Level 3 Soil Assessment for Productive Land (Landcare)

DOCUMENT DETAILS

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Level 3 Soil Assessment for Productive Land (Landcare)
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1. Introduction

Landcare Farming aims to develop a robust yet accessible soil evaluation and monitoring method to support and encourage improvement in the natural capital of soil on farms.

The method aims to comply with Accounting for Nature's Standard for environmental accounting and contribute to sustainable agriculture and conservation.

2. Aim

The aim of this method is to provide farmers with a scientifically sound and consistent approach to measuring, reporting and verifying changes in soil condition over time. It will allow farmers to evaluate the productive health of their soils at both paddock and / or farm scale. The method establishes credible metrics to support investment in sustainable farming and natural capital.

The intention to develop an accessible and user-friendly soil monitoring and evaluation method requires a process that is affordable, and relatively simple and easy to understand. The confidence level for the proposed method is Level 3 as per section 1.5 of the Accounting for Nature Standard (2019). The use of both reference data and expert panel-derived targets for soil properties are likely to have an accuracy of 80% or greater. This method therefore aims to detect a 40% change in actual soil condition over time.

3. Purpose

Landcare Farming is dedicated to caring for the nation's lands and waters. Change in resource condition that delivers improvements in soil and water quality must be measurable. This method serves to ensure collection of meaningful, interpretable and affordable data to inform on-farm decisions that improve natural capital.

Linking reference condition to industry benchmarks provides valuable information on how natural systems have been changed in the service of agricultural production. Some soil measures will have changed out of necessity to sustain agricultural production; some measures have been negatively impacted as a result of agricultural practices. The purpose of this method is to highlight these changes and impacts through assigning Econd® and Pcond scores so that farmer decision-making is supported by accurate and scientifically valid information.

4. Scale

Significant challenges apply to any method that addresses soil condition across the great breadth of farming landscapes in Australia. For this reason, the method is designed to be applied at a farm scale. That the breadth of agricultural commodities produced across Australia is relatively narrow means that industry benchmarks for production are relatively consistent. Obvious exceptions exist such as truffles or blueberries which have specific preferences for highly alkaline and highly acid soils respectively. However, for a method to have broad application across a range of soil types and climatic zones, the selected industry benchmarks aim to cover off on the vast majority of crops and pastures grown.

5. Scope

This method aims to measure change in soil condition over time. Accounting for Nature (AfN) uses 'reference condition benchmarking' to create a common unit of measure for building sets of environmental accounts that are capable of describing the condition of any environmental asset. The common unit – an Econd® – is an index of environmental condition between 0 and 100. A score of 100 describes the reference condition of an asset, generally agreed to be the condition of the soil before clearing by European settlers.

The AfN Standard requires that one, or a combination, of the following approaches be used to determine reference condition:

- Observation at reference condition sites (i.e., relatively untouched by agricultural practices);
- Historical record of the reference condition of a site;
- A robust model that estimates the reference condition of the soil; or,
- Expert opinion on the reference condition of the soil.

Reference-state measurement or estimation must be carried out for each assessment area. It is recognised that reference sites may not exist in some regions in view of the length of time since conversion to agriculture. However, any undisturbed area may yield valuable information to inform reference condition such as roadsides or areas of native vegetation which were never cleared. Some of these areas may have been impacted by historical practices such as grazing but may not have received fertiliser or other chemical. In such cases, reference condition of some soil properties may not have changed much, such as pH or soil carbon. Reference to historical information relating to land use and management practices is recommended. Care is required in determining possible levels of impact but confidence levels will increase in line with the number of reference sites or soil samples that are available. It is likely that some additional assistance will be required. Possible sources of knowledge or advice include soil scientists, agronomists, or local historians.

This method aims to also develop a set of production accounts for agriculturally productive soil – hereafter referred to as productive soil – that describe the condition of the soil asset on a farm in terms of industry benchmarks. The common unit for productive soil is termed a Pcond. Similar to the Econd®, it also is an index between 0 and 100, but where 100 describes a soil in excellent condition for agricultural production. 'Excellent' condition is defined by a range of parameters informed by expert panel assessment (DPIPWE, 2004; Hill et al., 2003).

The Australian Soil Classification (Isbell & NCST, 2016) is the principal guiding system against which soil properties will be assessed. Soil Orders (as per the Australian Soil Classification) or local soil classifications will be the minimum scale of reporting.

Whilst metrics for soil biological function have not been included in this method for reasons of cost and interpretability, soil carbon shall be used as a surrogate measure of ecological condition in view of its importance as the primary energy source for soil life (Fontaine et al., 2003).

6. Selection of indicators

Sbrocchi et al. (2015) reference Karlen's definition of soil condition *viz.*: *a measure of the soil's capacity 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 and habitation*. In this method, indicators are selected based on their importance to healthy soil and to direct grower's attention to where greatest environmental and production benefits will accrue.

In selecting indicators, the cost and effort required must be taken into consideration to minimise expense and avoid diminishing returns. Sbrocchi et al. (2015) recognise an ideal of seven indicators, viz. acidification, organic carbon, water erosion, wind erosion, secondary salinity, nutrients, physical condition and biological condition. It is recognised that not only would these indicators involve considerable expense, but that sufficient data may not be available for reference or benchmarking purposes. The selected indicators in table 1 below aim to provide core information on changes to natural capital. Commercial testing for physical and biological condition is limited, technically challenging and costly. Soil nutrients should be monitored as part of best agronomic practice while soil carbon and groundcover provide surrogate data on the likely states of physical and biological condition.

Specific targets or ranges have been selected based on expert opinion and industry best practice for the selected indicators. Cotching and Kidd (2010) explain the use of targets in soil monitoring.

> *"It is important that … soil targets can be used by a range of stakeholders. Farmers can use them at the paddock scale to check whether they are maintaining or degrading soil condition, NRM Regions can use them as benchmarks for reporting against resource condition targets, and they can be used as a basis for State of Environment reporting. The soil targets should be used at the paddock scale as simply that, i.e., a target. If results are below target, this does not necessarily imply that a "threshold" has been reached where production will be dramatically reduced or even fail. If a result falls below the target value or outside the desired range, then the response should be to ask the question: "Is the result to be expected due to local conditions and are there likely to be undesirable impacts?" If the answer is that the result is "normal" or explainable by local profile information, then the response should be to continue monitoring. If the answer is that the result is not expected, then a management response is required in order to correct the soil condition."*

The soil properties and targets in this method have broad application across landscapes but local conditions may require locally relevant adjustments. For example, the target for phosphorus may not be appropriate for dryland, broad acre cropping or grazing systems in the drier regions of Australia. Questions arising will need to be answered with expert help from local advisers, agronomists or soil scientists.

Indicators for this method aim for simplicity, affordability and most importantly, repeatability to ensure consistent and reliable recording of Econd® and Pcond scores. Selected indicators are shown in Table 1.

This method does not mandate the measurement of bulk density or, to achieve the same impact, the sampling of constant mass of soil rather than a standard depth, because of the challenge in measurement. It is important to note, however, that not knowing the mass of the soil when reporting percentage attribute levels will increase the uncertainty in the measure. In particular, as organic matter increases, bulk density is likely to decrease. Therefore, a soil carbon percentage measurement may overestimate the change. The reverse is also true. While this is not likely to result in a large loss in certainty, it requires awareness and where possible, supplementary measurement.

Indicator	Measure	How this measure informs soil condition
Soil acidification	pH in water and $CaCl_2$ (pH units)	Soil acidification is a major land degradation issue facing much of Australia. Many landscapes are also dominated by alkaline soils. Acidification and alkalisation are important to nutrient supply and plant performance. pH is understood as a response to cation balances in soils – low pH values are characterised by high hydrogen, aluminium or manganese; high pH is typically characterised by elevated calcium, magnesium and / or sodium. Elevated magnesium and sodium have consequences for soil structure (magnesicity, sodicity) and hydraulic conductivity. Acidification is a higher risk in poorly buffered soils (e.g. sandy textures) and agricultural activities (removal of produce and some fertilisers) can be strongly acidifying.
Soil organic carbon	% dry weight basis	Soil organic matter (SOM) is the product of decomposing organic material of plant or animal origins. Soil organic carbon is a fixed component of SOM. In environments where disturbance is expected as part of normal management practices, inputs of SOM must be increased to offset losses promoted by soil disturbance. High levels of SOM inputs are essential for the maintenance of high biological function and high microbial biomass is essential for SOM sequestration. A substantial component (~60%) of SOM derives from microbial biomass (Coonan et al., 2020). A significant change in management practices in the form of intercropping, cover cropping and maintenance of groundcover is required to sequester carbon via plant residues and microbial biomass.
Soil salinity	Electrical conductivity saturated extract (dS/m)	High salt levels present risks to production. Assessment of electrical conductivity (EC) is carried out on 1:5 water extracts (i.e., 5 parts water to one part soil). Results are multiplied by the relevant conversion factor to determine the saturated extract and assess the amount of salt in the soil. This measure applies on land affected by both primary and secondary salinity. Primary salinity is the natural occurrence of salts in the landscape arising from geomorphological drivers. Secondary salinity is salinisation of soil, surface water or groundwater due to human activity (e.g. land clearing, irrigation etc.).
Extractable phosphorus	Olsen P (mg/kg)	Olsen Phosphorus is selected as an indicator of nutrient depletion or enrichment. Many Australian soils are naturally deficient in phosphorus and many native plants have developed adaptations to these conditions. Raising P levels on native pastures impacts community structure. Low phosphorus can be an impediment to production on agricultural lands and fertilising has been widely practised as a result. This has led to

Indicator	Measure	How this measure informs soil condition
		many instances of over-application of fertilisers with negative consequences for the environment.
Groundcover	% total groundcover	Erosion by water and wind has been identified as a major soil degrading process. Where erosion occurs, rates of soil removal are likely greater than soil formation (Stockmann et al., 2014). Permanent groundcover is the most effective way to manage erosion and this must be emphasised at vulnerable times of year. Permanent groundcover is inextricably linked to soil carbon sequestration and improvement in natural capital. To the greatest extent possible, groundcover should consist of summer and winter active species to promote living roots year-round. While the focus is very firmly on living groundcover, all organic material including leaf litter, stubble or bark, counts as groundcover for this indicator.

Table 1. Selected indicators for soil condition assessment.

7. Levels of assurance

The AfN Standard assigns confidence levels which are a reflection of the robustness of processes used to determine environmental asset condition.

This method aims for Level 3. A **Level 3 (Moderate)** confidence level applies to Methods that include a limited set of indicators and are likely to have moderate accuracy (≥80%) when measuring the condition of environmental assets and detecting change in their condition through time.

The selected level relates to challenges developing both Econd® and Pcond indices. The AfN Standard (s1.5) requires that a confidence level assigned to an Econd® for soil must be the same as the level assigned to the method used to calculate it. It is difficult to assign high confidence to reference conditions for agricultural land for reasons discussed above. It is therefore important the measurement is consistently made against the reference values so that emerging trends in data provide evidence of change in soil condition over time. Using this approach, the potential for quality data on farms for the specified indicators is high and as a result, the Pcond should provide a moderately high level of confidence in results achieved.

Methodologies and sources include:

- National Natural Resource Management Monitoring and Evaluation Framework, NRM Ministerial Council 2002.
- Monitoring Soil Change. McKenzie et al, 2002. CSIRO Publishing.
- Monitoring soil condition across Australia. McKenzie, N.J. and Dixon, J. (eds) 2006.
- Tasmanian Soil Condition, Evaluation and Monitoring (SCEAM) methods and protocols (DPIPWE, 2004)
- National Soil Quality Review and Program Design (Hill et al., 2003)
- Expert panel input from Victorian soil scientists.

8. Process

8.1. Define the project area

The first step in the process is defining the project area. This method has been developed for use at the farm scale. However, it is recognised that farms differ considerably in scale and distribution. Selection of the project area depends on the purpose of the account. For the purpose of verification of change in soil condition over time, it is recommended that the farm is the project area. For each project area, a consistent geographical area shall be selected.

The output from defining the project area should be a polygon within a spatial data file compatible with geographical information systems, such as a shapefile, in a commonly applied static datum such as the Geographic Datum of Australia 1994.

8.2. Compile existing data

Proponents will need to access existing data from a range of on-line or print sources. Table 2 provides some useful resources for soil condition assessment. There is also a need to determine the dominant soil orders (or soil sub-types) in each assessment area of each project area. Determination of soil orders is a technical undertaking that may well require the assistance of a soil scientist. Initial contact should be made with the local Landcare officer who should be able to locate a suitably qualified person.

Data	**Description**	**Where do I access this?**
Existing soil sites in and around the assessment area; Existing soil mapping in assessment area	There may have been soil sites sampled for the selected indicators. *This may assist with assigning reference condition scores.*	National: Australian Soil Resource Information System (ASRIS) https://www.asris.csiro.au/ Soil and Landscape Grid of Australia https://www.clw.csiro.au/aclep/soilandlandscapegrid/ Victoria: Victorian Resources On-line http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/vrohome NSW: eSpade https://www.environment.nsw.gov.au/topics/land-and-soil/information/espade Queensland: Globe https://qldglobe.information.qld.gov.au/ South Australia: Data SA https://data.sa.gov.au/data/dataset/soil-type Tasmania: Soil maps https://dpipwe.tas.gov.au/agriculture/land-management-and-soils/land-and-soil-resource-assessment/soil-maps-of-tasmania Western Australia: https://www.agric.wa.gov.au/identifying-wa-soils/soil-classification-western-australia Northern Territory: https://depws.nt.gov.au/rangelands/information-and-requests/land-soil-vegetation-information
Soil surveys, Land Capability	Past surveys or land capability assessments may be available	Local land services, State govt departments, local governments, catchment management authorities, Landcare.

Data	Description	Where do I access this?
Assessments etc.		

Table 2. Available resources to determine soil orders and soil types in the assessment area.

8.3. Define assessment units

Assessment units refer to areas within the project area. Soil type (soil order) and land-use should be the primary determinant for selection of assessment units. The individual landholder will determine if an assessment unit is a single paddock, part of a large paddock, or a collection of paddocks. The size of the assessment unit is dependent on the size and layout of the farm. The principal determinant in selecting assessment units is consistency of soil type and land-use. A uniform soil order must cover the whole of the assessment unit. Where soil orders intersect, they should be separated into distinct assessment units and sampled separately.

8.4. Sampling plan

Sampling intensity is dependent on assessment unit size, see Table 3, below.

Assessment Unit Area	Minimum number of composite sample sites required per assessment unit
≤10 hectares	1 composite sample site
10 – 100 ha	1 composite sample site per 10 ha (for example, an assessment unit that is 90 ha, will require 9 composite sample sites)
>100 hectares	10 composite sample sites

Table 3. Summary of sampling intensity

As defined above, soil type (soil order) and land-use combinations should be the primary determinant for selection of assessment units. Larger farms (>100ha) are likely to have a limited number of soil type / land use combinations. For this reason, sampling intensity may be reduced on large landholdings. For example, if a farm is 1,000ha and is made up of 5 assessment units (based on soil type / land use combinations), a minimum of 10 composite samples will be required for each of the assessment units that exceed 100 ha (you may exceed 10 sample sites per assessment unit if required or desired). Composite sample sites (transects) should be selected as representative sites of the assessment unit so that any trend observed in the sampled area can be assumed to also be indicative of changes in the whole assessment unit.

Sampling should occur along a geo-referenced transect of not less than 100m selected for its representativeness of the assessment unit as a whole. Composite topsoil samples should be made up of not less than 10 subsamples along the transect. The transect shall be laid out along the contour if possible. The transect shall be more than 25m from fences, laneways, buildings, other infrastructure, or natural rock.

Topsoils shall be sampled to a depth of 10cm. Where shallow topsoils overlie heavier subsoils, sample to the depth of the topsoil only. Subsamples shall be bulked and thoroughly blended in a clean plastic bucket. The use of galvanised tools should be avoided. A 250g sample shall be drawn off for analysis (as per table 3) at a NATA-accredited laboratory. Samples should be immediately dispatched to the laboratory via Australia Post's overnight express service or similar. If samples are taken on a Friday, or are to be held for a few days to complete sampling, they should be stored in a fridge (not freezer) for not more than one week.

Sampling for pH, salinity, phosphorus and soil organic carbon shall occur in a consistent season but not be done when soils are excessively dry or excessively wet. In dryer locations sampling should be undertaken in wetter months and conversely, in wetter locations, sampling should be undertaken in drier months. To the greatest extent possible, sampling should occur in the same month and under similar weather conditions (i.e., similar temperature and soil moisture conditions). Cropping soils should be sampled shortly after harvest or before sowing. Sites fertilised within the previous three months should be avoided.

Groundcover assessments shall be carried out using remote sensed imagery. The CSIRO-developed VegMachine (2021) is recommended but there is a range of sources[1] through which landholders can access aerial imagery for their property such as TERN's fractional cover mapping. Green / photosynthetic and non-green / non-photosynthetic fractions should be used. Non-living organic groundcover is accepted as groundcover. This assessment

[1] TERN-ANU Landscape Data Visualiser (https://maps.tern.org.au/#/). Fractional cover layer in the TERN Data Discovery Portal (https://portal.tern.org.au/#/61c40d82)
RaPP Map complements other Australian initiatives such as VegMachine© (vegmachine.net) and FarmMap4D Spatial Hub (farmmap4d.com.au), which deliver higher spatial resolution (30 metre) but lower temporal resolution (3 monthly seasonal compilations) of ground cover. URL: http://map.geo-rapp.org/
https://vegmachine.net/
https://www.farmmap4d.com.au/ - requires subscription

aims to determine groundcover – and conversely, bare ground – across a twelve-month period. Aerial imagery shall provide monthly measures of groundcover. The percentage groundcover for each month shall be averaged over a 12-month period to determine a single value. This value will be used to determine the Indicator Condition Score for groundcover.

8.5. Assessment of soil condition

Selected Reference Benchmarks for both the Pcond and Econd® for each soil indicator are set out in table 4 below. The identification of relevant indicators together with the methodology for data collection have been derived from existing methodologies and sources and adapted for this method.

Indicators are consistent with the nationally adopted 'soil matters for target':

- Soil acidification
- Soil organic carbon
- Erosion by water
- Erosion by wind (McKenzie & Dixon, 2006)

Reference values for both the Econd® and Pcond must be determined for each assessment area. Reference values for the Econd® must be determined by the account developer for each underlying soil type within the project area in accordance with the processes described in Section 5.

Reference values for the Pcond are based on industry best practice values. As discussed above in Section 6, Reference values for the Pcond have broad application across landscapes but local conditions may require locally relevant adjustments. Questions arising will need to be answered with expert help from local advisers, agronomists or soil scientists. Determination of Reference Benchmarks for the Econd® and regionally specific Pconds will also require the assistance of local advisers, agronomists or soil scientists.

Soil property	Soil orders	Land use categories	Depth	Annual rainfall (mm)	Reference value for Econd®	Reference value for Pcond
Soil pH (1:5 in water)	All	Pastures, cropping & horticulture	10cm	All	TBD[#]	5.5 – 7.5
		Native veg / Forestry	10cm		TBD[#]	4.5 – 7.5
Soil salinity [ECse (dS/m)]	Ferrosols Vertosols Dermosols Hydrosols	All	10cm	All	TBD[#]	< 2.0
	Chromosols Kandosols Kurosols Podosols Sodosols Tenosols Calcarosols Rudosols	All	10cm		TBD[#]	< 3.0
Organic C (% w/w)	Chromosols Kandosols Kurosols Podosols Sodosols Tenosols Calcarosols Rudosols	All	10cm	All	TBD[#]	> 2
	Dermosols Ferrosols Hydrosols	Cropping & Annual horticulture	10cm	> 800	TBD[#]	> 3
				< 800	TBD[#]	> 2
		Pastures, Perennial horticulture & Native veg / Forestry	10cm	> 800	TBD[#]	> 4
				< 800	TBD[#]	> 3
	Vertosols	Cropping & annual horticulture	10cm	>800	TBD[#]	> 4
				<800	TBD[#]	> 3
		Pastures, Perennial horticulture & Native veg / Forestry	10cm	>800	TBD[#]	> 5
				<800	TBD[#]	> 4
Extractable phosphorus Olsen P (mg/kg)	All	Pastures & Perennial horticulture Cropping & annual horticulture	10cm	All	TBD[#]	10 - 23
		Native veg / forestry	10cm	All	TBD[#]	5 - 20
Groundcover (%)	All	Pastures, perennial horticulture & forestry	n/a	All	TBD[#]	>90
		Cropping			TBD[#]	>75

Table 4. Soil reference values by soil order (adapted from DPIPWE, 2004)

[#] To Be Determined by account developer with assistance from local adviser, soil scientist or ecologist.

Reference condition benchmarking is used to create a common unit of measure for building sets of environmental accounts that describe the condition of any environmental asset. As discussed in section 5, one, or a combination, of the following approaches should be used.

- Observation at reference condition sites (i.e., relatively untouched by agricultural practices);
- Historical record of the reference condition of a site;
- A robust model that estimates the reference condition of the soil; or,
- Expert opinion on the reference condition of the soil.

Indicator condition scores to be used in both Econd® and Pcond calculations shall be assigned for all assessment units as per table 5.

SOIL PROPERTY	**Indicator condition score (ICS)**
pH (pH units)	
Within reference value range	100
≤0.5 above or below reference value range	80
0.5-1.0 above or below reference value range	60
>1.0-1.5 above or below reference value range	40
>1.5-2.0 above or below reference value range	20
>2.0 above or below reference value range	0
Organic carbon (% w/w)	
within or above reference value range	100
≤0.25 below reference value range	80
>0.25-0.5 below reference value range	60
>0.5-0.75 below reference value range	40
>0.75-1.0 below reference value range	20
>1.0 below reference value range	0

SOIL PROPERTY	Indicator condition score (ICS)
Soil salinity (dS/m)	
Within reference value range	100
≤1.0 above reference value range	80
>1.0-2.0 above reference value range	60
>2.0-3.0 above reference value range	40
>3.0-4.0 above reference value range	20
>4.0 above reference value range	0
Extractable Phosphorus (Olsen P, mg/kg)	
Within reference value range	100
<2 above or below reference value range	80
2.0 – 4.0 above or below reference value range	60
4.1 – 6.0 above or below reference value range	40
6.1 – 8.0 above or below reference value range	20
>8.0 above or below reference value range	0
Groundcover (%)	
At or above reference value	100
<10 below reference value	90
11-20 below reference value	80
21-30 below reference value	60
31-40 below reference value	40
41-50 below reference value	20
>50 below reference value	0

Table 5. Indicator condition scores for soil properties

9. Calculating Indicator Condition scores and the Econd®

For each sample site, soil properties (indicators) must be measured. Results shall be averaged for each assessment unit if more than one sample was collected, and an indicator condition score assigned. The indicator condition scores for Econd® calculation should be assigned based on the reference value or range for Econd®, which shall be determined by the account developer. Indicator condition scores are not weighted, i.e., equal value is assigned to each of the four indicators.

The assessment unit Econd® is determined by averaging the indicator condition scores for each soil property for reference condition.

The sub-asset (e.g. soil order) Econd® is determined by summing the assessment unit Econd® weighted against the relative size of each assessment unit, i.e., if a Ferrosol soil order determined assessment unit A, and that soil order occupies 59% of the farm, and a Sodosol determined assessment unit B and is 41% of the farm, the scores for assessment units A and B are multiplied by 59% and 41% respectively and added together to provide a single figure for the Econd®.

The final asset Econd® is the sum of the sub-asset Econd® scores multiplied by the area weighting (i.e., area of the farm under each land use). See Appendix A for a worked example and Appendix B for the excel formulas for the ICS.

10. Calculating Indicator Condition scores and the Pcond

For each sample site, soil properties (indicators) must be measured. Results shall be averaged for each assessment unit and an indicator condition score assigned. The indicator condition score for Pcond calculation should be assigned based on the reference value for Pcond, shown in table 3. Indicator condition scores are not weighted, i.e., equal value is assigned to each of the four indicators.

The assessment unit Pcond is determined by averaging the indicator condition scores for each soil property for industry benchmarks.

The sub-asset Pcond is determined by summing the assessment unit Pcond weighted against the relative size of each assessment unit, i.e., if assessment unit A is 59% of the farm, and assessment unit B is 41% of the farm, the scores for assessment units A and B are multiplied by 59% and 41% respectively and added together to provide a single figure for the Pcond.

The final asset Pcond is the sum of the sub-asset Pconds multiplied by the area weighting (area of the farm). See Appendix A for a worked example and Appendix B for the excel formulas for the ICS.

11. Re-sampling

It is recommended that assessment units are re-visited no sooner than three years from original testing. When resampling, the same sub-sample sites shall be resampled with slight locational adjustment (up to 2m) if required to allow for clean resampling or emerging obstacles.

As discussed under s.8.4 above, to the greatest extent possible, sampling should occur in the same month and under similar weather conditions (i.e., similar temperature and soil moisture conditions). Follow up testing will allow capture of trend data to inform the landholder of changing trends over time.

12. REFERENCES

Accounting for Nature (2019). *Accounting for Nature® Standard Version 2.1* https://www.accountingfornature.org/the-afn-standard

Coonan, EC., Kirkby, CA, Kirkegaard, JA, Amidy, MR, Strong, CL & Richardson, AE, 2020. 'Microorganisms and nutrient stoichiometry as mediators of soil organic matter dynamics', *Nutrient Cycling in Agroecosystems* (2020) 117:273-298, Springer.

Cotching, WE, & Kidd, DB, 2010. *Soil quality evaluation and the interaction with land use and soil order in Tasmania, Australia.* Agriculture, Ecosystem & Environment, Vol 137, Issues 3-4, pp 358-366, Elsevier.

DPIPWE, 2004, *Soil Condition Evaluation And Monitoring (Sceam) Project Tasmania - Methodology & Protocols*, Hobart.

Fontaine, S, Mariotti, A and Abbadie, L 2003, 'The priming effect of organic matter: a question of microbial competition?', *Soil Biology and Biochemistry,* 35, pp. 837-843.

Hill, RB, Sparling, G, Frampton, C and Cuff, J. 2003. *National Soil Quality Review and Program Design*, New Zealand.

McKenzie, N.J. and Dixon, J. (eds) 2006, *Monitoring soil condition across Australia: recommendations from the Expert Panels*, National Land and Water Resources Audit.

McKenzie, N., Henderson, B. & McDonald, W. 2002. *Monitoring Soil Change. Principles & Practices for Australian Conditions*. CSIRO Land & Water, Technical Report 18/02, May 2002. CSIRO Publishing.

Sbrocchi C., Davis R., Grundy M., Harding R., Hillman T., Mount R., Possingham H., Saunders D., Smith T., Thackway R., Thom B., and Cosier P. (2015) *Technical Analysis of the Australian Regional Environmental Accounts Trial*. Wentworth Group of Concerned Scientists, Sydney.

Stockmann, U, Minasny, B and McBratney, AB. 2014. 'How fast does soil grow?', *Geoderma,* 216 (2014) 48-61

VegMachine, 2021. https://vegmachine.net/

13. APPENDIX A – WORKED EXAMPLE

APPENDIX A - WORKED EXAMPLE ECOND

Sub-asset	Assessment unit	Indicator	Reference Benchmark MIN	MAX	Tested value or average tested value	Indicator Condition Score for Econd●	Assessment unit Econd●	Sub-asset Econd●	Asset Econd●
FERROSOL	Native vegetation	Soil organic carbon (%)	6.00	7.00	5.75	80.00	90.00	51.86	64.55
		Soil pH	4.80	5.50	5.50	100.00			
		Soil Electrical Conductivity (dS/m)	1.00	1.50	1.60	80.00			
		Extractable phosphorus (mg/kg)	10.00	20.00	15.00	100.00			
		Ground cover (%)	100.00		90.00	90.00			
	Grazing pastures	Soil organic carbon (%)	6.00	7.00	4.90	0.00	58.00		
		Soil pH	4.80	5.50	6.00	80.00			
		Soil Electrical Conductivity (dS/m)	1.00	1.50	2.10	80.00			
		Extractable phosphorus (mg/kg)	10.00	20.00	25.00	40.00			
		Ground cover (%)	100.00		92.00	90.00			
	Cropping paddock	Soil organic carbon (%)	6.00	7.00	3.20	0.00	48.00		
		Soil pH	4.80	5.50	6.20	60.00			
		Soil Electrical Conductivity (dS/m)	1.00	1.50	1.60	80.00			
		Extractable phosphorus (mg/kg)	10.00	20.00	12.00	100.00			
		Ground cover (%)	100.00		30.00	0.00			
	Olive grove	Soil organic carbon (%)	6.00	7.00	4.50	0.00	40.00		
		Soil pH	4.80	5.50	7.60	0.00			
		Soil Electrical Conductivity (dS/m)	1.00	1.50	1.70	80.00			
		Extractable phosphorus (mg/kg)	10.00	20.00	8.00	60.00			
		Ground cover (%)	100.00		78.00	60.00			
SODOSOL	Native vegetation	Soil organic carbon (%)	3.00	4.00	2.80	80.00	94.00	83.15	
		Soil pH	6.60	7.30	7.10	100.00			
		Soil Electrical Conductivity (dS/m)	1.50	2.50	1.90	100.00			
		Extractable phosphorus (mg/kg)	6.00	10.00	8.00	100.00			
		Ground cover (%)	100.00		90.00	90.00			
	Grazing pastures	Soil organic carbon (%)	3.00	4.00	2.10	20.00	76.00		
		Soil pH	6.60	7.30	7.20	100.00			
		Soil Electrical Conductivity (dS/m)	1.50	2.50	3.20	80.00			
		Extractable phosphorus (mg/kg)	6.00	10.00	9.00	100.00			
		Ground cover (%)	100.00		88.00	80.00			
	Cropping paddock	Soil organic carbon (%)	3.00	4.00	1.70	0.00	36.00		
		Soil pH	6.60	7.30	7.30	100.00			
		Soil Electrical Conductivity (dS/m)	1.50	2.50	2.60	80.00			
		Extractable phosphorus (mg/kg)	6.00	10.00	20.00	0.00			
		Ground cover (%)	100.00		30.00	0.00			
	Olive grove	Soil organic carbon (%)	3.00	4.00	2.20	20.00	72.00		
		Soil pH	6.60	7.30	7.30	100.00			
		Soil Electrical Conductivity (dS/m)	1.50	2.50	3.10	80.00			
		Extractable phosphorus (mg/kg)	6.00	10.00	5.00	80.00			
		Ground cover (%)	100.00		85.00	80.00			

Table 2. AREA WEIGHTINGS

Sub-asset	Assessment unit	Area (ha)	Weighting
FERROSOL		1,177	**59%**
	Native vegetation	*28*	*2%*
	Grazing pastures	*691*	*59%*
	Cropping paddock	*15*	*1%*
	Olive grove	*443*	*38%*
SODOSOL		803	**41%**
	Native vegetation	*362*	*45%*
	Grazing pastures	*391*	*49%*
	Cropping paddock	*16*	*2%*
	Olive grove	*34*	*4%*
TOTAL		**1,980**	

APPENDIX A - WORKED EXAMPLE PCOND

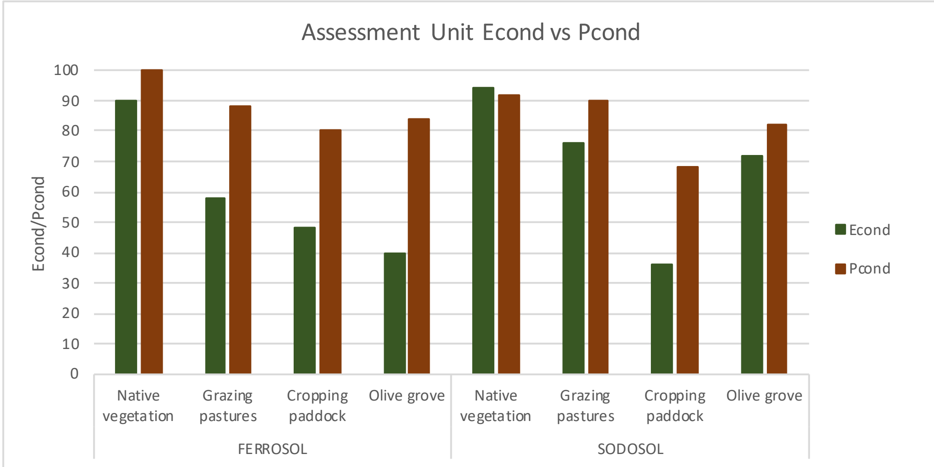
Sub-asset	Assessment unit	Indicator	Industry Benchmarks MIN	Industry Benchmarks MAX	Tested value or average tested value	Indicator Condition Score Pcond	Assessment unit Pcond	Sub-asset Pcond	Asset Pcond
FERROSOL	Native vegetation	Soil organic carbon (%)	4.00		5.50	100.00	100.00	86.68	88.08
		Soil pH	4.50	7.50	5.50	100.00			
		Soil Electrical Conductivity (dS/m)	2.00		1.60	100.00			
		Extractable phosphorus (mg/kg)	10.00	23.00	15.00	100.00			
		Ground cover (%)	90.00		90.00	100.00			
	Grazing pastures	Soil organic carbon (%)	4.00		4.90	100.00	88.00		
		Soil pH	5.50	7.50	6.00	100.00			
		Soil Electrical Conductivity (dS/m)	2.00		2.10	80.00			
		Extractable phosphorus (mg/kg)	10.00	23.00	25.00	60.00			
		Ground cover (%)	90.00		92.00	100.00			
	Cropping paddock	Soil organic carbon (%)	3.00		3.20	100.00	80.00		
		Soil pH	5.50	7.50	6.20	100.00			
		Soil Electrical Conductivity (dS/m)	2.00		1.60	100.00			
		Extractable phosphorus (mg/kg)	10.00	23.00	12.00	100.00			
		Ground cover (%)	90.00		30.00	0.00			
	Olive grove	Soil organic carbon (%)	4.00		4.50	100.00	84.00		
		Soil pH	5.50	7.50	7.60	80.00			
		Soil Electrical Conductivity (dS/m)	2.00		1.70	100.00			
		Extractable phosphorus (mg/kg)	10.00	23.00	8.00	60.00			
		Ground cover (%)	90.00		78.00	80.00			
SODOSOL	Native vegetation	Soil organic carbon (%)	2.00		2.80	100.00	92.00	90.12	
		Soil pH	4.50	7.50	7.10	100.00			
		Soil Electrical Conductivity (dS/m)	3.00		1.90	100.00			
		Extractable phosphorus (mg/kg)	10.00	23.00	8.00	60.00			
		Ground cover (%)	90.00		90.00	100.00			
	Grazing pastures	Soil organic carbon (%)	2.00		2.10	100.00	90.00		
		Soil pH	5.50	7.50	7.20	100.00			
		Soil Electrical Conductivity (dS/m)	3.00		3.20	80.00			
		Extractable phosphorus (mg/kg)	10.00	23.00	9.00	80.00			
		Ground cover (%)	90.00		88.00	90.00			
	Cropping paddock	Soil organic carbon (%)	2.00		1.70	60.00	68.00		
		Soil pH	5.50	7.50	7.30	100.00			
		Soil Electrical Conductivity (dS/m)	2.00		2.60	80.00			
		Extractable phosphorus (mg/kg)	10.00	23.00	20.00	100.00			
		Ground cover (%)	90.00		30.00	0.00			
	Olive grove	Soil organic carbon (%)	2.00		2.20	100.00	82.00		
		Soil pH	5.50	7.50	7.30	100.00			
		Soil Electrical Conductivity (dS/m)	3.00		3.10	80.00			
		Extractable phosphorus (mg/kg)	10.00	23.00	5.00	40.00			
		Ground cover (%)	90.00		85.00	90.00			

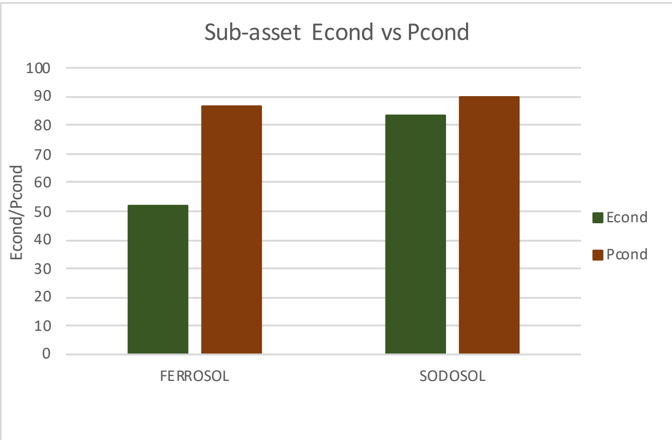
Table 2. AREA WEIGHTINGS

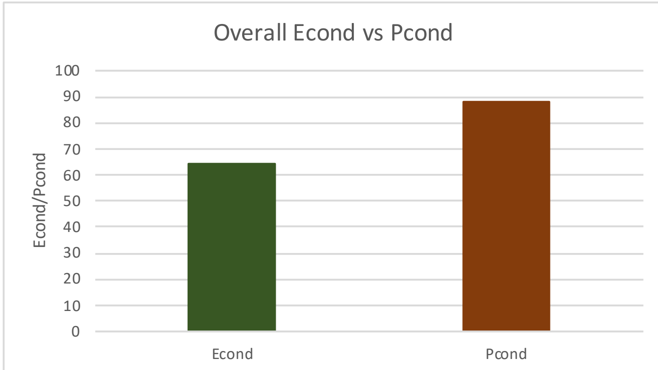
Sub-asset	Assessment unit	Area (ha)	Weighting
FERROSOL		1,177	**59%**
	Native vegetation	*28*	*2%*
	Grazing pastures	*691*	*59%*
	Cropping paddock	*15*	*1%*
	Olive grove	*443*	*38%*
SODOSOL		803	**41%**
	Native vegetation	*362*	*45%*
	Grazing pastures	*391*	*49%*
	Cropping paddock	*16*	*2%*
	Olive grove	*34*	*4%*
TOTAL		**1,980**	

	Sub-Asset	Assessment Unit	Assessment Unit Econd®	Sub-asset Econd®	Econd®
Econd	FERROSOL	Native vegetation	90.00	51.86	64.55
		Grazing pastures	58.00		
		Cropping paddock	48.00		
		Olive grove	40.00		
	SODOSOL	Native vegetation	94.00	83.15	
		Grazing pastures	76.00		
		Cropping paddock	36.00		
		Olive grove	72.00		

	Sub-Asset	Assessment Unit	Assessment Unit Pcond	Sub-asset Pcond	Pcond
Pcond	FERROSOL	Native vegetation	100.00	86.68	88.08
		Grazing pastures	88.00		
		Cropping paddock	80.00		
		Olive grove	84.00		
	SODOSOL	Native vegetation	92.00	90.12	
		Grazing pastures	90.00		
		Cropping paddock	68.00		
		Olive grove	82.00		







14. Appendix B – Excel Formulas

OBS = Observed or measured value

REF = Reference value

<table>
<tr><td rowspan="1">Soil Organic Carbon</td><td colspan="2">Same formula for Econd® and Pcond
=IF(OBS<(REF-1),0,
IF(OBS<(REF-0.75),20,
IF(OBS<(REF-0.5),40,
IF(OBS<(REF-0.25),60,
IF(OBS<(REF),80,100)))))</td></tr>
<tr><td>Soil pH</td><td colspan="2">Same formula for Econd® and Pcond
=IF(OBS<(REF_{MIN}-2),0, IF(OBS>(REF_{MAX}+2),0,
IF(OBS<(REF_{MIN}-1.5),20,
IF(OBS<(REF_{MIN}-1),40,
IF(OBS<(REF_{MIN}-0.5),60,
IF(OBS<(REF_{MIN}),80,
IF(OBS<=REF_{MAX},100,
IF(OBS<=(REF_{MAX}+0.5),80,
IF(OBS<=(REF_{MAX}+1),60,
IF(OBS<=(REF_{MAX}+1.5),40,
IF(OBS<=(REF_{MAX}+2),20))))))))))</td></tr>
<tr><td rowspan="2">Soil Electrical Conductivity</td><td colspan="2">Different formula for Econd® and Pcond</td></tr>
<tr><td>Econd®
=IF(OBS<(REF_{MIN}-4),0,
IF(OBS>(REF_{MAX}+4),0,
IF(OBS<(REF_{MIN}-3),20,
IF(OBS<(REF_{MIN}-2),40,
IF(OBS<(REF_{MIN}-1),60,
IF(OBS<(REF_{MIN}),80,
IF(OBS<=REF_{MAX},100,
IF(OBS<=(REF_{MAX}+1),80,
IF(OBS<=(REF_{MAX}+2),60,
IF(OBS<=(REF_{MAX}+3),40,
IF(OBS<=(REF_{MAX}+4),20))))))))))</td><td>Pcond
=IF(OBS<=REF,100,
IF(OBS<=(REF+1),80,
IF(OBS<=(REF+2),60,
IF(OBS<=(REF+3),40,
IF(OBS<=(REF+4),20,
IF(OBS>(REF+4),0))))))</td></tr>
<tr><td>Extractable Phosphorus</td><td colspan="2">Same formula for Econd® and Pcond
=IF(OBS<(REF_{MIN}-8),0, IF(OBS>(REF_{MAX}+8),0,
IF(OBS<(REF_{MIN}-6.1),20,
IF(OBS<(REF_{MIN}-4.1),40,
IF(OBS<=(REF_{MIN}-2),60,
IF(OBS<(REF_{MIN}),80,
IF(OBS<=REF_{MAX},100,
IF(OBS<(REF_{MAX}+2),80,
IF(OBS<=(REF_{MAX}+4),60,
IF(OBS<=(REF_{MAX}+6),40,
IF(OBS<=(REF_{MAX}+8),20))))))))))</td></tr>
<tr><td>Ground cover</td><td colspan="2">Same formula for Econd® and Pcond
=IF(OBS<(REF-50),0,
IF(OBS<(REF-41),20,
IF(OBS<(REF-31),40,
IF(OBS<(REF-21),60,
IF(OBS<(REF-11),80,
IF(OBS<(REF),90,100))))))</td></tr>
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