SoilsForLife

Wilmot Soil Report

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Introduction

Profile of a Wilmot soil

The following field and laboratory assessment of a Wilmot soil complements the Wilmot Case Study Ecological Report. The assessment builds on existing soil and landscape information and discusses the properties and characteristics of a Wilmot soil in relation to land management over time.

Geology

The Wilmot property is located on the Wongwibinda Plateau and Ebor Basalt subregions of the New England Tablelands bioregion (Thackway and Cresswell 1995; Environment Australia 2000) and traverses two major geologies (Figure 1). The western half of the property is on sedimentary argillite (hardened mudstone) and the eastern half of the property is on volcanic basalt (with minor occurrences of volcanic trachyte). Localised granite intrusions are recognisable above-ground as granite rock outcrops (DPIE 2020).

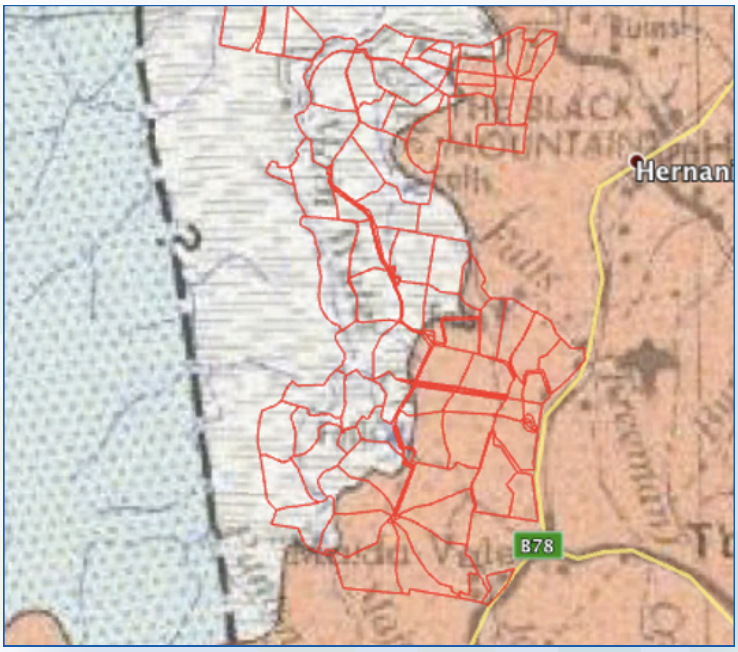


Figure 1. The Wilmot property and paddock boundaries overlaying the Dorrigo-Coffs Harbour 1:250,000 Geological Sheet (1971).

Landforms

Wilmot is located on what Mitchell (2002) describes as a hilly benched plateau in the Northern Tablelands region of New South Wales (Figure 2). The local landforms include hilly to rolling hills and moderate slopes with terraces and flood plains lower in the landscape. Groundcover on Wilmot is typically greater than 80 per cent and ranges from sclerophyll forest and timbered scrub (dominated by low woody shrub species) to extensively cleared areas of native and improved pastures (Figure 3).

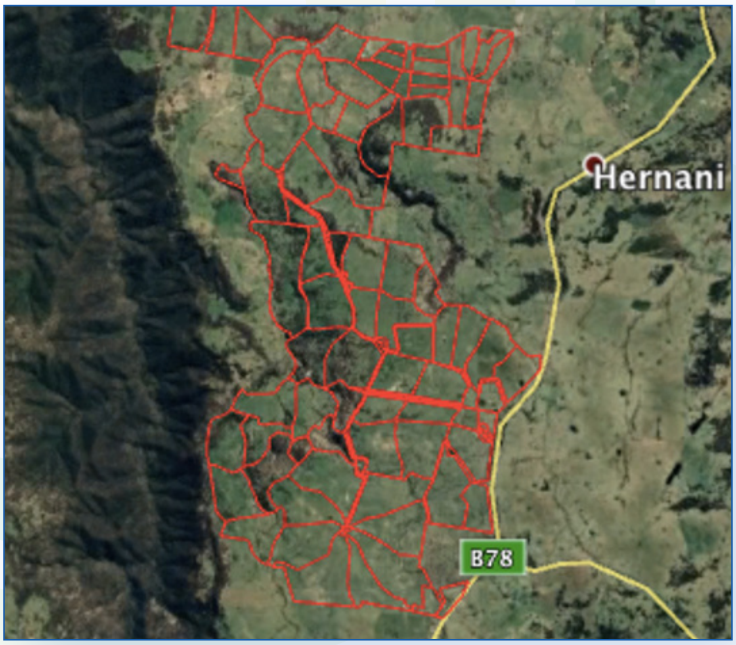


Figure 2. The Wilmot property and paddock boundaries overlaying satellite imagery showing the Guy Fawkes River Gorge to the West.

Figure 3. A typical Wilmot landscape.

Soils

The Wilmot soils have formed in situ (in place) from the weathering of the sedimentary mudstone and volcanic basalts (with minor occurrences of soils formed on volcanic trachyte), or from the alluvium and/or colluvium derived from these geologies.

There are four main soil types on Wilmot. The mudstone-derived soils are described as low fertility, acidic, uniform loams from the Red Earths Great Soil Group; and low fertility, acidic, texture-contrast soils from the Podzolics Great Soil Group (Stace et al. 1968). The basalt-derived soils are described as fertile, acidic, strongly structured clay soils and are either from the Chocolate Soils or Krasnozems (high in free iron) Great Soil Groups. Minor occurrences of lighter (sandier textured), stonier soils occur on the trachyte, and soils that are prone to waterlogging occur in drainage lines and lower in the landscape (Figure 4).

Figure 4. Soils prone to waterlogging in drainage lines and lower in the landscape.

Soil development is a result of at least five major soil-forming factors (climate, organisms, relief, parent material and time). Any one (or combination) of these soil-forming factors may dominate in a landscape. At Wilmot, the local climate (in particular the high rainfall) influences the weathering of the mudstone and basalt parent materials and biological decomposition, resulting in an increased rate of soil formation and soils with unique characteristics.

These soil characteristics determine soil function and soil productivity which, on Wilmot, may be defined as the capacity of the soils to produce pasture yields to support the grass-fed finishing of beef cattle under regenerative land management practices (Figure 5).

Figure 5. Wilmot pastures support the grass-fed finishing of beef cattle. *Photo by Mike Terry*

Methods

Site and soil location

Soils For Life observed, described and sampled a soil ('the Wilmot soil') at a site in the Billy's 2 South paddock of the Wilmot property (Figure 6). The location of the soil observation was recorded using a GPS creating a benchmark location or reference site for the future assessment and/or monitoring of soil condition at the property (Figure 7).

Soil description

The Wilmot soil was excavated by hand auger and the resulting soil profile (Figure 8) was described in the field according to the nationally endorsed standards described in 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 and soil colour and mottling.

Figure 6 The site of the soil profile investigation in Billy's 2 South paddock on Wilmot's basalt country.

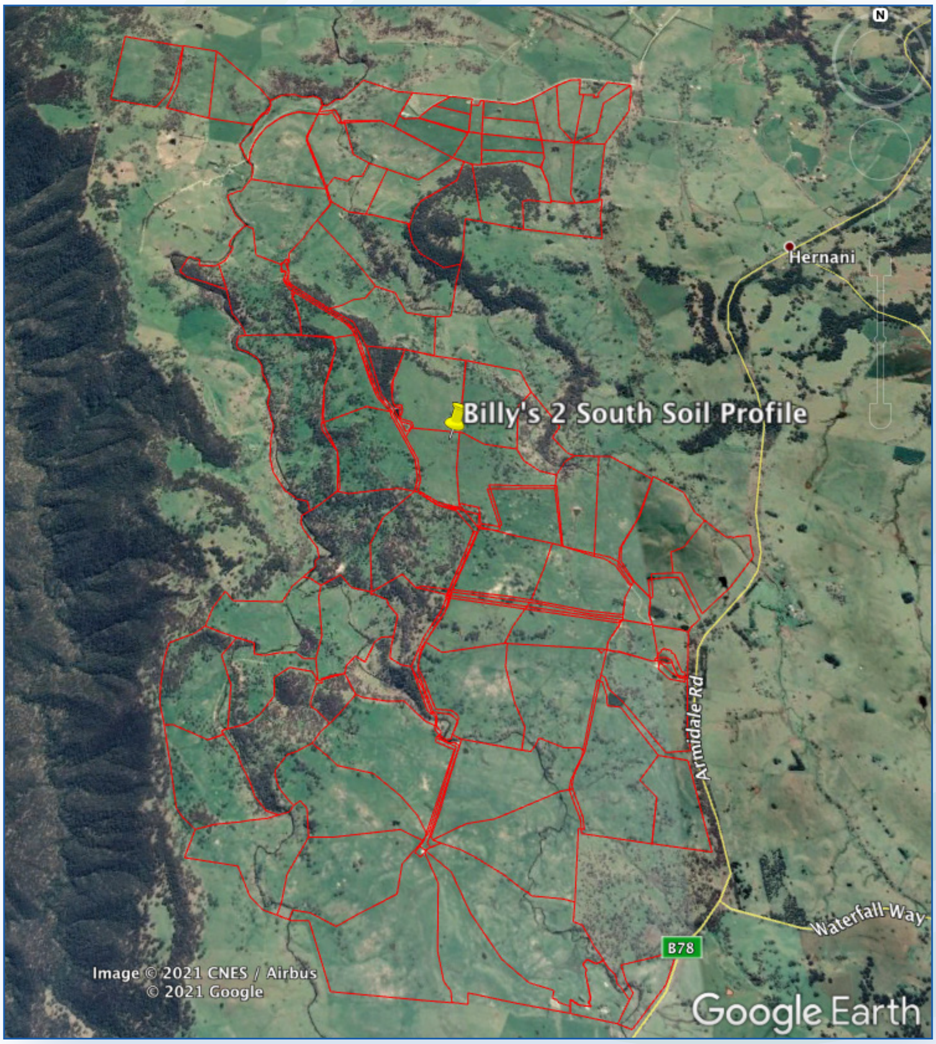


Figure 7. Location of the Wilmot soil profile in the Billy's 2 South Paddock of the Wilmot property.

Figure 8. The Wilmot soil profile.

Soil sampling and analysis

One individual soil sample was collected from four depths in the excavated soil profile (4 individual samples in total) for soil chemical analyses. A composite sample (a subsample of 20 individual samples randomly collected from 0-10 cm depth across the site) was collected for soil 'fertility' analyses (representing the typical soil testing that is performed on farming properties to determine the nutrient status of the topsoil). A sixth and final sample (individual) was collected from 0-10 cm depth for soil microbial analyses.

Laboratory analyses were undertaken to determine the chemical and biological status of the Wilmot soil. The resulting dataset also provided an insight into current soil condition, potential productivity and allowed the soil to be classified according to the Australian Soil Classification (Isbell and NCST 2016) for the purposes of communication and land use management.

A total of four 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. The sixth sample was submitted to Microbiology Laboratories Australia for analysis of soil microbial functional groups.

Results

Existing soil mapping

One objective of assessing soils in the field and the laboratory is to confirm and/or update historical information and existing soil mapping. According to the Great Soil Group Soil Type map of NSW (DPIE 2020), there are four dominant soil types on Wilmot:

1. Red Earths (low fertility uniform or gradational soils on sedimentary or granitic parent materials)
2. Podzolics (low fertility, texture-contrast soils on sedimentary or granitic parent materials)
3. Chocolate Soils (fertile soils on basalt parent materials)
4. Krasnozems (fertile soils that are high in free iron on basalt parent materials).

The Red Earths, Podzolics, Chocolate Soils and Krasnozems of the Great Soil Groups (Stace et al. 1968) correspond to the Kandosols, Chromosols or Kurosols, Dermosols and Ferrosols of the Australian Soil Classification (ASC) (Isbell and NCST 2016). According to the ASC Soil Type map of NSW DPIE 2020), the Wilmot soil is a Ferrosol (Figure 9).

The existing mapping of the Great Soil Groups (DPIE 2020), soil orders and the concept of the soil orders of Australian Soil Classification (Isbell et al. 1997) relevant to Wilmot are summarised in Table 1.

Table 1. The Great Soil Group Types (DPIE 2020) and the concept of the Australian Soil Classification orders (Isbell and NCST 2016) on Wilmot.

Great Soil Group[1]	Soil Order[2]	Concept of the Soil Order[2]
Red Earth	Kandosol	Soils lacking an abrupt increase in texture between the topsoil and subsoil and, at most, are weakly structured and do not contain carbonates
Podzolic	Chromosol	Soils with an abrupt increase in texture between the topsoil and subsoil that are not strongly acid or sodic
Podzolic	Kurosol	Soils with an abrupt increase in texture between the topsoil and subsoil that are strongly acid
Krasnozem	Ferrosol	Soils lacking an abrupt increase in texture between the topsoil and subsoil that are well-structured and high in free iron oxide
Chocolate Soil	Dermosol	Soils lacking an abrupt increase in texture between the topsoil and subsoil that are well-structured

[1] Great Soil Group Type map of NSW (DPIE 2020); [2] Isbell and NCST (2016); [3] Isbell et al. (1997)

Australian Soil Classification

- Chromosols
- Dermosols
- Ferrosols
- Hydrosols
- Kandosols
- Kurosols
- Not Recorded
- Organosols
- Podosols
- Rudosols
- Sodosols
- Tenosols
- Vertosols

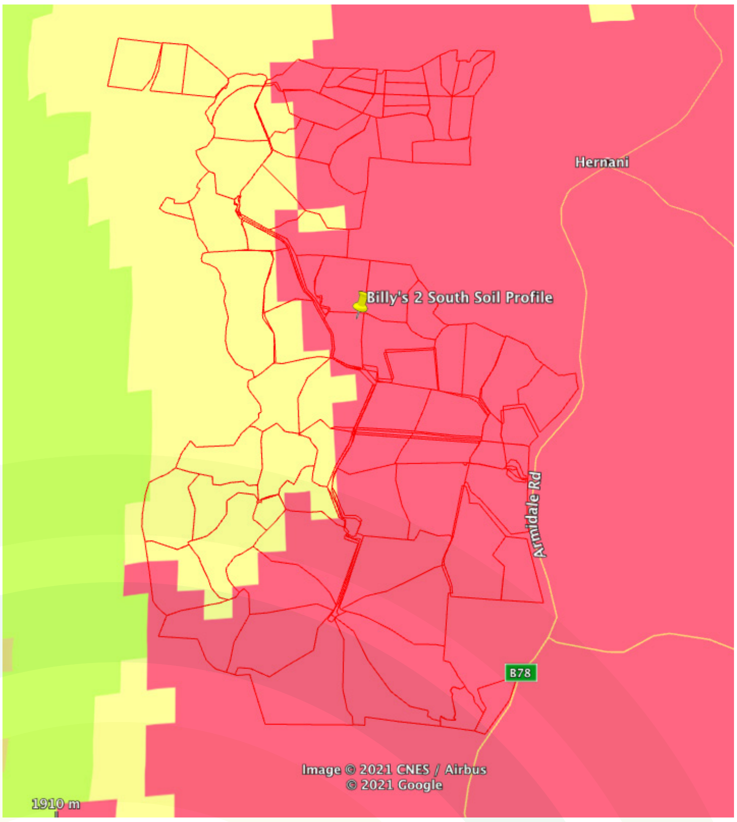


Figure 9. The Australian Soil Classification Type map of NSW (DPIE 2020) showing two of the dominant soil orders (Kandosols and Ferrosols) on Wilmot.

Site and soil description

The Wilmot site and soil were described according to the Australian Soil and Land Survey Field Handbook (NCST 2009). The site information for Billy's 2 South paddock is summarised in Figure 10.

SOIL PHYSICAL PROPERTIES

The soil description, including an interpretation of the Wilmot soil's physical properties of soil surface condition, soil texture and soil structure which govern infiltration, soil stability, and water and nutrient movement and/or storage within the profile, is summarised in Figure 11.

SOIL CHEMICAL PROPERTIES

The laboratory results (soil chemical properties) are summarised in Figure 12 and were interpreted following research into the existing literature. The desirable ranges for the measured soil properties serve as a general indication for the grazing of pastures in NSW (Peverill et al. 1999; Horneck et al. 2011; Hazelton and Murphy 2016). The soil profile charts reflect a "traffic light" approach where **green**, **orange** and **red** represent **good**, **moderate** or **poor**, thus allowing the status of each of the soil properties to be assessed at a glance.

SOIL CLASSIFICATION

According to the field and laboratory assessment of the Wilmot soil's physical and chemical properties, the soil profile described in Billy's 2 South paddock is either a Dermosol or a Ferrosol (most likely a Ferrosol), which corresponds to the existing soil information and mapping.

SOIL BIOLOGICAL PROPERTIES

The soil biological properties assessed for the Wilmot soil serve as an indicator 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 13 and Figure 14.

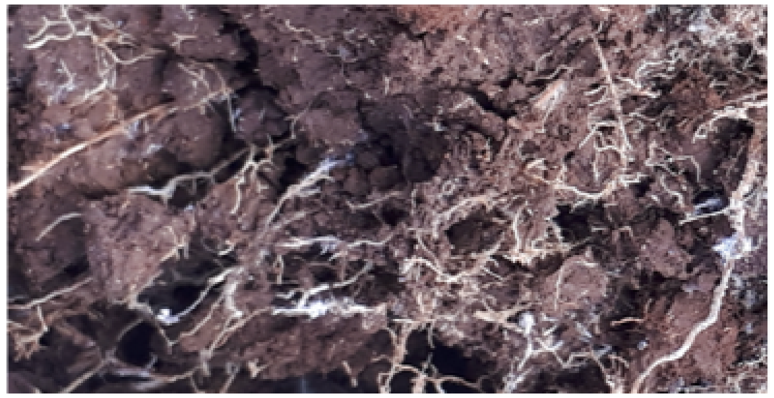
SITE INFORMATION

Project (Property) Wilmot	**Date** 31/7/20	**Scribe** DIAJ	**Location (Paddock)** Billy's 2 South	**Observation Type (e.g. auger boring)**	Manual auger boring	**GPS Latitude (Decimal Degrees to 5 places)** -30.312161	**Map Sheet No.**	**ASC (existing mapping)**	Ferrosol
Dominant Vegetation Form	Non-woody	**Ground Cover %**	Dense (>70%)	**Aspect**	North	**GPS Longitude (Decimal Degrees to 5 places)** 152.390478	**Map Scale**	**ASC Ground Truth**	Dermosol or Ferrosol
Secondary Vegetation Form	Non-woody	**Ground Cover %**	Dense (>70%)	**Slope %**	2	**Rock Outcrop**	No rock outcrop	**Erosion Type**	None evident
Vegetation (list all species)	Cocksfoot, Fescue, Rye, Couch					**Drainage (site)**	Well-drained	**Erosion Extent**	None evident
Landform	Simple slope	**Soil Surface Condition**	Self-mulching			**Land Use**	Grazing	**Erosion State**	None evident

Landscape Photo (Facing North)

Landscape Photo (Facing East)

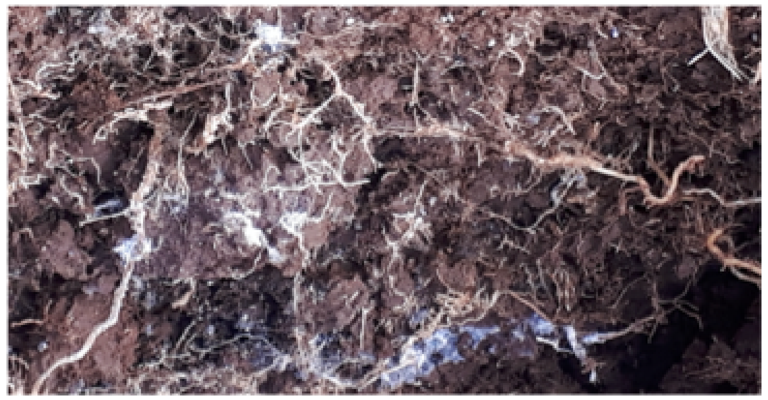
Topsoil structure and roots



Landscape Photo (Facing South)

Landscape Photo (Facing West)

Topsoil structure and roots



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

SOIL PROFILE DESCRIPTION

Horizon	Depth of Horizon (cm)	Profile Photo	Boundary Distinctness and Shape	Field Texture Grade	Moist and Dry Colour	Mottle (colour, abundance)	Segregations (abundance, nature)	Coarse fragments (abundance, size)	Structure (type)	Structure (grade)	Consistence (Soil Water Status)	Roots Abundance & Root Size	Field pH and Lab pH_{CaCl}	Lab EC_{water} (dS/m)	Depth of Sample for Lab (cm)
A1	0-30		Diffuse (>100 mm) Smooth	Silty Loam (~25% clay)	Dark reddish brown 5 YR 3/3	None	Not recorded Unidentified	Not recorded Not recorded	Polyhedral	Moderate	Weak (moderately moist)	Abundant (>200) Fine (1-2 mm)	5 4.4	0.03	0-30
B2	30-85		Abrupt (5-20 mm) Smooth	Silty Clay Loam (~35% clay)	Dark reddish brown 5 YR 3/4	None	Not recorded Unidentified	Not recorded Not recorded	Polyhedral	Strong	Very weak (moderately moist)	Many (25-200) Fine (1-2 mm)	6 4.7	0.01	30-85
B3	85-108		Abrupt (5-20 mm) Wavy	Silty Clay Loam (~35% clay)	Dark reddish brown 5 YR 3/4	Few	10-20 % Unidentified	2-10 % 2-6 mm	Polyhedral	Strong	Firm (moderately moist)	No roots (0) Not recorded	6.5 4.5	0.01	85-108
BC	108+			Sandy Clay Loam (coarse) (~20-30 % clay)	Dark reddish brown 5 YR 3/4	Few	10-20 % Unidentified	10-20 % 2-6 mm	Polyhedral	Strong	Strong (moderately moist)	No roots (0) Not recorded	6.5 4.1	0.01	108+

Figure 11. The Wilmot soil profile description.

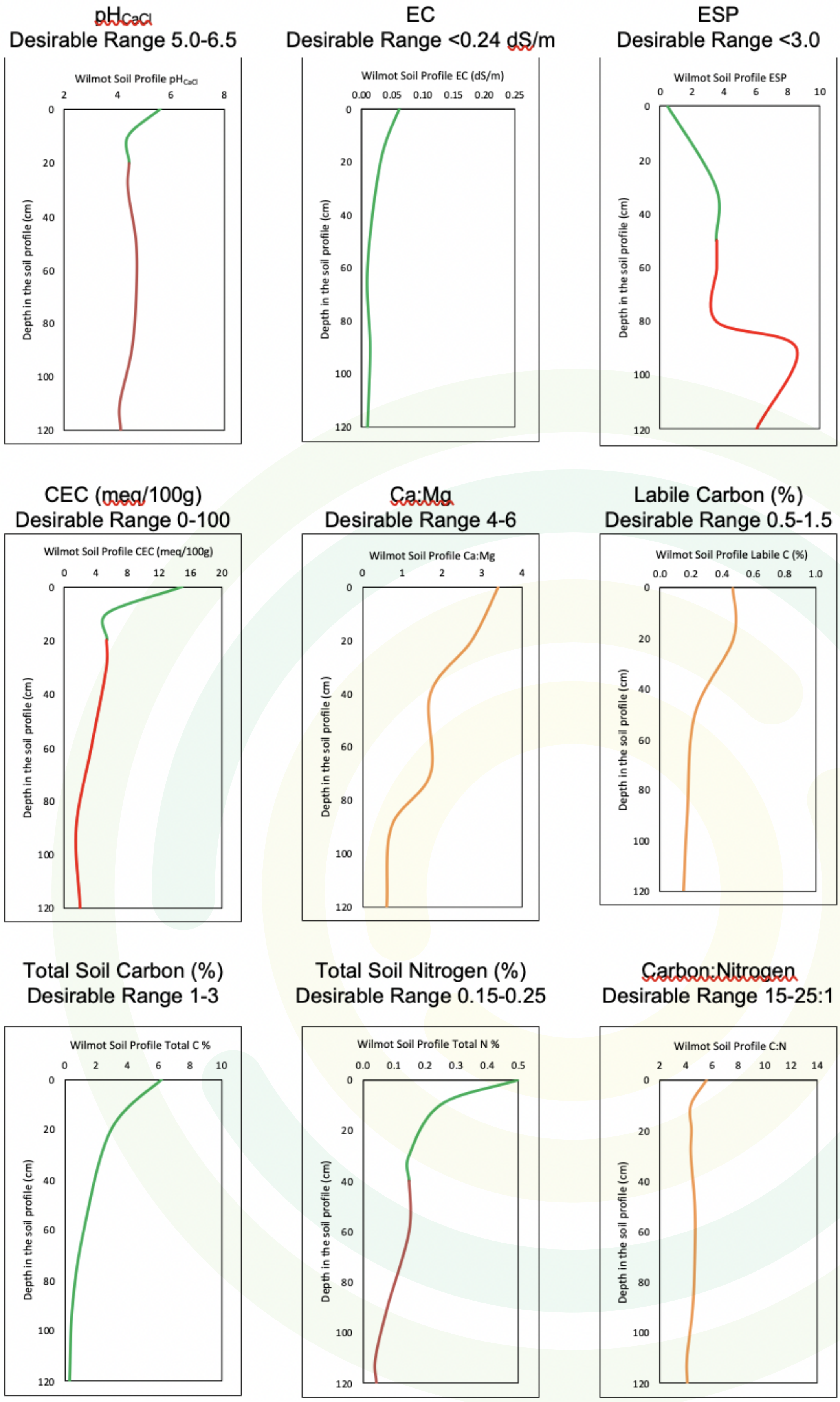


Figure 12. Soil chemistry of the Wilmot soil profile.

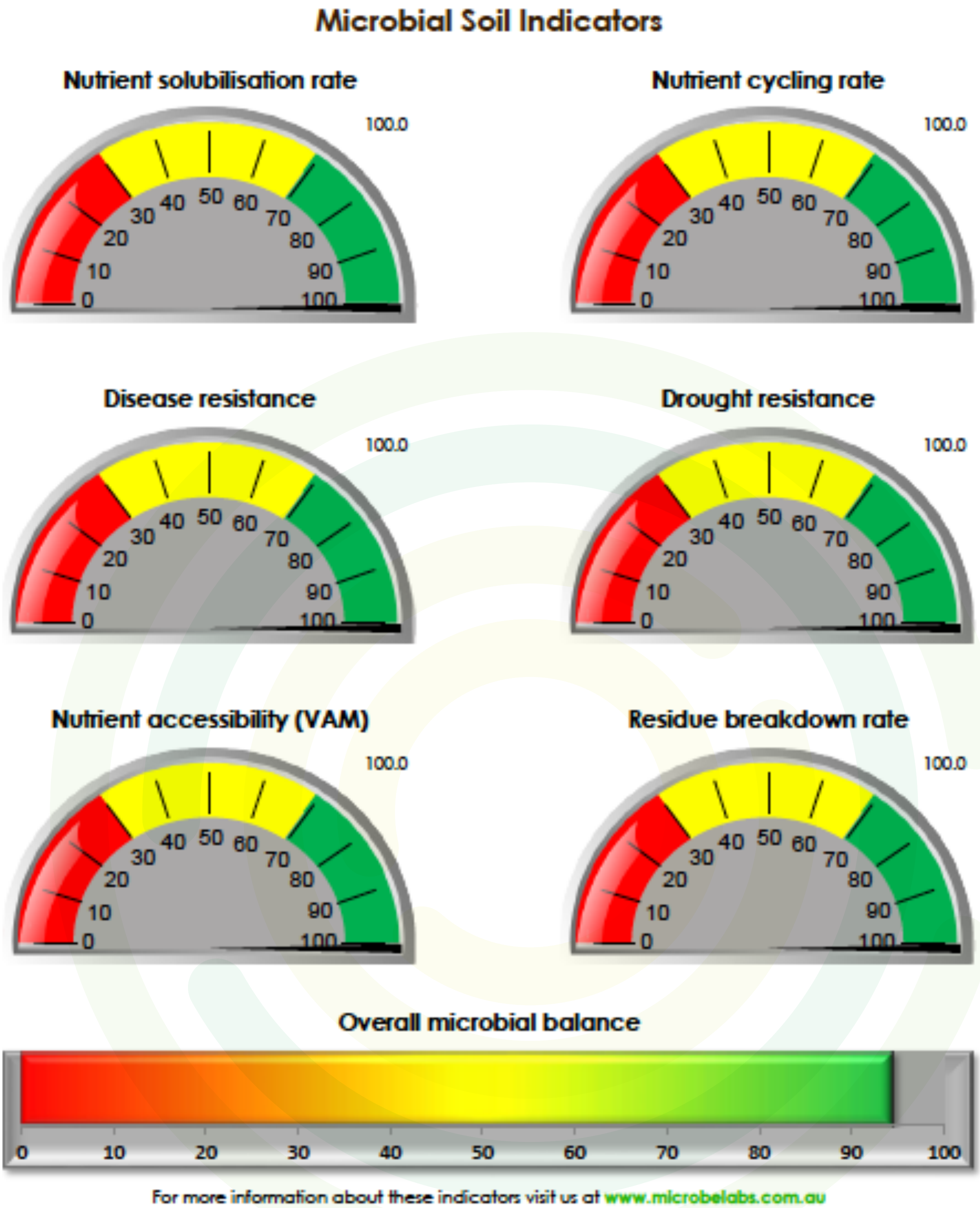


Figure 13. Key microbial indicators of the Wilmot topsoil (0-10 cm).

Key Microbe Groups

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Total microorganisms	148.5	50.0
Total bacteria	37.7	15.0
Total fungi	106.8	33.8

Microbial indicators	Yours	Guide
Microbial diversity	39.6	80.0
Fungi : Bacteria	2.8	2.3
Bacterial stress	0.8	< 0.5

Group	Biomass (mg/kg) Yours	Biomass (mg/kg) Guide
Bacteria		
Pseudomonas	3.785	1.000
Actinomycetes	7.040	1.000
Gram positive	22.193	4.000
Gram negative	15.544	11.000
Methane oxidisers	0.000	0.500
Sulphur reducers	0.000	< 0.005
True anaerobes	1.014	< 0.005
Eukaryotes		
Protozoa	3.918	1.300
Mycorrhizal fungi (including VAM)	31.115	10.000

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

Poor Fair Good

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 groups, Nitrogen needs to be monitored as high amounts of this nutrient may be kept by the microbes thus competing with the plants. 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 good indicating a balance between both groups. 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.

Figure 14. Key microbial functional groups of the Wilmot topsoil (0-10 cm).

Discussion

At Wilmot, the above-ground observations and measurements of groundcover and yield are useful indicators of agricultural productivity. However, as described in the Wilmot Case Study: Ecological Report, the below-ground soil observations and measurements better reflect the capability and condition of the soils, and it is these factors, together with weather and water, that determine the productive potential of the land.

In recognition of the importance of soil health, there has been a significant focus on monitoring the soils at Wilmot since 2011. This includes a suite of soil chemical properties measured by Wilmot Cattle Company as part of baseline soil testing to assess change and trend in macro-nutrients and soil organic carbon (SOC) over time. These data are publicly available (Regen Network (2020a). In addition to this soil monitoring, Carbon Link began extensive sampling of the Wilmot soils to a depth of 1 metre in 2020, however these data are not publicly available.

The publicly available soil data collected by Wilmot Cattle Company have been referred to for the purpose of this discussion (Regen Network 2020b). Together with the results of the Soils For Life assessment, they provide further insights into the improvement in soil condition and potential soil productivity as a result of management practices at Wilmot.

Soil physical properties

The soil physical properties assessed at Wilmot 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.

Soil surface condition is indicative of both soil type and land management. The "self-mulching" surface of the Wilmot soil suggests the topsoil, while aggregated, is loose and easily disturbed. Grazing management practices such as time controlled rotational grazing, which has been shown to increase groundcover at Wilmot, reduces the erosion risk for these soils.

The silty loam topsoil of the Wilmot soil ensures adequate nutrient and water holding capacity. The gradual increase in texture to a silty clay loam, and the favourable depth of the profile (140 cm+) with no obvious physical limitations, will provide good longer term water storage for pastures.

The Wilmot soil has moderate to strong structure with well-formed, distinct, polyhedral-shaped peds (Figure 15). The strong structure is a recognised property of the basalt soils (Dermosols and Ferrosols) that dominate the eastern half of the Wilmot property.

Soil aggregation and stability are supported by plant roots, which were observed to 80 cm depth in the Wilmot soil and were abundant in the topsoil (Figure 16). This root biomass, and its associated rhizosphere, will contribute to nutrient cycling and soil organic matter, in turn increasing soil organic carbon.

Figure 15. The strong structure of the Wilmot subsoil (70-100 cm depth).

[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).

[2] 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 16. Topsoil root abundance in the Wilmot soil and groundcover in the Billy's 2 South paddock.

Soil chemical properties

The soil chemical properties assessed at Wilmot are useful indicators of the soil's chemical condition, including the potential to retain nutrients. Soil pH is in the **acid** range and borders on being classified as **strongly acidic** beyond 20 cm depth, which will constrain the availability of plant nutrients and can result in aluminium toxicity.

This relationship between soil pH and aluminium is supported by the historical Wilmot soil data, which illustrate that decreasing soil pH can lead to an increase in aluminium (Figure 17). Soil pH measurements show that, on average, soil pH has increased in a number of paddocks since 2011 (Figure 18) with the application of lime in 2013 a contributing factor.

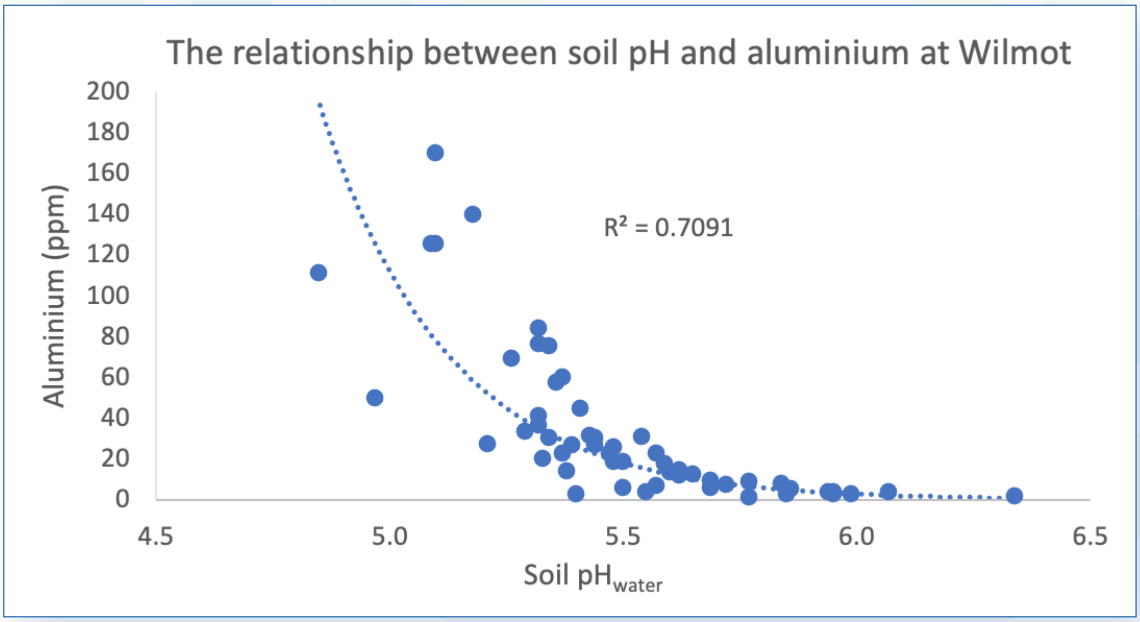


Figure 17. The relationship between soil pHwater and aluminium of soil samples collected at 0-15 cm depth by Wilmot from a number of paddocks between 2011 and 2018 (data source: data collected by Wilmot Cattle Company and reported in Regen network 202b).

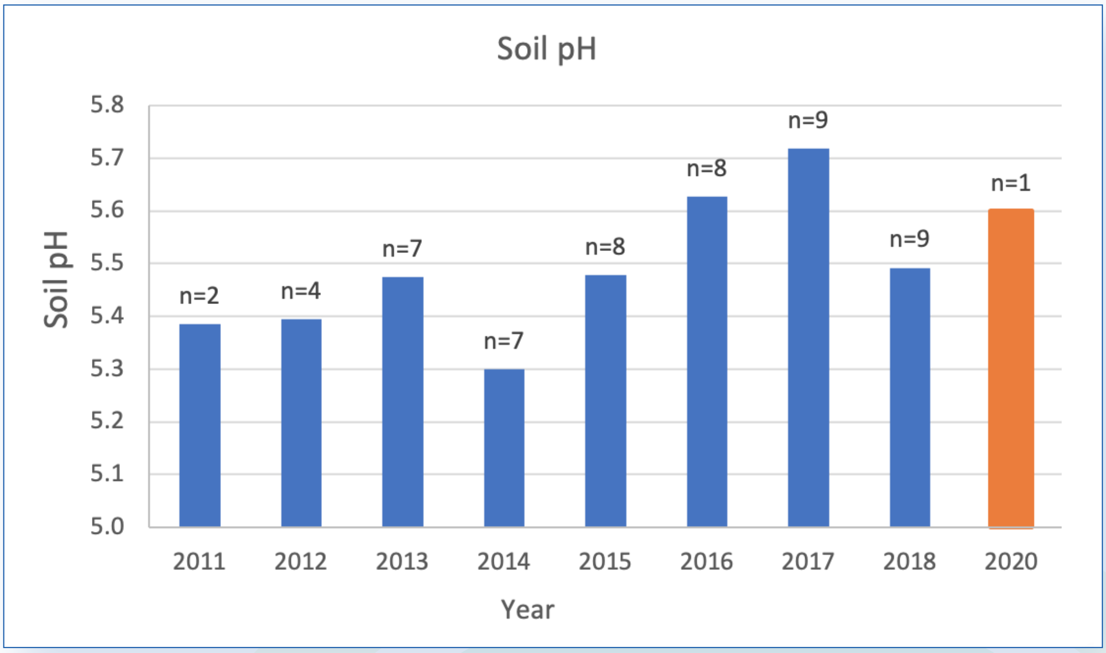
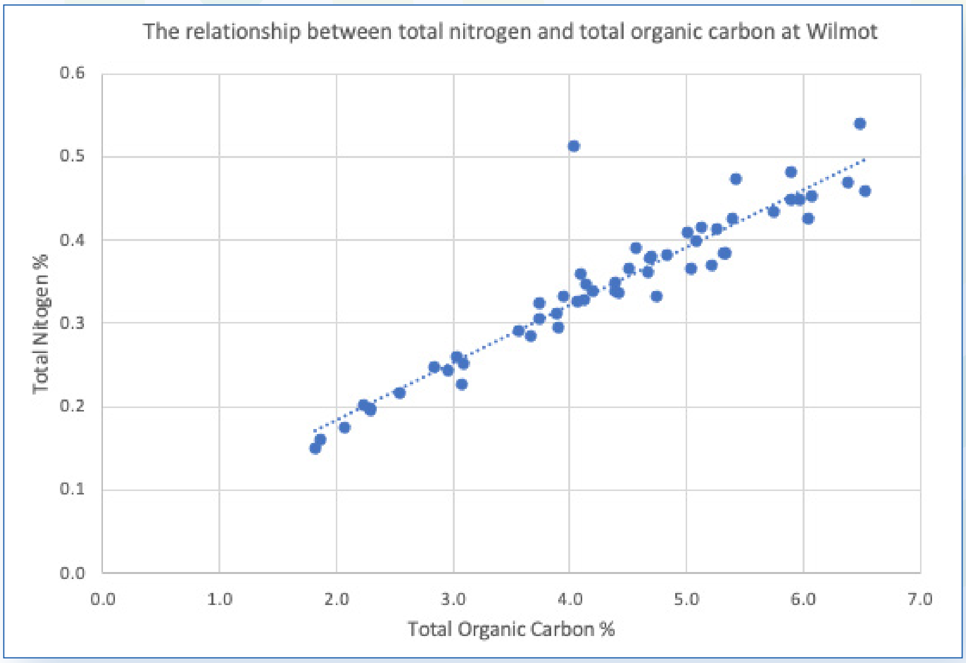


Figure 18. Average soil pHwater of soil samples collected at 15 cm depth by Wilmot from a number of paddocks between 2011 and 2018 (blue columns) (Rdata source: data collected by Wilmot Cattle Company and reported in Regen network 2020b) and soil pHCaCl of the Wilmot soil (orange column) (Soils for Life 2020).

The electrical conductivity (EC) of the Wilmot soil is very low indicating salinity is not an issue), however the exchangeable sodium percentage (ESP) is **high** (>6) and Ca:Mg is less than 2:1, indicating the deeper subsoil is sodic and prone to instability and dispersion.

The basic cations of calcium (Ca), magnesium (Mg), sodium (Na) and potassium (K), are all at the lower end of their respective desirable ranges however the topsoil composite sample reflects a **moderate** to **good** cation exchange capacity (CEC) of 15 meq/100g, indicating the topsoil has a reasonable capacity for retaining nutrients. The CEC below 10 cm depth in the soil profile is **low** and, in general, the soil will have an equally low buffering capacity and may be prone to further acidification.

The Wilmot soil's total soil nitrogen is within the desirable range in the topsoil and total soil carbon is at the high end of the desirable range for pasture production in NSW. The relationship between carbon and nitrogen in soils is well established, as nitrogen increases in the soils at Wilmot, so too does the carbon content (Figure 19).



Soil organic carbon (0-15 cm) was also monitored on Wilmot from 2011 until 2019. As discussed in the Wilmot Case Study: Ecological Report, these data indicate that, over time, soil organic carbon levels have improved from baseline levels.

Figure 19. The relationship between total nitrogen (%) and total organic carbon (%) for soil samples collected at 0-15 cm depth by Wilmot between 2011 and 2018 (data source: data collected by Wilmot Cattle Company and reported in Regen network 202b).

Although the total carbon levels in the Wilmot soil are good, the labile carbon component (representing more recent additions of organic matter) of the total soil carbon is moderate (below the desirable range). Because labile soil carbon is a food source for the soil microbes that recycle nutrients, the nutrient supply to pastures may be less than optimal.

Soil Biology

Microbiology Laboratories Australia (MLA) reported that the key microbial indicators in the Wilmot soil are all excellent and the total soil biomass and key functional group indicators are also very good. Microbial diversity, however, is considered moderate. The recommendation to monitor plant available nitrogen is relevant given the Wilmot topsoil has good total nitrogen and the abundant microbes will retain the nitrogen thereby competing with the plants.

Conclusions

- The local climate (in particular the high rainfall) influences both the physical and chemical aspects of rock weathering and biological decomposition, resulting in an increased rate of soil formation in the region.
- The natural Wilmot soils vary in fertility depending on the parent materials upon which they have formed. Soil fertility ranges from moderate on the sedimentary mudstone to high on the basalt parent materials.
- The silty loam to silty clay loam texture and the strong structure of the Wilmot soil in Billy's 2 South paddock allows for the movement of water or nutrients and will not limit the growth of plant roots.
- The Wilmot soil has favourable physical properties, however the silty loam topsoil is prone to degradation. This risk is managed with land management practices, including rotational grazing which maintains groundcover and promotes root growth.
- The natural Wilmot soils have a number of land use limitations including soil acidity with the potential for aluminium toxicity and a low cation exchange capacity below 10 cm depth.
- Despite these limitations, soil nitrogen and soil carbon are either within or above the desirable range for pastures in NSW. This may be due to increased nutrient cycling, which is just one of the benefits of maintaining high levels of groundcover during intensive rotational grazing management.
- The decrease in paddock size, introduction of rotational grazing, longer resting of paddocks, and maintaining of groundcover has increased soil resilience and minimised the risk of soil loss and land degradation on Wilmot.

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