# Assessing soil health following conversion from forestry to pasture in Canterbury

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## Abstract

Soil health was assessed across land conversions from forestry (*Pinus radiata*) to irrigated dairy pasture. Samples were collected and indicators of soil fertility, organic matter, soil physical condition and biological activity assessed. Soil health scores were calculated from the indicators and distance from optimum shown in radar plots. Soil health was improved for pastoral land use following conversion from forestry. The time since forestry ceased and irrigation commenced had a signification effect on indicators of soil health, although many were not optimum even for the sites longest out of forestry/under irrigation. The main factors contributing to lower scores across all sites were suboptimal fertility, high C:N ratios, high macroporosity, low microbial respiration and low earthworm abundance and diversity. Some aspects (*e.g.*, fertility) could be managed through nutrient application, while other aspects are more difficult to manage (*e.g.*, C:N ratio and biological activity). Management targeting these properties may accelerate the path to a healthy and well-functioning soil. The inclusion of a wider range of indicators can help to better understand and manage soils during the conversion from forestry to pasture. This approach could be useful across all pasture systems to help ensure well-functioning soils.

**Keywords:** soil fertility; organic matter, soil physical condition, biological activity

## Introduction

The life sustaining capacity of the soil is based on a healthy soil, which can be defined as having good structure, appropriate water storage and drainage, readily available nutrients and a diversity of beneficial macro- and microorganism populations. Maintaining the underlying physical, chemical and biological components of a soil enables it to continue to function and provide ecosystem services to sustain living things and be resilient to degradation and other unfavourable perturbations.

Literature on soil health (including quality) is vast, but there is no universally accepted methodology to assess health, due to a diversity of landscapes and uses in which they need to be applied (Bünemann et al. 2018). Soil health often refers to dynamic properties which can change with management; however, it is governed by inherent soil properties (land suitability). In New Zealand, soil quality is often described using a basic suite of indicators (*e.g.*, pH, Olsen P, mineralisable nitrogen, total soil carbon, total soil nitrogen, bulk density and macroporosity) developed from a project spanning 500 soils (Lilburne et al. 2004; Sparling et al. 2008). This approach has been employed by regional councils for monitoring quality and State of Environment reporting (Drewry et al. 2017) but has only included pseudo biological indicators for the assessment of biological status.

This work added indicators to this basic suite of indicators in the present study (*e.g.*, soil C:N ratio, available water capacity, microbial respiration, earthworm abundance and diversity and pasture insect pests) to gain further insights into the response of soil health under changing land use. This expanded indicator set was used to assess how conversion from forestry (*Pinus radiata L.*) to irrigated pastoral agriculture (dairy production) influenced soil health, with reference to optimal ranges. The aims were to 1) assess how soil health changed following conversion from forest to pasture, and 2) develop a method to assess and visualise soil health in relation to optimal ranges relevant to pasture systems.

## Materials and Methods

### Site selection

Sites were selected from land that was previously part of the Eyrewell Forest, north of the Waimakariri River near Christchurch, New Zealand (Figure 1). All sites were located on a Pallic Firm Brown soil (NZSC), *viz.*, Lismore silt loam. This was characterised as shallow, well drained and moderately stony (www.smap.landcareresearch.co.nz). Average annual temperature and rainfall at this location are 11.5ºC and 650 mm, respectively.

This work included sampling an existing forest site (*Pinus radiata*, dryland), two dairy farms (Hāmua and Farm 1) and a support block (Farm 16). The dairy farms and support block were between 3 to 10+ years post

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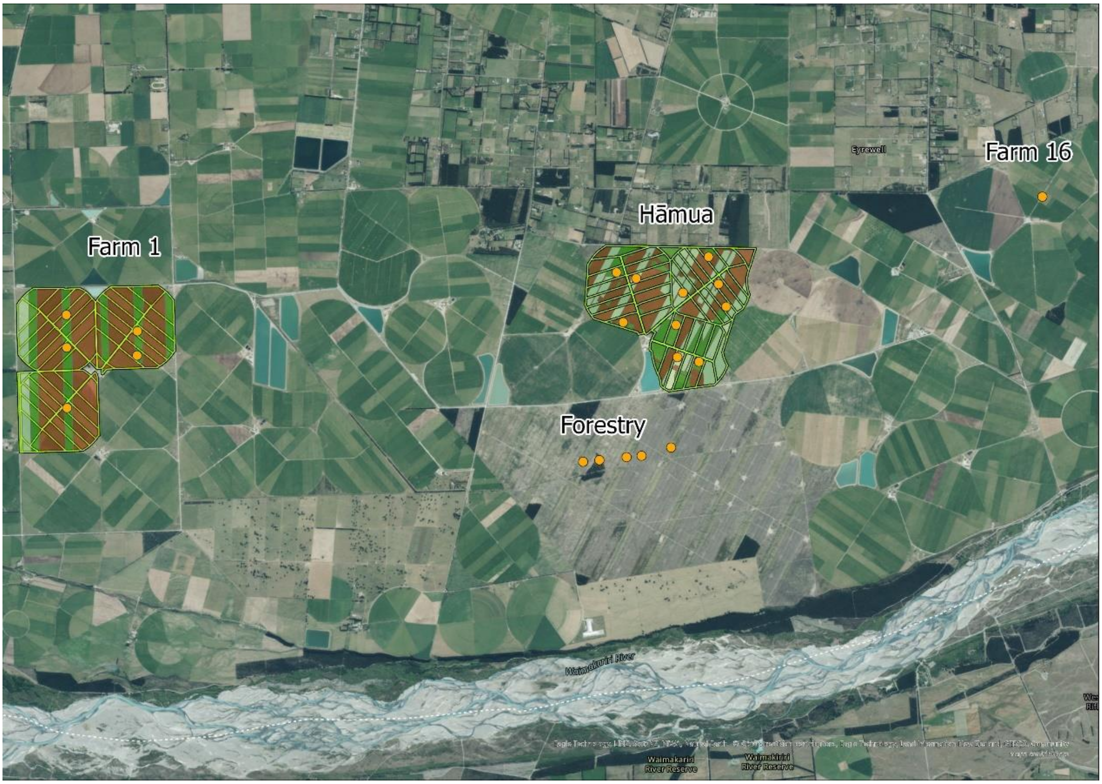

**Figure 1** Location of sample sites on Ngāi Tahu properties, North Canterbury. Samples sites shown as yellow dots. Within each farm areas where forestry had ceased (green) is shown in comparison to those more recently converted from forestry (brown).

conversion from forestry. Irrigation was introduced to the dairy farms and support block between two- and seven-years post conversion (not necessarily the same order, see Table 1). Each of the farm sites was selected to ensure that time since forestry ceased was the same, with the exception of the Hāmua farm, where half of the paddocks sampled had no *P. radiata* since at least 2009 (Hāmua no trees) and the other five had *P. radiata* before 2015, (Hāmua trees). A previous trial site was sampled at Farm 16, and the data were pooled for this farm.

## Sampling and analysis

Soil samples were collected in May 2019 to determine a suite of indicators that encompassed fertility, organic matter, physical and biological soil attributes, as described below.

Thirty soil cores (25 mm diameter × 75 mm deep) were collected for each paddock and bulked for analysis. Forest floor litter was cleared from the soil surface prior to sampling. Soil was air dried and then passed through a 2 mm sieve before analysis. Samples were analysed for pH (1:2.5 soil:water) and Olsen phosphorus (P) concentrations (Olsen et al. 1954). Soil total nitrogen (N) and carbon (C) concentrations were analysed following the Dumas combustion method using an Elementar Vario Max Cube Analyser (Bremner 1996). Anaerobically mineralisable nitrogen (AMN) was determined over a seven day incubation period (Keeney and Bremner 1966).

**Table 1** Number of paddocks sampled at each site, including details on years since forestry ceased and irrigation commenced.

| | Forestry | Hāmua Trees | Hāmua No trees | Farm 16 | Farm 1 |
|---|---|---|---|---|---|
| Land use | *Pinus radiata* | Dairy production | Dairy production | Dairy support | Dairy production |
| Number of paddocks sampled | 5 | 5 | 5 | 8 | 5 |
| Years since forestry ceased | 0 | 4 | 10+ | 3 | 7 |
| Years since irrigation commenced | 0 | 2 | 2 | 3 | 7 |

Triplicate undisturbed core samples (100 mm diameter, 75 mm deep) were collected for measuring bulk density and soil hydraulic properties. Due to the stone content of the soil, samples were difficult to collect and so results may not be fully representative of each site. Pressure plates were used to determine field capacity (−10 kPa) and wilting point (−1500 kPa) (Gradwell 1960) moisture contents of the Lismore soil. Soil macroporosity (air-filled porosity at −10 kPa soil water pressure) was determined as the volumetric difference between total porosity and water content at −10 kPa. Total available water capacity (AWC) was calculated as the difference between field capacity and wilting point. Bulk density was determined by oven-drying at 105°C for 48 h and then weighing soil cores. Stone content in each sample was determined and used to correct measurements of volume and weight.

Microbial respiration was determined using a MicroResp assay (Campbell et al. 2003) for subsamples taken from soil fertility cores. Colorimetric $CO_2$-traps, consisting of 96-well plates of a cresol red-based pH indicator which were sealed to corresponding 96-well plate containing soil and incubated at 22°C for 5 h. Absorbance of the $CO_2$-traps was measured at 590 nm (Biolog microplate spectrophotometer) immediately prior to sealing to the soil and then at the end of the incubation. The $CO_2$ produced was calculated through the change in absorbance over 5 h.

Five soil turves (200 × 200 × 200 mm) were collected from each paddock and hand-sorted for soil invertebrates. Earthworms and all insect pasture pests (*e.g.*, grassgrub, porina, and clover root weevil) were identified and counted. The risk of root pathogen pressure was estimated as the ratio of anaerobically mineralisable N to total N. Early results from New Zealand-wide sampling dairy farms have shown this ratio to be an indicator of soil-borne plant disease pressure, but more testing is required to confirm this (Dignam et al. 2022). The indicator was included here to show the range of possible risks to soil functioning.

### Soil health score

Soil health scores were compared to optimal ranges, which have been previously defined for pasture soils for the following soil indicators: pH, soil total C, soil total N, AMN, BD (Sparling et al. 2008), Olsen P (Roberts and Morton 2016), macroporosity (Houlbrooke et al. 2011), earthworm abundance and diversity (Schon et al. 2022), and pasture insect pests (Ferguson et al. 2019). Optimal ranges for some indicators are not well established for New Zealand soils, and remain provisional for available water capacity (www.smap.landcareresearch.co.nz), microbial respiration (Doran et al. 1997) and pasture disease risk (Dignam et al. 2022). Note optimal ranges may change as additional research data are provided and scientific understanding improves.

Where available, optimal ranges specific to soil type were used and compared to targets specific to High Class soils that are productive, deep, free-draining, friable soils formed from volcanic tephra, *e.g.*, Egmont black loam, (A. Roberts pers. Comm). This comparison was made as Ngāi Tahu Farming recognised that the Lismore soil being farmed had a Land Use Capability rating of Class 4 (ourenvironment.scinfo.org.nz) that was suitable for occasional cropping, pastoralism, tree crops and forestry, but had significant limitations for arable use or cultivation. Whilst this soil will never reach the status of Class 1 land, this approach allowed Ngāi Tahu Farming to recognise the limitations that influence their ability to farm the land sustainably.

Values at or within their optimal range were given a value of 1. If they were below their optimal range their score was calculated using Equation 1. If values were above their optimal range, scores were calculated using Equation 2. Theoretical minimum and maximum values represent the potential range possible for each indicator. Scores were plotted to represent proximity to optimal ranges. When values were below suboptimal (values not presented) an extra weighting (1.5x) was given in the equation, with a minimum score of 0 possible.

**Equation 1**

$$\text{Score} = 1 - \frac{\text{optimal - measured value}}{\text{optimal – theoretical minimum}}$$

**Equation 2**

$$\text{Score} = 1 - \frac{\text{measured value - optimal}}{\text{theoretical maximum – optimal}}$$

### Statistical analysis

For total soil C, N, C:N ratio and macroporosity, changes since conversion from forestry and to irrigation were examined using linear regression. Quadratic regressions were applied to examine changes in pH, Olsen P, AMN, bulk density and AWC. The time since irrigation did not necessarily correspond to years since conversion from forestry. A comparison between invertebrates (*e.g.*, earthworms and insect pasture pests) was determined using analysis of variance (ANOVA) to assess the influence of years since forestry and irrigation. The ANOVA was applied to each invertebrate variable separately from other variables. For all invertebrate variable analyses, years was used as a factor, because invertebrate abundance did not exhibit changes that can be described by a continuous numerical function during the study period. In addition, total earthworm abundance and clover root weevil abundance was $\log_e(x+1)$-transformed prior to the ANOVAs, to

**Table 2** Soil indicators and measures used to assess soil health at Ngāi Tahu properties, North Canterbury in May 2019. 'Optimal' target or range (given specific to sedimentary soils if possible), and 'target' for high producing pasture. See methods for references for optimal ranges. SEM values are given in parenthesis.

| Indicators | Measure (Target) | Optimal | Forestry Trees | Hāmua No trees | Hāmua | Farm 16 | Farm 1 | P-value Forestry ceased | Irrigation commenced |
|---|---|---|---|---|---|---|---|---|---|
| Soil acidity | pH | 5.5-6.3 **(5.8-6.0)** | 🟨 5.2 (±0.1) | 🟩 6.3 (±0.1) | 🟥 6.6 (±0.1) | 🟩 6.2 (±0.3) | 🟩 5.7 (±0.1) | <0.001 | <0.001 |
| Phosphorus availability | Olsen P (µg/ml) | 20-30 **(30-35)** | 🟨 7.6 (±0.4) | 🟨 18.2 (±1.9) | 🟩 22.8 (±4.7) | 🟥 51.0 (±4.5) | 🟩 29.0 (±3.0) | 0.113 | 0.008 |
| Total soil carbon | C (%) | >3.5 **(>6)** | 🟩 8.6 (±1.3) | 🟩 8.6 (±0.6) | 🟩 7.4 (±0.4) | 🟩 8.3 (±0.2) | 🟩 8.9 (±1.1) | 0.387 | 0.624 |
| Total soil nitrogen | N (%) | 0.25-0.70 **(0.6-0.7)** | 🟩 0.31(±0.04) | 🟩 0.36 (±0.01) | 🟩 0.42 (±0.03) | 🟩 0.40 (±0.03) | 🟩 0.53 (±0.04) | 0.008 | <0.001 |
| Organic matter quality | C:N ratio | 8-12:1 **(9-11:1)** | 🟥 27.0 (±1.0) | 🟥 23.5 (±0.8) | 🟥 17.7 (±0.3) | 🟥 20.5 (±1.4) | 🟥 16.5 (±1.1) | <0.001 | 0.001 |
| Mineralisable N | AMN (kg/ha) | 50-250 **(80-200)** | 🟩 78 (±13) | 🟩 165 (±7) | 🟩 244 (±14) | 🟩 158 (±18) | 🟩 209 (±9) | <0.001 | <0.001 |
| Soil density | BD (g/cm$^3$) | 0.9-1.3 **(0.7-0.9)** | 🟩 0.91(±0.04) | 🟨 0.86 (±0.02) | 🟩 1.01(±0.06) | 🟨 0.80 (±0.04) | 🟩 0.99 (±0.03) | 0.003 | 0.229 |
| Soil macroporosity | MP (%) | 8-30 **(10-15)** | 🟨 41.7 (±1.5) | 🟨 34.7 (±0.9) | 🟨 32.0 (±2.5) | 🟨 40.3 (±1.0) | 🟨 26.9 (±0.8) | <0.001 | <0.001 |
| Available water capacity$_1$ | AWC (mm/100mm) | >6 **(>20)** | 🟩 8.8 (±1.9) | 🟩 14.2 (±1.6) | 🟩 11.1 (±1.1) | 🟩 11.6 (±1.1) | 🟩 15.5 (±1.3) | 0.003 | 0.007 |
| Soil microbial respiration$^2$ | Resp (µg/g/h $CO_2$-C) | 1.25-5 | 🟨 1.00 (±0.12) | 🟩 1.32 (±0.74) | 🟨 0.95 (±0.09) | 🟨 1.18 (±0.60) | 🟨 1.08 (±0.08) | 0.493 | 0.853 |
| Earthworm abundance | EW (m$^{-2}$) | >400 | 🟨 0 (±0) | 🟨 3 (±3) | 🟨 38 (±21) | 🟨 5 (±1) | 🟨 195 (±103) | <0.001 | <0.001 |
| Earthworm diversity | EW div | 3 | 🟨 0 (±0) | 🟨 1 (±0.1) | 🟨 2 (±0.2) | 🟨 2 (±0.2) | 🟨 2 (±0.2) | <0.001 | <0.001 |
| Pasture disease risk$^3$ | AMN:TN | >2 | 🟨 1.7 (±0.3) | 🟩 3.1(±0.3) | 🟩 3.9 (±0.3) | 🟩 3.9 (±0.4) | 🟩 2.7 (±0.3) | 0.009 | 0.001 |
| Pasture insect pests | Porina (m$^{-2}$) | <20 | 🟩 1 (±1) | 🟩 2 (±1) | 🟩 0 (±0) | 🟩 0 (±0) | 🟩 2 (±1) | 0.109 | 0.069 |
| | Grassgrub (m$^{-2}$) | <150 | 🟩 0 (±0) | 🟩 0 (±0) | 🟩 0 (±0) | 🟩 0 (±0) | 🟩 2 (±1) | 0.242 | 0.135 |
| | Clover root weevil (m$^{-2}$) | <130 | 🟩 0 (±0) | 🟩 87 (±34) | 🟩 76 (±17) | 🟩 2 (±2) | 🟩 32 (±14) | <0.001 | <0.001 |

Shading shows whether values below (yellow), at (green) or above (red) optimal range. Note ranges may change as science knowledge improves.

[1] Measure for sampled depth rather than the whole soil profile.

[2] Optimal range from overseas studies (Doran et al. 1997).

[3] This is a potential indicator of pasture disease risk but further research is required (Dignam et al. 2022).

stabilise variation. All ANOVAs were carried out with statistical software SAS version 9.3.

## Results

The range of soil indicators and their optimal ranges are shown in Table 2. Many of these indicators were not optimum and were typically low under forestry. It is important to acknowledge that the optimal ranges used were for pasture, rather than forest soil, to allow for comparison following conversion. The use of forestry-specific indicators, often with wider target ranges (Sparling et al. 2008), was only available for a few indicators (*e.g.*, pH, Olsen P, total soil N, C:N and AMN). If these target ranges were applied for the forestry sites, all except the C:N ratio would be at optimum under forestry (with only soil pH and Olsen P changing). The number of years since forestry ceased or irrigation commenced tended to have a significant effect on indicators measured. However, Olsen P levels, which were low under forestry, were found both above or below optimum ranges under pasture (Table 2), and variable at the paddock level (Schon and Roberts 2020).

Soil total C was high across all sites (>7.4%, compared to 2.8% in the A horizon at the nearby Eyrewell Scientific Reserve (Molloy and Ives, 1972)) with little difference between forestry and pasture (Table 2). Soil total N was lower under forestry, although still within optimal range. Under pasture, soil total N and readily available N (AMN) was higher, reflecting greater fertiliser N inputs and recycling of dung and urine from the grazing. While the soil C:N ratio was reduced, the ratio remained above optimal levels for pasture. From the samples that were collected, the soil appeared friable. This was supported by high macroporosity, although values were higher than expected under pasture and may have been a result of the high stone and organic matter content and short history of dairying on these soils. Soil macroporosity declined with years under pasture (Table 2). Since this was above optimal, its reduction at this stage of the conversion would improve soil health but needs to be monitored to ensure compaction does not become an issue.

Microbial respiration was low across all sites and is likely an indication of low microbial activity and rates of decomposition (Table 2). Earthworms were absent under forestry and were low across other sites. Earthworm abundance was highest at Farm 1, which had been under permanent pasture and irrigation for the longest period. Earthworm populations in one paddock reached abundances of nearly 600/m$^2$ but were less than 200/m$^2$ in other paddocks across the farm. Pressure on pasture from pests and diseases appears to be limited at the sites sampled.

Total soil health scores were lowest under forestry (63.8%) and highest at Farm 1 (91.1%; Table 3). A similar trend was seen when using high producing pasture targets, although differences, especially in regards to organic matter properties and soil physical condition, were more pronounced (Tabel 3). Although 'Hāmua no trees' had been out of forestry for longer, it was likely that the longer period of irrigation at Farm 1 had a positive influence on total soil health score. The soil health scores are summarised in radar plots (Figure 2). A score of one was given when an indicator was optimal, with a score of less than one if it was either above or below optimal range.

## Discussion

Sampling sites previously under exotic forest showed that conversion to pasture changed soil health metrics. The overall soil health score was higher at sites out of forestry for longer (Hāmua no trees and Farm 1), but many indicators remained below optimal. The main factors contributing to a lower score across all sites was suboptimal soil fertility, high C:N ratios, high macroporosity, low microbial respiration and low earthworm abundance and diversity. These factors encompassed most aspects of the soil health spectrum, which had potential implications for soil functioning and provided opportunity to improve indicators over time.

The comparison of soil specific optimum ranges with targets for high producing pasture soils highlighted the balance of opportunities and limitations specific to a site. Across the Ngāi Tahu properties, the largest difference between the two scores (soil specific

**Table 3** Soil health scores at selected Ngāi Tahu properties, North Canterbury in May 2019 in relation to the optimal range specific to soil type. Where target is different for high producing pasture, score is given in parenthesis. Each variable contributing to the total soil health score can have a maximum value of 1. The percentage at soil specific optimal range and at high producing target also given, the higher the value the better.

| | Forestry | Hāmua Trees | No trees | Farm 16 | Farm 1 |
|---|---|---|---|---|---|
| Soil acidity | 0.89 (0.80) | 1 (0.88) | 0.86 (0.76) | 1 (0.92) | 1 (0.97) |
| Phosphorus availability | 0.07 (0) | 0.91 (0.61) | 1 (0.76) | 0.86 (0.89) | 1 (0.97) |
| Total soil carbon | 1 (1) | 1 (1) | 1 (1) | 1 (1) | 1 (1) |
| Total soil nitrogen | 0.88 (0.51) | 1 (0.59) | 1 (0.69) | 1 (0.66) | 1 (0.88) |
| Organic matter quality | 0.2 (0.17) | 0.38 (0.35) | 0.8 (0.77) | 0.54 (0.51) | 0.84 (0.81) |
| Mineralisable N | 1 (0.42) | 1 (0.91) | 1 (0.78) | 1 (0.87) | 1 (0.96) |
| Soil density | 1 (0.99) | 0.94 (1) | 1 (0.88) | 0.86 (1) | 1 (0.90) |
| Soil macroporosity | 0.12 (0) | 0.65 (0.16) | 0.85 (0.27) | 0.23 (0) | 1 (0.66) |
| Available water capacity | 1 (0.44) | 1 (0.71) | 1 (0.56) | 1 (0.58) | 1 (0.78) |
| Soil microbial respiration | 0.80 | 1 | 0.86 | 0.94 | 0.76 |
| Earthworm abundance | 0 | 0.01 | 0.10 | 0.01 | 0.49 |
| Earthworm diversity | 0 | 0.33 | 0.67 | 0.67 | 0.67 |
| Pasture disease risk | 0.85 | 1 | 1 | 1 | 1 |
| Pasture insect pests | 1 | 1 | 1 | 1 | 1 |
| Percentage at soil specific optimal | 63.8 | 80.2 | 86.7 | 79.4 | 91.1 |
| Precentage at high producing target | 49.8 | 68.2 | 72.1 | 71.8 | 84.5 |

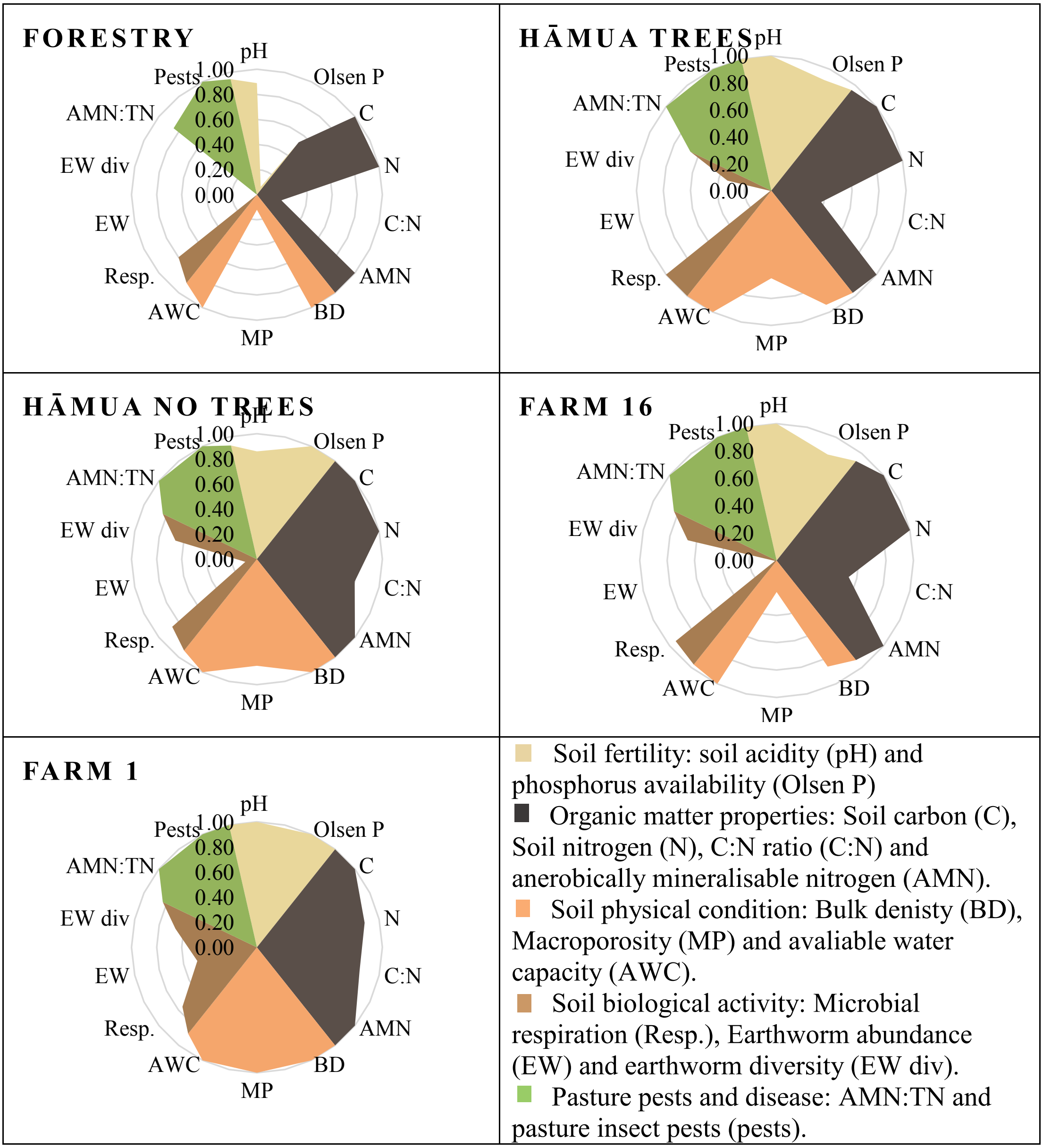

**Figure 2** Radar plots showing overall soil health for Ngāi Tahu properties, North Canterbury in May 2019 in relation to soil-specific optimal ranges. The greater the distance from 1.0 the further away from optimal.

optimum and high producing targets) shown in Table 3 were for organic matter properties (*e.g.*, soil total nitrogen and mineralisable nitrogen) and soil physical condition (macroporosity and available water capacity). These aspects of appeared to have the greatest impact on the overall potential of this site.

Soil fertility measures were not necessarily within the optimal range, despite being actively managed. Nutrient status was variable between paddocks within each farm and could partially be explained by previous history (*e.g.*, time since forestry, Hāmua trees compared to no trees). Comprehensive soil tests (*e.g.,* all paddock testing on farms) could add value by understanding the nutrient status, with the correct type (*e.g.,* nutrient) and rate of fertiliser and/or lime could then be applied on a ‘paddock by paddock’ basis. Changing status of the soil C:N ratio and N availability within the soil is critical to continue to monitor the C:N ratio and then recognise when mineralisation rates in soils were net positive, and then N fertiliser applications have to be adapted. Herbage analysis may be used to understand N uptake by plants. Hedley et al. (2009) suggested that N and P fertiliser can be reduced as soon as three years after conversion from forestry to pasture, even though the C:N ratio may not have dropped to optimal levels. Understanding the point when less N fertiliser is required for pasture response was critical in soils which are vulnerable to N leaching losses. Going forward, the addition of nutrients such as potassium, magnesium, calcium and sulphur (sulphate-S and organic S) which have known target ranges and are assessed for soil fertility monitoring may also be useful as an assessment of soil health.

Although soil macroporosity was above optimal (higher than expected), there is risk in the future from intensive grazing especially during wet weather on the soil physical structure (Ministry for the Environment & Statistics, 2021). Good management of wet soil to avoid degradation of structure is important, especially when managing stock movement during wet periods when the soil is saturated and susceptible to pugging and compaction.

Soil biological indicators were low across all sites, with poor microbial respiration and earthworm abundance. Adequate soil moisture is important, as the pastures were sampled when moisture was low, despite being irrigated. At Farm 1, where earthworms were most abundant, soil moisture was >7% higher than the other sites (Schon and Roberts 2020). Although irrigation appeared to improve the development of soil health across the sites sampled, even after seven years, it was not at optimal levels. Accelerating improvements in soil health during conversion from forestry to pasture likely requires action beyond standard best management practice. For example, stimulating soil biology may maintain physical integrity and provide a ready supply of organic matter inputs.

The use of soil health indicators with target ranges was useful, with radar plots showing the distance each indicator was away from its optimal range, providing a powerful tool for summarising data for communicating with stakeholders. It is timely to consider which indicators can be best used to provide a base understanding of soil health on-farm, and ensuring targets are appropriately defined for a given land use. All indicators used in this study may not necessarily have been required as a measure in an on-farm setting. Some indicators may be best used in a given situation or to answer a specific question (*e.g.,* AWC under irrigation). There are other potential indicators (*e.g.*, hot water extractable carbon) that may be suitable for inclusion once targets have been further defined. However, there are still aspects of the soil system which are difficult to measure and do not have defined target ranges. For example, microbial diversity and functional activity remains difficult to measure on farm and challenging to interpret.

## Conclusions

Changes in soil health indicators showed improvement in pastoral land use following conversion from forestry. Both the cessation of forestry and the commencement of irrigation benefitted the development of better soil health for pasture. However, there were still several properties requiring improvement. This included the management of nutrients to stay within optimal levels. Over time, the soil C:N ratio was expected to improve and biological activity to increase, however, management practices to target these properties could accelerate the path to a healthy and well-functioning soil.

This study demonstrated the potential to include a wider range of indicators beyond soil nutrient fertility, to better understand and manage soils on-farm including during the conversion from forestry to pasture. Visual presentation of the data would be useful to assess which indicators are not at optimal range for land managers and to paint a clear picture for other stakeholders and owners of the current state of soil health and where soil health can be practically improved. This approach can be applied to all pasture systems.

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