SoilsForLife

Milgadara Soil Report

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Introduction

This soil report presents a review of existing soil information and a field and laboratory assessment of a Milgadara soil profile to complement the Milgadara Case Study: Ecological Report. The purpose of the assessment was to increase our knowledge and understanding of the Milgadara soil in relation to changes in practice implemented by the land managers, Rhonda and Bill Daly.

Soil landscape

Milgadara is located on the Crowther soil landscape[1] (Andersson and McNamara 2009) which is typically represented by undulating to rolling low hills with slopes of less than 15% gradient. The soils have formed from the weathering of coarse-grained granodiorite parent materials or from associated alluvial materials.

The Crowther soil landscape includes moderately deep (>30 cm), well-drained, stony soils on the upper slopes and deeper (50 to >100 cm), well-drained (red), texture-contrast soils and non texture-contrast earths and sands on the mid to upper slopes. Moderately well-drained (brown) and imperfectly drained (yellow) versions of these soils occur on the lower slopes and deep (>100 cm), texture-contrast soils with dispersive subsoils may occur on the lower slopes and drainage depressions.

Soil function

At least five (major) soil-forming factors (climate, organisms, relief, parent material and time) interact to give the Milgadara soils their unique, inherent characteristics that determine how well the soils function as a storer, supplier and cycler of nutrients, carbon and water, and as a habitat.

As Rhonda and Bill have learned, understanding soil function is fundamental to maximising soil productivity. At Milgadara, soil productivity is defined as the capacity of the soils to produce:

- a pasture yield to support grazing for prime lamb production and/or cattle
- a profitable cereal, canola or legume crop yield under regenerative land management

[1] A soil landscape is a soil mapping unit that integrates soil and topographic features so the map can be viewed in terms of soil and land qualities and limitations.

Methods

Above-ground observations and measurements such as groundcover and yield are useful indicators of agricultural productivity for Milgadara. However, below-ground soil observations and measurements will better reflect the soil capability[2] and the soil condition[3] on the property and it is these two factors, together with seasonal temperatures and water availability, that will determine the productive potential of the land.

Site and soil location

The site of the soil observation in 135 Acre paddock was selected based on "The Site Concept" of Speight and McDonald (NCST 2009) and is considered to be representative of the landform, vegetation, land surface and other land features at Milgadara. The location of the soil observation was recorded using a GPS, effectively creating a 'benchmark location' or reference site for the future assessment and/or monitoring of improvements in soil condition at the property (Figure 1).

Figure 1. The site in 135 Acre paddock, selected as representative of the typical landform, vegetation and land features at Milgadara.

Soil description

The soil was excavated using a hand auger with a 100 mm diameter Jarratt auger head. The soil profile, hereby referred to as the Milgadara soil, is shown in Figure 2 and was described in the field according to the Australian Soil and Land Survey Field Handbook (NCST 2009). Some soil characteristics, such as drainage, were inferred from other soil features, including rooting depth, soil colour and mottling.

[1] Soil (or land) capability is the inherent physical capacity of the soil (or land) to sustain a range of land uses and management practices in the long term without degradation to soil, land, air and water resources (OEH 2012).

[3] Key soil attributes in relation to known or perceived target or threshold values measured by long-term monitoring. Soil condition is often considered a measure of soil health or quality (Bennett et al. 2019)

Figure 2 The Milgadara soil profile (SFL 2020).

Soil sampling and analysis

One individual soil sample was collected from 0-10 cm, 20-30 cm and 50-60 cm depths in the excavated soil profile (three individual samples in total). These depths represent the soil horizons (layers that display different characteristics) that were observed when describing the soil profile.

A composite sample (a subsample of 20 individual samples randomly collected from 0-10 cm depths across the site) was collected for soil 'fertility' analyses. This sample represents the soil testing that is typically performed on farming properties to determine the nutrient status of the topsoil. A fifth and final individual sample was collected from 0-10 cm depth for microbial analysis.

The three individual samples and one composite sample were submitted to Environmental Analysis Laboratories (EAL), a National Association of Testing Authorities (NATA) and Australian Soil and Plant Analysis Council (ASPAC) accredited laboratory, for soil chemical analysis. The fifth sample was submitted to Microbiology Laboratories Australia (MLA).

Results

One objective of assessing soils in the field and the laboratory is to confirm and/or update historical information and existing soil mapping. Existing soil mapping identified the soils at Milgadara as belonging to the Lithosol, Red-brown Earth and Earth Great Soil Groups (Stace et. al. 1968).

The Lithosols, Red-brown Earths and Earths of the Great Soil Groups correspond to the Rudosols, Chromosols and Kandosols of the Australian Soil Classification (ASC) (Isbell and NCST 2016). According to the ASC Soil Type map of NSW (DPIE 2020), the dominant soil type at Milgadara is a Red Chromosol. The soil landscape, Great Soil Groups (DPIE 2020) and the concept of the soil orders of the Australian Soil Classification (Isbell et al. 1997) relevant to Milgadara are summarised in Table 1.

Table 1. Soil landscape, great soil group type (DPIE 2020), Soil Order and the concept of the Soil Order (Isbell and NCST 2016) at Milgadara.

Soil Landscape[1]	Land System[2]	Soil Order[3]	Concept of the Soil Order[4]
Crowther	Lithosol	Rudosol	Soils that have been little affected by soil forming processes and show negligible development
Crowther	Earth	Kandosol	Weakly structured soils lacking an abrupt increase in texture between the topsoil and subsoil that do not contain carbonates
Crowther	Red-brown Earth	Chromosol	Soils that have an abrupt increase in texture between the topsoil and subsoil and are not strongly acid or sodic

[1] Anderrson and McNamara (2009); [2] Stace et al. (1968); [3] Isbell and NCST (2016); [4] Isbell et al. (1997).

Site and soil description

The Milgadara site and soil were interpreted and described according to the Australian Soil and Land Survey Field Handbook (NCST 2009) and are summarised in Figure 3 and Figure 4. Based on the field observation and laboratory analyses, the Milgadara soil is a Brown Chromosol according to ASC (Isbell and NCST 2016).

SITE INFORMATION

Figure 3. Site information for the Milgadara soil location.

Project (Property)	Milgadara
Date	07/10/2020
Scribe	BROK
Location (Paddock)	135 Acre
Observation Type (e.g. auger boring)	Manual auger boring
GPS Latitude (Decimal Degrees to 6 places)	-34.393680 S
Map Sheet No.	Not applicable
ASC (existing mapping)	Chromosol
Dominant Vegetation Form	Non-woody
Ground Cover %	Dense (>70%)
Aspect	South
GPS Longitude (Decimal Degrees to 6 places	148.474640 E
Map Scale	Not applicable
ASC Ground Truth	Brown Chromosol
Secondary Vegetation Form	Non-woody
Ground Cover %	Dense (>70%)
Slope %	9
Rock Outcrop	No rock outcrop
Erosion Type	None evident
Non-woody vegetation (list all species)	Cocksfoot, fescues, perennial rye, lucerne, clover, plantain, chicory and tillage radish.
Drainage (site)	Well-drained
Erosion Extent	None evident
Landform	Mid-slope
Soil Surface Condition (dry)	Soft
Land Use	Pastures for grazing
Erosion State	None evident

Landscape Photo (Facing North)

Landscape Photo (Facing East)

Soil Surface Condition Photo

Site Type (check site, described site, described + sampled site)	Described + Sampled
Microrelief	None
Type	None evident
Vertical (m)	
Horizontal (m)	
Sampled	

Landscape Photo (Facing South)

Landscape Photo (Facing West)

Other Photo

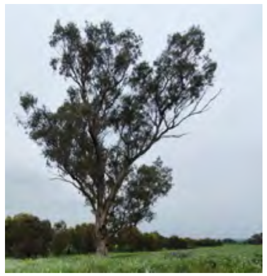
Other Information

Woody vegetation species include stringy bark (Eucalyptus macroryncha), white box (Eucalyptus albens), yellow box (Eucalyptus melliodora), red gum (Eucalyptus blakelyi) and rough-barked apple (Angophora floribunda).

Dominant Vegetation Photo 1

Dominant Vegetation Photo 2

Other Vegetation Photo



SOIL PROFILE DESCRIPTION

Figure 4. A description of the Milgadara soil

Horizon	Depth of Horizon (cm)	Profile Photo	Boundary Distinctness and Shape	Field Texture Grade	Moist Colour	Mottle (colour and abundance)	Segregations (abundance and nature)	Coarse Fragments (abundance and size)	Structure (type)	Structure (grade)	Consistence (soil water status)	Roots (abundance and size)	Field pH and Lab pH_{water}	Lab EC_{water} (dS/m)	Depth of Sample for Lab (cm)
A	0-15		Abrupt (5-20 mm) Smooth	Silty Loam (~25% clay)	Very Dark Brown 7.5YR 2.5/2	None	None	Very few (<2%) Fine (2-6 mm)	Polyhedral	Weak	Weak (moderately moist)	Many (25-200) Fine (1-2 mm)	8.5 8.2	0.03	5-15
A2	15-45		Abrupt (5-20 mm) Smooth	Loam (~25% clay)	Brown 7.5YR 4/4	None	Few (2-10%) Iron-manganese concretions	Very few (<2%) Fine (2-6 mm)	Polyhedral	Weak	Very Weak (moderately moist)	Common (10-25) Fine (1-2 mm)	8.5 8.5	0.01	15-30
B2	45-90+			Light Medium Clay (~40% clay)	Strong Brown 7.5YR 5/6	Few	Common (10-20 %) Iron-manganese concretions	Very few (<2%) Fine (2-6 mm)	Polyhedral	Moderate	Firm (moderately moist)	Few (1-10) Very Fine (<1 mm)	8.0 7.6	0.01	50-60

Other information Soil aggregate stability was assessed in the field by immersing soil aggregates in demineralised water and recording whether the aggregates slaked and/or dispersed. Soil aggregates from all three horizons were stable.

Soil chemistry

The soil chemical properties of the Milgadara soil are summarised in Table 2 and were interpreted following research into the existing literature to determine the desirable ranges and expert knowledge. The desirable ranges serve as a general indication for the grazing of pastures in NSW (Peverill et al. 1999; Horneck et al. 2011; Hazelton and Murphy 2016). A "traffic light" approach representing good, moderate or poor allows the status of each of the soil properties to be assessed at a glance.

Table 2. Soil chemistry of the Milgadara soil.

Soil Depth (cm)	pH_{CaCl} (pH units) Desirable Range 5.0-6.5	pH_{Water} (pH units) Desirable Range 6.0-7.5	$EC_{1:5}$ (dS/m) Desirable Range <0.24	ECe (dS/m) Desirable Range <2.8	ESP (%) Desirable Range <3.0
0-10 (Fertility)	7.7	8.2	0.20	0.46	0.21
0-10	7.5	8.2	0.15	0.43	0.13
20-30	7.7	8.5	0.07	0.18	0.25
50-60	6.9	7.6	0.04	0.15	0.69

Soil Depth (cm)	Exch. Ca (meq/100g) Desirable Range 2-30	Exch. Mg (meq/100g) Desirable Range 1-15	Exch. Na (meq/100g) Desirable Range 0.05-5.0	Exch. K (meq/100g) Desirable Range 0.2-2.0	CEC (meq/100g) Desirable Range 0-100
0-10 (Fertility)	28.9	10.6	0.09	0.67	40.0
0-10	26.2	7.1	0.07	0.85	34.3
20-30	6.7	2.0	0.07	0.40	9.1
50-60	1.9	3.2	0.07	0.50	5.7

Soil Depth (cm)	Ca:Mg Desirable Range 4-6:1	Total N (%) Desirable Range 0.15-0.25	Total C (%) Desirable Range 1-3	Labile C (%) Desirable Range 0.5-1.5	C:N Desirable Range 15-25:1
0-10 (Fertility)	2.7	0.31	8.90	-	-
0-10	3.7	0.33	9.29	1.75	29
20-30	3.4	0.03	1.00	0.13	28
50-60	0.6	0.02	0.26	0.05	33

Soil biology

The soil biological properties of the Milgadara soil serve as indicators of the general health and resilience of the soil system. The results of the analyses conducted by Microbiology Laboratories Australia (2020) are presented in Figure 5 and Figure 6.

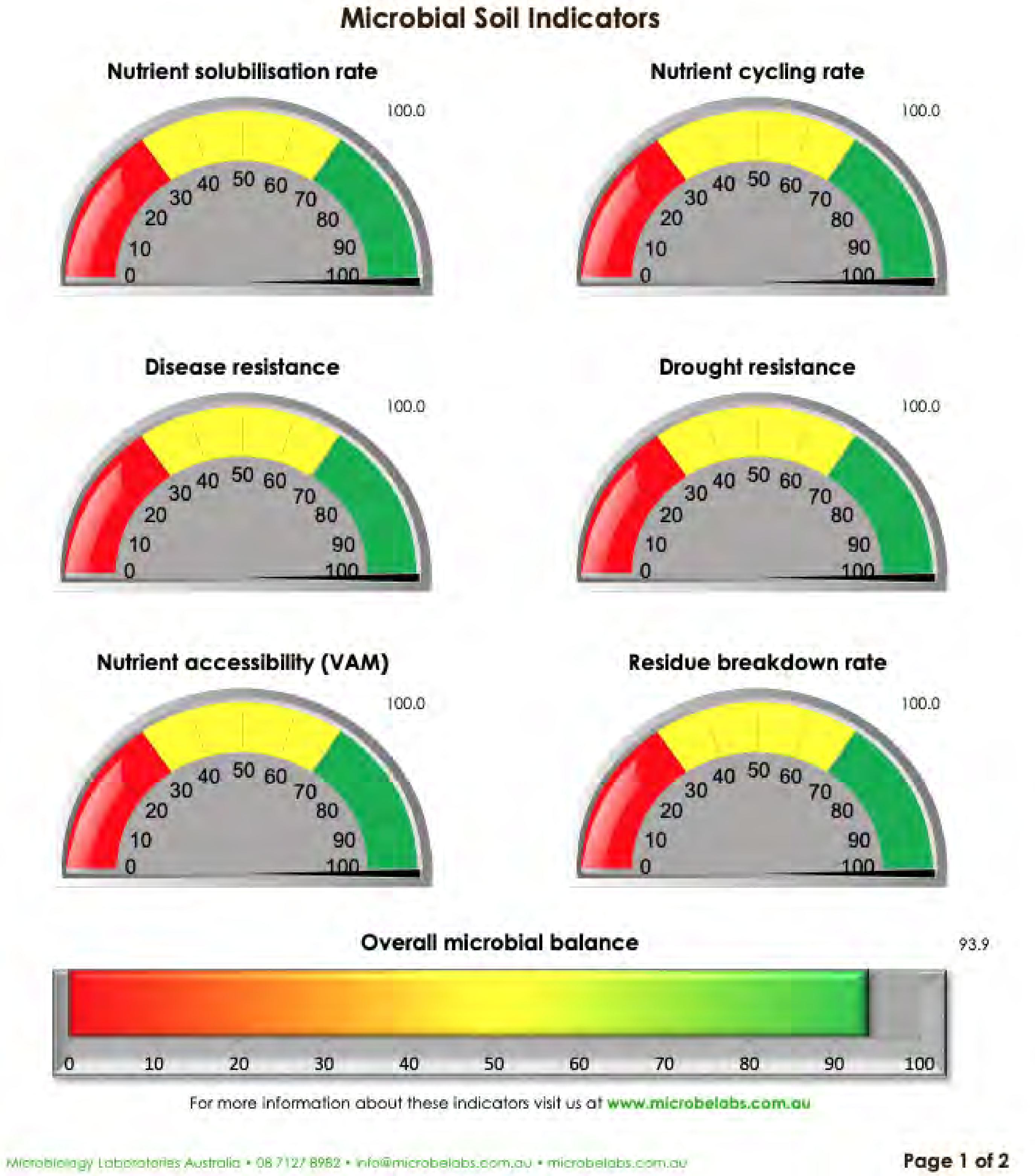


Figure 5. Microbial indicators of the Milgadara topsoil sample (0-10 cm).

Key Microbe Groups

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Total microorganisms	149.7	50.0
Total bacteria	29.6	15.0
Total fungi	113.1	33.8

Microbial indicators	Yours	Guide
Microbial diversity	36.0	80.0
Fungi : Bacteria	3.8	2.3
Bacterial stress	0.2	<0.5

Key *BDL = Below Detectable Limit (0.001 mg/kg)

Poor — Fair — Good

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Bacteria		
Pseudomonas	5.533	1.000
Actinomycetes	3.693	1.000
Gram positive	14.846	4.000
Gram negative	14.716	11.000
Methane oxidisers	0.000	0.500
Sulphur reducers	0.000	<0.005
True anaerobes	0.655	<0.005
Eukaryotes		
Protozoa	7.001	1.300
Mycorrhizal fungi (including VAM)	32.099	10.000

Comments

The soil indicators were all good. The total mass of microbes in your sample was very good. Biomasses of other key desirable microbe groups were also good. However, with these microbial levels, Nitrogen needs to be monitored as high amounts of this nutrient may be kept by the microbes thus competing with the plant. Protozoa, which were very good here, are important for nutrient transfer and cycling between soil trophic levels, and can be sensitive to agrochemicals, particularly herbicides. True anaerobes were elevated, which indicates that this soil was recently waterlogged, or compacted. Microbial diversity was fair. The fungi to bacteria ratio was highly elevated and needs to be balanced. These results suggest that management practices should initially focus on building microbial diversity. Re-test periodically, and once biomass has improved concentrate on minimising True anaerobes, building microbial diversity and biomasses of any key desirable groups that remain low.

Explanations

Microbe Wise for Soil measures the living biomass of key microbial groups important for soil health and productivity directly from your sample. It uses molecular ('DNA type') technology to analyse the unique cell membrane 'fingerprint' of each microbe group to identify and quantify well-known microbial groups essential to important soil processes. The Microbe Wise method allows for some unique features, such as a measure of microbial diversity, a valuable indicator of soil system resilience. Results are presented in a way that allows you to easily assess the microbial health of your soil in detail and indicates what that means in practice. Always compare your results with a control sample. Guide values are included as a help, but because a large number of factors affect microbiology the guide levels may not be optimal for your specific conditions. Visit www.microbelabs.com.au for more information.

Disclaimer

Analysis by Microbiology Laboratories Australia Pty Ltd ACN [illegible]. The information in this report should be used under consideration of particular production conditions. The guide levels are derived from published data and ongoing research carried out by Microbiology Laboratories Australia. They are intended as a general guide only and do not take into account your specific conditions. Comparison of results with those obtained using other methods may be inaccurate, as accurate interpretation relies on specific sampling and analysis methods. Microbiology Laboratories Australia and its employees or agents will not be liable for any loss or damage arising from the use of the information supplied in this report. Please seek specific guidance and recommendations from a qualified agriculture professional.

Figure 6. Key microbial functional groups of the Milgadara topsoil sample (0-10 cm).

Discussion

Soil laboratory analyses were undertaken to determine the chemical and biological status of the Milgadara soil. The resulting dataset also provided an insight into current soil condition and potential soil productivity.

Soil physical properties

The soil physical properties assessed at Milgadara are useful indicators of the soil's physical condition and potential to resist degradation. In particular, soil texture and structure will govern the soil-water relations and affect plant root elongation and shoot emergence.

The silty loam to light medium clay textures of the Milgadara soil, the favourable depth (90 cm+) and no obvious physical limitations ensures adequate short term and long term water storage capacity. The light medium clay texture and moderate structure of the subsoil, as recorded in the soil description sheet (Figure 5) will allow for the movement of water and nutrients and will not limit the growth of plant roots.

Soil chemical properties

The soil chemical properties assessed at Milgadara are useful indicators of the soil's chemical condition, including its potential to retain nutrients. The pH of the Milgadara soil grades from alkaline (pH_{CaCl} 7.7) in the topsoil to slightly alkaline (pH_{CaCl} 6.9) in the subsoil. This pH range is conducive to both biological and chemical activity and will not constrain the availability of plant nutrients or pasture production.

The Milgadara soil has very high (~9%) total carbon levels and the labile carbon component of the total soil carbon (representing more recent additions of organic matter) is also high (>1.75% and above the desirable range). Because labile soil carbon is a food source for the soil microbes that cycles nutrients, the microbes in the Milgadara soil are likely to be well-fed and able to provide a more than adequate supply of nutrients to the crops and pastures.

Total soil nitrogen in the Milgadara soil is slightly higher than the desirable range (>0.25%). Although nitrogen is an essential nutrient for plant growth and development, high levels of total nitrogen might not equate to high levels of plant available nitrogen, particularly if the carbon to nitrogen ratio (C:N) is high (the amount of soil carbon is high relative to the amount of soil nitrogen). In the case of the Milgadara soil, the high C:N (>25:1) indicates that nitrogen may be utilised and "tied up" by the microbes, resulting in less being available to the plants.

The common macro-nutrients of calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}) and potassium (K^{+}) are key chemical elements influencing the characteristics of agricultural and native ecosystems (Gray and Bishop 2018). These basic cations are all within their respective desirable range with the exception of sodium (Na), which is at the lower end of its desirable range.

The levels of basic cations result in the Milgadara soil having a good cation exchange capacity (CEC), likely due to the organic soil amendments (as opposed to the clay type weathered from the granodiorite parent material). This observation is supported by the drop in CEC from 34 to 9 meq/100 g at 20 cm depth in the profile.

Although the Milgadara topsoil is described as having a good CEC (40 meq/100 g), organic matter typically has a CEC ranging from 250 to 400 meq/100 g (Moore 1998), therefore the ongoing building of soil organic matter will increase the capacity of the Milgadara soil to supply and retain both water and nutrients. It should be noted however, that increasing soil organic matter will also increase the C:N, which may reduce the availability of nitrogen.

The soil chemistry results, when considered alongside the soil physical properties (silty loam texture and moderate structure), support the conclusion that the Milgadara soil has a good capacity to supply and retain nutrients.

Soil biological indicators

The soil biological indicators, total soil biomass and key functional groups, for the Milgadara soil are very good, however the microbial diversity and bacterial biomass are considered fair. The fungi:bacteria is fair (slightly elevated), indicating an imbalance in both groups. As discussed earlier, the ongoing monitoring of plant available nitrogen will be particularly important in this soil as the organic matter in the soil increases and subsequently raises the moderate C:N.

Conclusions

- The Milgadara soil has favourable physical characteristics for retaining water and nutrients however, the silty loam topsoils will be prone to structural degradation.
- The soil has a high fertility status and is benefiting from the addition of organic matter to increase the capacity to retain and supply water and nutrients to plants.
- The ongoing monitoring of soil carbon and nitrogen, in particular plant available nitrogen, will assist in managing the C:N towards optimal availability of carbon for soil microbes and nitrogen for plants.
- Although total soil biomass is good, microbial diversity in the Milgadara soil is considered moderate and the balance of fungi and bacteria could be improved by building the bacterial biomass.
- Abundant groundcover across Milgadara will maximise the capture of solar energy for photosynthesis, minimise the risk of soil erosion and subsequent land degradation, and increase soil resilience.
- The adoption and implementation of regenerative land management practices have greatly decreased the reliance on pesticides, herbicides and fertilisers at Milgadara and regular applications of composts to pastures and crops have regenerated the soils and the landscape.

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