on their own properties for long periods of time, and offered to share their data:

> *I have been involved in a wide range of soil research over 30 years... On my farm, I have noted an improvement in the physical state of the soils since we took over 11 years ago and removed cattle from steep wet hills. Stabilising areas that were eroded and improving general soil surface.*
>
> *40 years of consistent fertiliser policy has seen growth in humus and pasture palatability for stock.*
>
> *Yes, many. Have transformed the soils on the farm from hard and compacted with 1-2cm topsoil and very poor drainage and grass growth in 2004, to now deep friable top soils of 15-20cm, with also friable subsoils and deep root penetration, and excellent pasture performance & recovery. Worm counts have risen markedly from nil to 20+. Soils feel springy & soft to walk on, not hard & jarring. Pugging damage now unusual, and drainage after heavy rainfall is through the soils not surface run-off. Soils perform better in winter with continued growth & also during droughts in summer.*
>
> *I have long term monitoring that I can share. Using regenerative ag practices, we have matured substantial improvements in topsoil depth, infiltration, forage quality etc.*

3.4 Attitudes to soil health

To better understand how people value soil as a resource, Questions 10 and 11 in the survey asked respondents how much they agreed with a range of statements about soil health and the importance of soil health in the provision of a range of ecosystem services.

3.4.1 Agreement with statements on soil health

Respondents were asked to rate their level of agreement with six statements relating to soil health and New Zealand's economy, the environment, society, culture, themselves, and policy.

All respondents completely or somewhat agreed that soil health is essential to New Zealand's economy and/or is essential for a healthy environment (Fig. 7). While the majority of respondents agreed that healthy soil is very important or important to a healthy society (95%) and is currently undervalued in New Zealand policy (88%), there were a few respondents who neither agreed nor disagreed, didn't know or thought the statements weren't relevant.

Many respondents also agreed that soil health is important to them personally (70%), while 19% neither agreed nor disagreed, and 10% didn't know or thought the statement was irrelevant. Fewer respondents agreed that soil heath is very important to them from a cultural perspective (50% agree) compared with the other statements, but another 20% somewhat agreed with this statement.

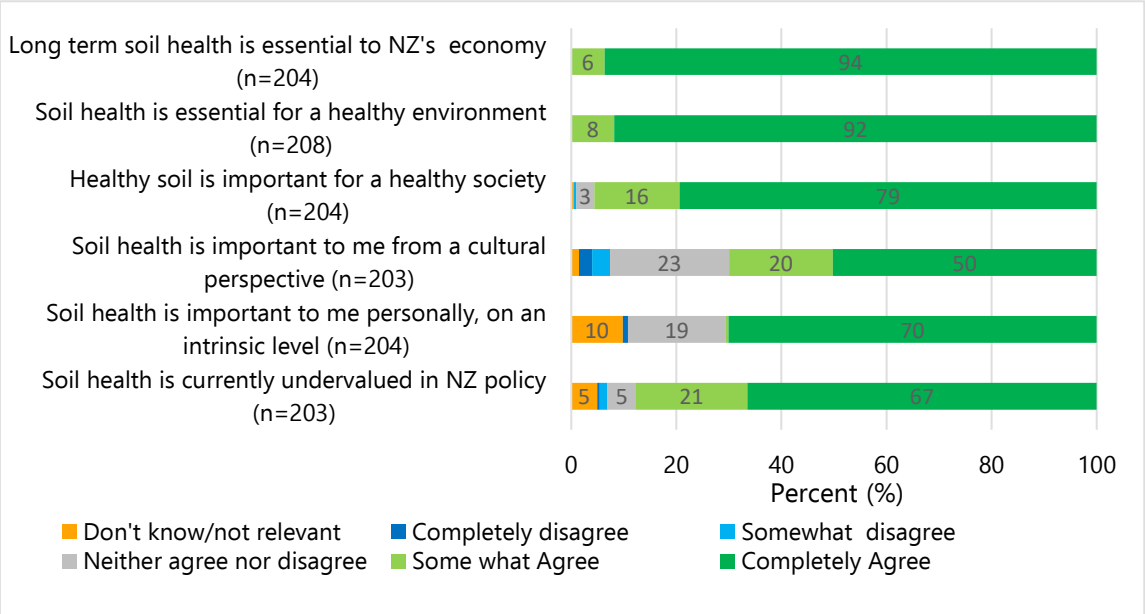

Figure 7. Respondents level of agreement or disagreement (%) with six statements about soil health.

3.4.2 Importance of soil health in provision of ecosystem services

Respondents were asked to rate the importance of soil health in six statements relating soil health to the provision of various ecosystem services. The majority of respondents thought soil health has an important role in the provision of all six services (Fig. 8). In the production of food, fibre and fuel, 92% of respondents believed that soil health is very important; no respondent thought soil health is unimportant or did not know whether soil health is important. Between 69 and 75% of respondents thought soil health is very important for water regulation, water purification & waste treatment, climate regulation, regulating natural hazards and for supporting biological services.

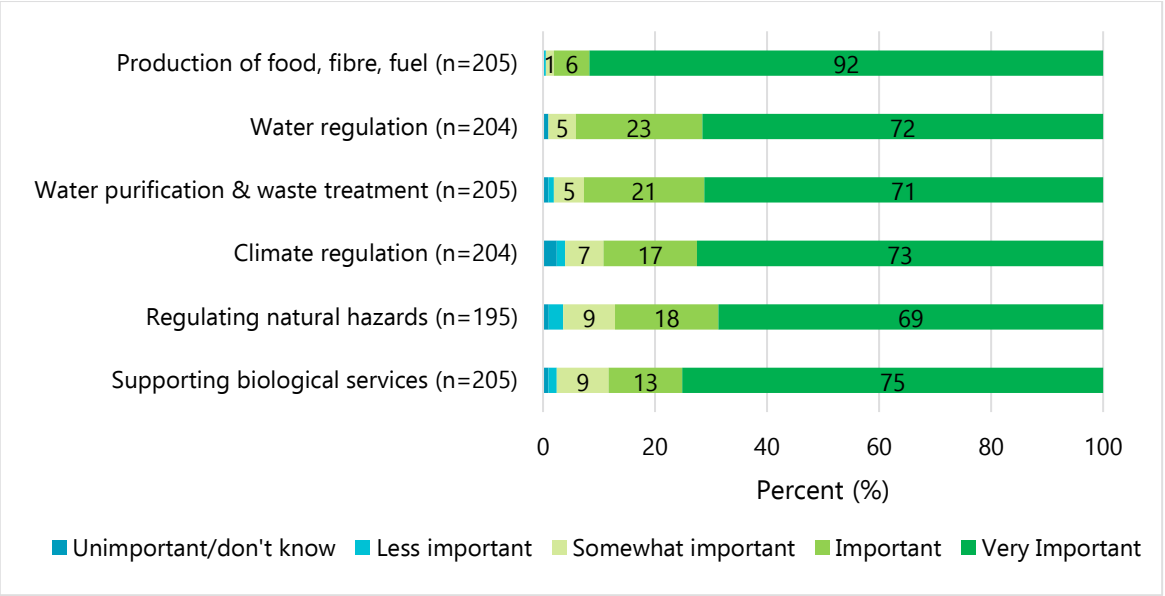

Figure 8. Respondents rating of the importance (%) of soil health to a range of ecosystem services.

4 Discussion and conclusion

The MBIE-funded project "soil health and resilience: oneone ora, tangata ora" aims to support the development of a longer term and more comprehensive view of soil health and resilience. The project also aims to develop an integrated soil health framework that can be used by a wide range of end-users, from primary industry, landowners, iwi/hapū, to central and local government.

4.1 Soil health attitudes and values

The first objective of the survey was to better understand how people think about soil health and how they value soil as a resource. Respondents were asked to define soil health, identify gaps in their understanding of soil health, and to give their views on the importance of soil health, including the relative importance of soil in the provision of various ecosystem services.

Respondents defined soil health in terms of the bio-physical properties, what they can see and identify, the soil's ability to produce and support life and the holistic, mauri or whole context view of a healthy soil. The most common soil health properties that are physically measurable are soil structure, the ability of soil to produce healthy plants and animals, the relationship among soil's biological, chemical, and physical properties, and the soil's ability to support living organisms.

Respondents identified many gaps in our current understanding of soil health that are linked to their definitions of healthy soil. Overall, respondents view soil health holistically: healthy soil is productive, sustains biota and human uses, is resilient to human and natural impacts, supports the ecosystem and provisions of ecosystem services, and should be treated as any other living, breathing organism. These views also included recognizing and

assessing the relationship between and among land use, land practices, ecosystem services, and cultural values.

However, many respondents were concerned that our current ways of viewing and regulating the land are causing increased stress on soils which in turn leads to declining crop productivity and ecosystem services, lost productive land, erosion, pugging, and other deteriorating soil health indicators. Respondents thought that some of these views and policies were the result of misinformation/pseudo-knowledge, trade-offs between soil health and productivity, and the pull to maintain the status quo of current knowledge, practices, and policies. Respondents suggested better application of our current knowledge (both from within New Zealand and from abroad), changes to current policy that reflect that better knowledge, and a more holistic, mātauranga view of our relationship to and with the land.

Many respondents expressed the opinion that there is a need to change how society views soil health, and to understand people's attitudes to and opinions of the different dimensions of soil health. In this survey, respondents agreed that soil health is very important to New Zealand's economy, environment and to society but that soil health is currently undervalued in New Zealand policy. From a personal and cultural perspective, soil health is also important to respondents.

With regards to ecosystem services, respondents thought that soil health is very important for the provision of food, fibre, and fuel. Overall, most respondents thought that soil health is important for the provision of water regulation, water purification/waste treatment, climate regulation, natural hazards, or supporting biological services.

4.2 Monitoring soil health

The second objective of the survey was to better understand how soil health is currently being monitored and the possible gaps in monitoring and management. This objective was achieved through questions related to current management of soil health, current soil health monitoring practices, gaps in how soil health is monitored, and observed long-term or significant changes in soil health.

The majority of respondents monitored soil health as part of their work or on their land and/or farm. Most farmers managed soil health on their land/farm using a combination of stock, e.g. stocking rates or using lighter stock, grazing, e.g. rotate stock around paddock, pasture, e.g. standoff stock during wet times, and cropping, e.g. mixed and rotational crops management. Many also subscribed to more biological/holistic/organic methods of farming, such as avoiding herbicides, pesticides, and artificial fertilisers, using organic fertilisers, compost, and growing green manure crops. They also used soil tests to determine the type, timing, and application rate of fertilisers.

Respondents identified numerous gaps in what, how, and how often soil is monitored. Many of these gaps reflect those identified in understanding and definitions of soil health. In particular, there are gaps in monitoring the interdependencies and interactions of land use, ecosystem services, and living organisms.

Several respondents highlighted the connection between soil structure and soil biology, in particular the effect of compaction, for example on the activity of insects and other biota. A recurring theme was the measurement of such biological aspects of soil health as soil microbiology (fungus, bacteria, etc.) and pests in the soil. Possible measurements or monitoring of soil structure and soil compaction include permeability, drainage, water-holding capacity, pugging, topsoil (and horizon) depth, and rooting depth.

Respondents also further emphasised the need to understand broader scale impacts and spatial factors of soil health. These broader impacts included disturbance, fragmentation and loss of productive soils, and different types of land use associated with soil.

Finally, respondents wanted better monitoring to better understand the soil's ability to renew, the integrity of soils in relation to taonga species, the health of animals and/or plants dependent on the soil, and the value of ecosystem services provided by soils beyond monetary value, both in stock and processes.

Through monitoring and working with soils, respondents have seen long-term and significant changes to soil health; however, there is variation in how, where, and what has changed.

While some respondents thought pasture productivity, topsoil and root depth, water storage/drainage, compaction and soil structure, and resilience to shocks e.g. drought, have improved over time, other respondents thought soil structure and integrity, nutrients and trace elements, compaction, erodibility, and soil stability (including slips), soil fertility and productivity, and root depth and organic matter were in decline. These differences could be explained by the spatial differences in observations and the ways in which respondents worked with soils i.e. the respondent's profession.

Across the survey there is a recurring emphasis on the importance of soil to support life, humans, and production, and on the interactions between physical, chemical, and biological elements. There is also broad agreement among the respondents that there is a strong need for greater awareness of the importance of soil, a more coordinated approach to managing and monitoring soil health, and a new approach to researching, monitoring, and managing the land.

4.3 Networking and engaging with soil health enthusiasts

The third objective of the survey was to connect the project with an immensely engaged community of people who are passionate about soil health and to understand their perspectives on the current state and future possibility of soil health. Using the snowball method to distribute this survey, we started with 100 known contacts and closed the survey with 235 responses from various stakeholders. This allowed us to broaden the network of interested parties and provide a platform for further engagement in the future.

4.4 Ongoing work in the Oneone ora, tangata ora project

The soil heath and resilience: oneone ora, tangata ora project is ongoing and this survey is only one part of the larger project. The survey results feed into a stakeholder mapping workshop that was conducted at a similar time as this survey. Both this survey and the workshop aim to contribute to the development of an integrated soil health framework that can be used by a wide range of end-users, from primary industry, landowners, iwi/hapū, to central and local government.

An adaptive approach to stakeholder involvement is an important aspect of this project. While we have identified a key set of initial stakeholders from current networks, the workshop, and this survey, we anticipate that this list will evolve and grow throughout the life of the project, depending on interest, expertise, and factors such as changing roles.

In addition, this survey has identified a range of perceived gaps in our efforts to monitor and understand soil health. The results of this survey will contribute both to the development of a shared understanding of soil health among stakeholders, and to the further development of the project.

Appendix 1 – Survey

INTRODUCTION

This short baseline survey is part of the new MBIE-funded project "soil health and resilience: oneone ora, tangata ora".

The project aims to support the development of a longer-term and more comprehensive view of soil health and resilience. It will also seek to develop an integrated soil health framework that can be used by a wide range of end-users, from primary industry, landowners, iwi/hapū, to central and local government.

To support these goals, we are seeking input from a wide range of soil professionals, land owners and other end-users. By seeking diverse perspectives at this early stage in the project, we hope the survey will provide us with:

1 A baseline understanding of the different ways people understand soil health and value soil as a resource.

2 Information on which aspects of soil health are currently being monitored, and where gaps are perceived

3 A network of interested parties who would like to keep in touch with progress in the project.

If you have any questions about the survey, please contact Electra Kalaugher at kalaughere@landcareresearch.co.nz. We estimate that it will take less than 10 minutes to complete and all questions are optional.

If you would like to go in the draw to win one of two restaurant vouchers or a donation to a charity of your choice, please provide a contact on the last page. The survey will close on Friday 16th June at 5pm.

We really appreciate you taking the time to share your knowledge and experience with us.

SURVEY QUESTIONS

Question 1: How important is soil to you in your profession?

Unimportant	Not really important	Somewhat important	Important	Very important
(1)	(2)	(3)	(4)	(5)

Question 2: I am a (Please check more than one if applicable)

- Farmer/grower/producer/landowner
- Researcher (soil)
- Researcher (other)
- Policy maker/planner or other local government
- Agricultural consultant/extensionist
- Soil consultant

- Primary sector support organisation – other
- Māori representative
- Other (comment): _____

Question 3: Type of farm (more than one answer can be checked):

- Dairy
- Drystock
- Horticulture
- Cropping
- Other (please specify): _____

Question 4: Do you actively manage soil quality or soil health on your farm? If so, please comment on your approach.

- _____

Question 5: How would you define Soil Health?

- _____

Question 6: Do you monitor soil quality or soil health as part of your work, or on your own land?

- _____

Question 7: Which aspects of soil quality and/or health do you monitor? (Please check all that apply)

- Basic soil test (pH; Olsen P; Cations - Ca, K, Mg, Na; Cation Exchange Capacity; Base Saturation; Volume Weight/Bulk density)
- Available N
- Other N tests (e.g. anaerobic mineralisable nitrogen, total N - please elaborate below)
- Other P tests (e.g. Resin P, total phosphorus, Bray, Truog or Mehlich - please elaborate below)
- ASC (phosphate retention)
- Sulphur (sulphate, extractable organic sulphur, total sulphur)
- Trace elements
- Electrical conductivity (EC)
- Organic matter
- Total C
- Carbon: nitrogen ratio
- Macro-porosity or total porosity
- Rooting depth or penetration resistance
- Aggregate stability
- Microbial biomass and/or composition

- Respiration
- Worm count
- Other (please specify): _____

Question 8: Are there other aspects of soil health you feel are important to monitor?

- _____

Question 9: Have you observed or measured any long term or significant changes to the soils you work with? If so, please elaborate.

- _____

Question 10: Please indicate how much you agree with the following statements:

Long term soil health is essential to NZ's economy	**Completely agree**	**Somewhat agree**	**Neither agree nor disagree**	**Somewhat disagree**	**Completely disagree**	**Don't know/ not relevant**
Soil health is essential for a healthy environment	**Completely agree**	**Somewhat agree**	**Neither agree nor disagree**	**Somewhat disagree**	**Completely disagree**	**Don't know/ not relevant**
Healthy soil is important for a healthy society	**Completely agree**	**Somewhat agree**	**Neither agree nor disagree**	**Somewhat disagree**	**Completely disagree**	**Don't know/ not relevant**
Soil health is important to me from a cultural perspective	**Completely agree**	**Somewhat agree**	**Neither agree nor disagree**	**Somewhat disagree**	**Completely disagree**	**Don't know/ not relevant**
Soil health is important to me personally, on an intrinsic level	**Completely agree**	**Somewhat agree**	**Neither agree nor disagree**	**Somewhat disagree**	**Completely disagree**	**Don't know/ not relevant**
Soil health is currently undervalued in NZ policy	**Completely agree**	**Somewhat agree**	**Neither agree nor disagree**	**Somewhat disagree**	**Completely disagree**	**Don't know/ not relevant**

Question 11: Please rate the importance of soil health in the provision of these services:

Production of food, fibre, fuel	**Very important**	**Important**	**Somewhat important**	**Less important**	**Unimportant/ Don't know**
Water regulation (e.g. flows)	**Very important**	**Important**	**Somewhat important**	**Less important**	**Unimportant/ Don't know**
Water purification & waste treatment	**Very important**	**Important**	**Somewhat important**	**Less important**	**Unimportant/ Don't know**
Climate regulation (e.g. carbon sequestration)	**Very important**	**Important**	**Somewhat important**	**Less important**	**Unimportant/ Don't know**
Regulating natural hazards (e.g. flooding, erosion control)	**Very important**	**Important**	**Somewhat important**	**Less important**	**Unimportant/ Don't know**
Supporting biological services (e.g. pollination, pest/disease regulation)	**Very important**	**Important**	**Somewhat important**	**Less important**	**Unimportant/ Don't know**

Question 12: Do you think there are any gaps in our current understanding and assessment of soil health? If so, please elaborate!

- _____

Question 13: Which region do you live in?

- Northland
- …
- Southland
- Outside of New Zealand

Question 14: What is your sex?

- Male
- Female
- Prefer not to answer

Question 15: Which ethnicity(s) do you most identify with?

- NZ Māori
- NZ European/Pākehā
- European (other)
- Asian
- Pacific Islander
- Middle eastern/Latin American/African
- Other: _____

THANK YOU

Thank you very much for taking the time to complete this survey. If you have any further questions about the project or this survey, please contact Electra Kalaugher at kalaughere@landcareresearch.co.nz.

If you would like to be kept up to date with the progress of this project, including the survey results, please enter your email into the box below. We plan to provide project updates on a quarterly basis, and will not share your contact details beyond their direct use in this project.