Environmental Condition Index (*Econd*)

Econds for soil condition were based on the minimum of the four indicator condition scores for each Soil Map unit: pH, carbon, salinity and water erosion. These indicators were expressed relative to an estimate of reference condition. The minimum indicator condition score used as the *Econd* represented the limiting factor to soil condition. Measures of soil condition *(Econds)* were calculated by selecting the minimum of indicator condition scores for each individual Soil Map unit, *m*:

$$Econd_m = min\ (ICS_{pH,m}, ICS_{salinity,m}, ICS_{erosion,m}, ICS_{carbon,m})$$

where ICS were the indicators of pH, salinity, erosion and carbon.

For example, if pH were the lowest of the indicator condition scores it would be used as the *Econd* for that Soil Map unit.

Econds for each Soil Map unit were aggregated to the 40-unit Landscape units and the NRM regional-scale to provide information about the condition at broader scales. *Econds* were aggregated using spatial weighting -

$$Econd_r = \sum_{m=1}^{m_{max}} Econd_m x \frac{A_m}{A_r}$$

where the *Econd* for a region *r* is the sum of all the *Econds* after they are multiplied by the fraction of the total area covered by Soil Map unit *m*.

Methods used to calculate *Econds* in Queensland Murray-Darling's account are summarised in **Table 23**. There is a well-established literature describing the strengths and weakness of the various ways in which soil indicators may be combined (OECD 2008; Karlen 2004; Andrews *et al.* 2001). There are different methods for integrating indicator condition scores into an *Econd,* so care and understanding is required in interpreting the results.

Table 23: Methods of calculating *Econds* for Queensland Murray-Darling Basin soil account

Scale	Calculation
NRM Region	Aggregation based on sum of spatially weighted Landscape units
Landscape unit (40 units)	Aggregation based on sum of spatially weighted Soil Map units
Soil Map unit (186 units)	Minimum indicator score per Soil Map unit (calculated for Soil Map units where data were available for all indicators)

Econds for the Queensland Murray-Darling Basin were calculated for 2015. The overall *Econd* for the region was 83. *Econds* for individual Soil Landscape units varied between 33 and 100 (**Table 24**). **Figure 23** shows *Econds* mapped in Soil Landscape units (40 units). *Econds* are presented in the soil account tables. *Econds* prior to 2015 were not calculated because data were not available for all indicators.

Table 24: *Econds* for Landscape units in the Queensland Murray-Darling Basin.

Landscape	*Econd*	Landscape (Cont…)	*Econd*
A1: Brigalow Plains	81	M2: Mulga Sand Plains	91
A2: Dunefields	95	M3: Soft Mulga	94
A3: Relict Alluvial Fan Of Maranoa	54	Q1: Carnavon (Quartzose) Sandstone Hills	97
A4: Sandhills, Warrego & Bulloo River	100	Q2: Carnavon (Quartzose) Sandstone Valleys	92
A5: Sand Ridges, Alluvium East Of Nebine	83	Sm1: Brigalow Uplands	73
A6: Spinifex Sand Plains	100	Sm2: Eastern Walloon Sandstone	25
Br1: Granite Landscapes	31	Sm3: Gidgee Plains	95
Br2: Granite Outcrops	66	Sm4: Gidgee Uplands	99
Br3: Limestone/Terra Rossa	49	Sm5: Open Downs	67
Br4: Traprock	41	Sm6: Rolling Downs	63
Bu1: Basaltic Uplands	37	Wa1: Bulloo Alluvia	100
C1: Channel Country	100	Wa2: Chenopod Alluvia Woodland	100
C2: Channel Swamps	100	Wa3: Clay Pans	86
Ea1: Alluvial River & Creek Flats	87	Wa4: Grasslands Of The Warrego Floodplain	83
Ea2: Condamine Alluvia	31	Wa5: River Red Gum Channels	89
Ea3: Coolibah Alluvia	60	Wa6: Woodland, Warrego & Paroo Floodplain	92
Ea4: Dumaresq Alluvia	55	Ws1: Box/Sandalwood On Red Soils	89
Ea5: Lower Balonne Leopardwood Plains	90	Ws2: Dissected Uplands & Scarps	93
Ea6: Yelarbon Desert	63	Ws3: Sandstones (Kumbarilla & Associated)	32
M1: Hard Mulga	87		

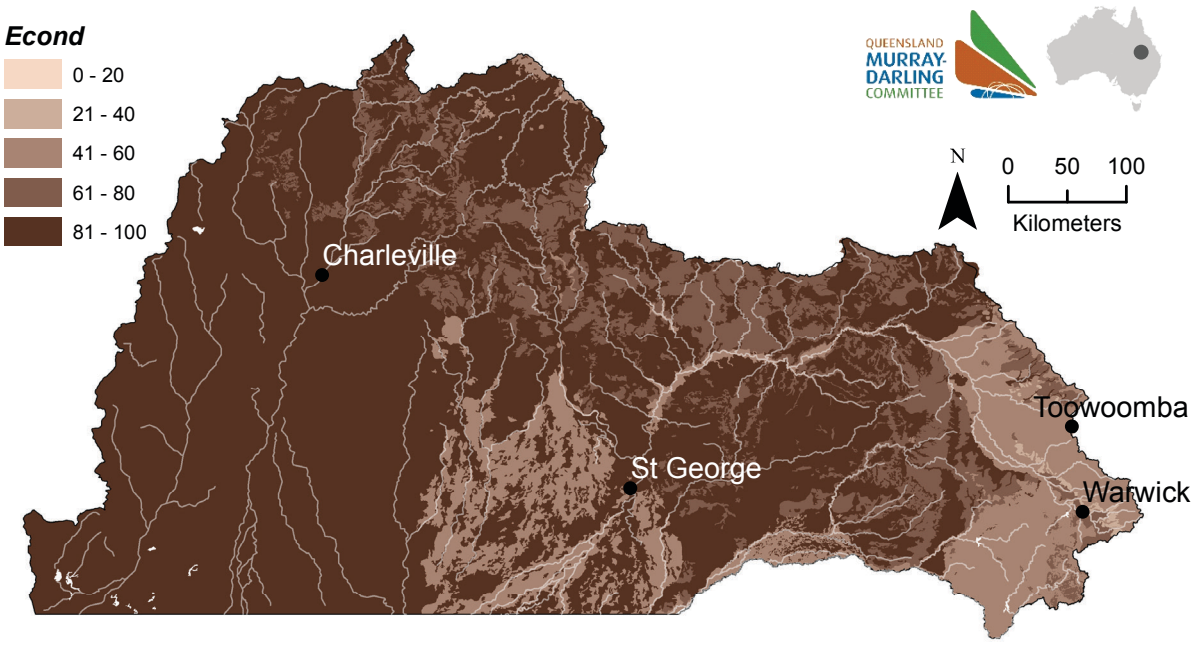

Figure 23: Condition of soils in the Queensland Murray-Darling Basin.

Aggregating indicators based on the minimum scores (see **Table 25**) allowed identification of the limiting factor affecting soil condition. Erosion was the most frequent limiting indicator contributing the minimum scores in 120 of 186 Soil Map units, followed by carbon (60), salinity (2) and pH (0). Scores were equal for all indicators in four remaining Soil Map units. Limiting factors appear to be non-randomly distributed across the Murray-Darling Basin (**Figure 24**). Salinity is generally the limiting factor affecting the eastern slopes, water erosion is generally the limiting factor in the northwest, and carbon is generally the limiting factor on the lowland plains.

Table 25: Example for Brigalow plains (550-625mm rainfall) showing how the minimum indicator score is used as the *Econd* for three dominant soil orders: dermosol, sodosol and vertosol

Indicator	Dermosol	Sodosol	Vertosol
pH	100	100	100
Water erosion	97	96	99
Salinity	90	100	100
Carbon	100	100	77
Econd	**90**	**96**	**77**

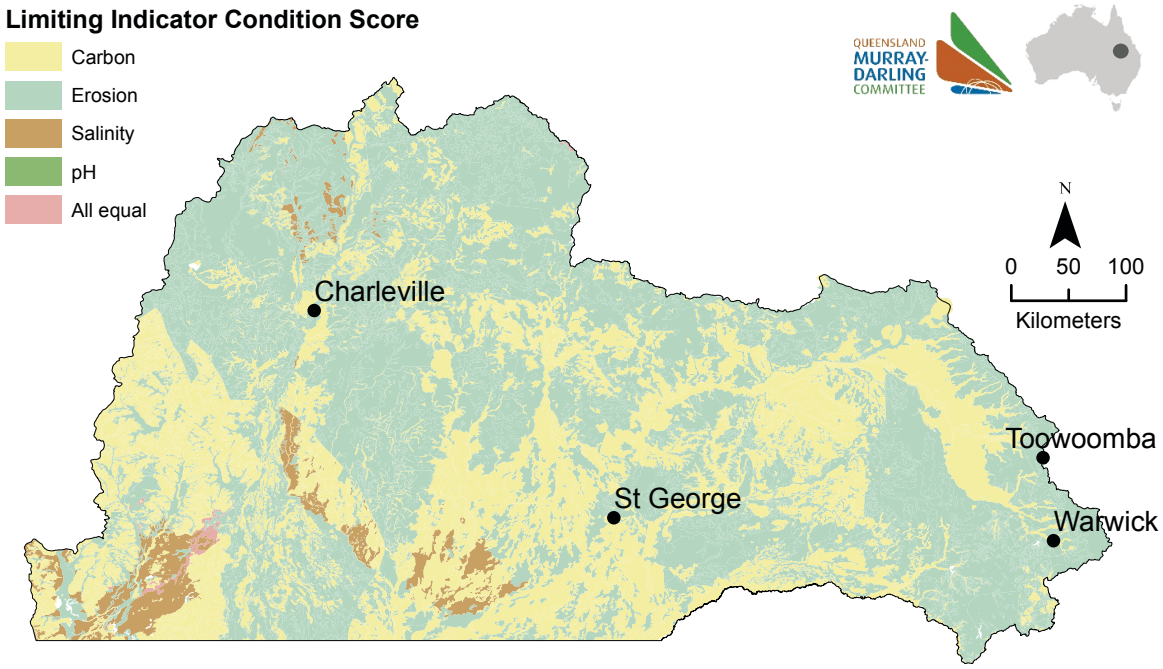

Figure 24: Map showing the indicator which limited the *Econd* in the Queensland Murray-Darling Basin, based on the lowest of the four indicators.

Discussion

The trial has shown that through a collaborative approach, a soil *Econd* can be produced despite complexities associated with a diverse soil asset and data availability. The soil *Econd* was based on key indicators for Australian soils: soil carbon, pH, erosion and secondary salinity. Other indicators were more challenging to measure and interpret so they were excluded from the current trial (wind erosion, nutrients, physical condition and biological condition). They remain important indicators in developing a soil accounting standard nonetheless and their absence influenced the way in which indicators were combined.

The account was a product of the collaboration between the regional body, state agencies and the national science organisation (CSIRO) throughout the trial. Collaboration allowed for sharing of knowledge, building on existing expertise and exchange of datasets. Sufficient resources need to be made available to facilitate this collaboration and enable continued generation of data and knowledge for the development of soil accounts in the future.

The soil account provided an opportunity to test novel elements of condition accounting, particularly the use of the dynamic reference condition. This approach recognised that the condition of environmental assets changes naturally, rather than assuming that condition remains in a fixed state. Scenario modelling was used to estimate reference condition in this trial, but other methods including proxies are available. Such an approach is particularly important for the soil asset that erodes naturally through time (**Figure 20**), but also for other assets which fluctuate or evolve naturally.

Another novel element of the approach to the soil account was the spatial expression of soil condition, by presenting data in detailed maps that showed variation of *Econds* and indicator condition scores across Soil Landscape units (**Figure 22**, **Figure 23**, **Figure 24**). These maps revealed spatial trends in *Econds* and allowed for identification of limiting factors across the region. For example, in some parts of the region the *Econd* was limited by soil erosion, while in other parts the *Econd* was limited by carbon or salinity (**Figure 24**). Including spatial data and mapping capabilities as part of environmental accounting is valuable for communicating complex information and interpreting results across diverse regions.

The trial also demonstrated that knowledge of the dynamics of land cover, both in the direct effect on erosion and as an index of management effectiveness, is critical for soil condition accounting, particularly for estimating erosion. In this trial, historical land cover maps were purpose-built using aerial photography, land use maps and satellite imagery. In the future, remote sensing methods may allow for finer spatial resolution and increased efficiency in estimating land cover across large areas. These techniques are likely to improve estimates of the vegetation cover factor (C-factor), an important management driver affecting soil loss.

Land management practices are more complex to account for, yet remain important drivers of soil condition and should be included in condition accounting. Some land management practices were modelled through the C-factor in the erosion model (eg zero and minimum till in 'new cropping' in **Table 20**). The next iteration of the soil erosion model could incorporate additional land management practices, such as contour farming and crop and pasture rotation. Including such practices is important for understanding whether they have led to improvements in soil condition, particularly in the Queensland Murray-Darling region where use of zero till is now widespread on the Darling Downs. Such factors should also be considered in soil carbon estimates, given the effects of land management practices on carbon content (Sanderman *et al.* 2010).

The approach to soil accounting is likely to evolve as new opportunities arise from advances in soil science and soil information that will increase the accuracy and impact of this form of regional analysis. This includes the emerging capability to use the new Soil and Landscape Grid of Australia (www.csiro.au/soil-and-landscape-grid) as a basis for finer and more capable soil/plant system modelling, and new developments in the dynamic measurement of soil cover using remote and proximal sensing in the paddock, across the farm and over the broader landscape. These developments along with this demonstrated approach should mean that soil condition accounts are feasible in NRM regions around the country.

The approach to measuring soil condition for environmental accounting purposes is distinct from other soil assessment programs which measure agricultural condition to improve the productive capacity of soil. The *Econd* measures soil condition relative to natural condition (ie unimproved). The 'natural condition' approach was suitable for environmental accounting, as it provided a consistent methodology across the whole landscape and its history, allowing changes to be identified so that appropriate management and farming practices can be directed. When applying this approach in agricultural regions, careful consideration is warranted where agricultural practices, such as application of fertilisers or irrigation, have altered the biophysical properties of the soil in order to improve its condition for agricultural productivity.

Conclusions

The biophysical condition of Australian soil, in concert with the climate and the land management systems we employ, affect the long term outcome of our land and the extent to which land use, productivity and a broader set of environmental services can be sustained. The methods used in the regional environmental accounts and described in this chapter show that soil indicators and a measure of soil condition can be assessed at relevant scales for management, against biophysical indicators.

It is possible to make useful statements on soil condition on the available subset of indicators (pH, soil carbon, erosion, secondary salinity) where these indicators are dominant in the landscape and where the assessment method accounts for the missing factors of condition (ie using a minimum concept).

Assessing current condition against the reference condition was shown to be possible and requires a reconstruction of the land management history of the system. This also facilitates hindcasting of the drivers of soil condition.

It has thus been possible to compute soil indicators and combine them effectively to yield a measure of soil condition *Econd* for QMDB that provides an encouraging initial assessment.

This trial has established the basis of an approach which has potential to be applied nationally across regions. It would be advisable to review the steps taken with QMDB to identify efficiencies and additional approaches to estimate condition processes. This could include the development of modelling and real-time data collection for soil monitoring.

The trial required access to knowledge, skills and data across the region, state agencies, CSIRO and other parties. Soil condition assessments at regional-scale across Australia will always require similar levels of collaboration.

While this trial was able to mine primary data from many state and national sources and generate new derived information, it is clear that ongoing soil monitoring and measurement will be an essential component of building a set of environmental accounts for Australia which include a measure of soil condition.

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