final report

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Sampling methodology for estimating the impacts of pasture type and management on soil carbon stocks in grazing lands

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Final report on: Fractionation of soil carbon samples for processing and analysis for organic carbon estimation of the particulate organic carbon (Particulate-C) and humus (Humus-C) and charcoal (Char-C) carbon fractions. Samples for fractionation are from Wambiana long-term research trial, collected as part of B.CCH.2007 measurement of total soil organic carbon. Samples are to be fractionated and then sent to CSIRO, Adelaide, for analysis, once current samples within the National Soil Carbon Research Program (SCaRP) are complete.

Abstract
In addition to measurement of total soil organic carbon stocks, the measurement of carbon fractions, particulate organic carbon (POC) and humus (HUM) may provide important information relating to turnover rates of carbon in the soil. These include: the roles different soil C fractions contribute towards soil health and plant productivity, carbon sequestration and the potential influence of soil carbon stock changes for measurement and monitoring purposes. To date, this MLA-funded project has: (i) undertaken and published a critical review of sampling designs for the measurement of soil organic carbon in grazing lands; (ii) developed a recommended sampling strategy for measurement of soil carbon in grazing lands based upon soil type, sampling scale, number and location of sampling points (published in peer-review journal); (iii) applied the recommended sampling methodology outlined above to assess SOC stocks in paddocks with varied grazing management (cell, rotation, continuous stocking and fire frequency and intensity), including northern Australian rangelands as part of the national Soil Carbon Research Program; (iv) reported findings of SOC stock and management effects from long-term grazing and leucaena research trials (Wambiana and Brian Pastures); and (v) provided recommendations for ongoing research efforts of soil carbon stock measurement in Australian rangelands. Using Wambiana long-term Research trial data from this project, we continue this work beyond total soil organic carbon assessment, to consider sampling methodology and statistical analysis of the soil organic carbon fractions, in accordance with national soil carbon research activities.

Project objectives
The objectives of the project are:

1. Identification and fractionation of soil organic carbon samples from Wambiana long-term research trial (2 paddocks representing moderate and heavy grazing) into the >50 and <50µm fractions, in accordance with national Soil Carbon Research Program (SCaRP) methodology.
2. Storage and transit of soil samples for further processing by CSIRO Adelaide laboratory, upon completion of current national Soil Carbon Research Program (SCaRP).

Success in achieving milestone
We have successfully achieved milestone 9, submission of the final report, as outlined below:

- **Identification of soil samples for fractionation**
  Soil samples from Wambiana long-term research trial, used to assess sampling design for determination of soil organic C stocks (Pringle et al. 2011; see Appendix 1) were identified from the soil archive and scheduled for fractionation.

- **Fractionation of identified soil samples for analysis of organic carbon, based upon national Soil Carbon Research Program (SCaRP) methodology.**
  Soils analysed for total organic carbon in fine earth (<2mm) fraction as part of this project, were sieved to the >50 and <50µm fractions using a Fritsch Vibratory Sieve Shaker with 50µm sieve. A subset of the >50 and <50µm fractions have been identified, based on %C values of fine earth fraction, for calibration data set for MIR analysis of organic carbon. Remaining samples will be archived for cross-validation of MIR results as required (Appendix 2 outlines an overview of SCaRP methodology).

- **Prepared samples to be sent to CSIRO Adelaide lab for analysis.**
  Communication with Dr Jeff Baldock, CSIRO Adelaide, is ongoing, to ensure samples are sent to CSIRO Adelaide lab for analysis upon completion of current SCaRP program activities (final SCaRP report due 30 June 2012).

- **Communication of project, including project status and outcomes**
  The project methodology has been communicated to a range of stakeholders and published as scientific journal articles; Appendices 1 and 2 summarise the main findings of these publications. Further, discussion is ongoing with Dr Jeff Baldock, CSIRO Adelaide, in order to transit samples to the CSIRO laboratory upon completion of the current national Soil Carbon Research Program (SCaRP) activities, and to identify calibration data set for estimation of POC, and where possible, HUM-C and Char-C.

Overall progress of the project

Initial project objectives have been fulfilled; further reporting of results will follow the timeline of reporting within the national Soil Carbon Research Program (Final report for northern rangelands component of SCaRP is scheduled for 30 June 2012).

Recommendations

An update to ongoing MLA project (B.CCH.2007) has been proposed (proposed progress update to MLA end August 2012) to enable Jeff to determine timeframe for soil fraction analysis.

List of Appendices

Appendix 1 – List of publications associated with this project are noted below:

1a. Critical review of sampling design for the measurement of soil organic carbon in Australian grazing lands (full article in pdf format is supplied as attachment to report).

CSIRO PUBLISHING

Review

www.publish.csiro.au/journals/trj

The Rangeland Journal, 2010, **32**, 227–246

A review of sampling designs for the measurement of soil organic carbon in Australian grazing lands

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Abstract. The accurate measurement of the soil organic carbon (SOC) stock in Australian grazing lands is important due to the major role that SOC plays in soil productivity and the potential influence of soil C cycling on Australia's greenhouse gas emissions. However, the current sampling methodologies for SOC stock are varied and potentially conflicting. It was the objective of this paper to review the nature of, and reasons for, SOC variability; the sampling methodologies commonly used; and to identify knowledge gaps for SOC measurement in grazing lands. Soil C consists of a range of biological materials, in various SOC pools such as dissolved organic C, micro- and meso-fauna (microbial biomass), fungal hyphae and fresh plant residues in or on the soil (particulate organic C, light-fraction C), the products of decomposition (humus, slow pool C) and complexed organic C, and char and phytoliths (inert, passive or resistant C); and soil inorganic C (carbonates and bicarbonates). Microbial biomass and particulate or light-fraction organic C are most sensitive to management or land-use change; resistant organic C and soil carbonates are least sensitive. The SOC present at any location is influenced by a series of complex interactions between plant growth, climate, soil type or parent material, topography and site management. Because of this, SOC stock and SOC pools are highly variable on both spatial and temporal scales. This creates a challenge for efficient sampling. Sampling methods are predominantly based on design-based (classical) statistical techniques, crucial to which is a randomised sampling pattern that negates bias. Alternatively a model-based (geostatistical) analysis can be used, which does not require randomisation. Each approach is equally valid to characterise SOC in the rangelands. However, given that SOC reporting in the rangelands will almost certainly rely on average values for some aggregated scale (such as a paddock or property), we contend that the design-based approach might be preferred. We also challenge soil surveyors and their sponsors to realise that: (i) paired sites are the most efficient way of detecting a temporal change in SOC stock, but destructive sampling and cumulative measurement errors decrease our ability to detect change; (ii) due to (i), an efficient sampling scheme to estimate baseline status is not likely to be an efficient sampling scheme to estimate temporal change; (iii) samples should be collected as widely as possible within the area of interest; (iv) replicate of laboratory analyses is a critical step in being able to characterise temporal change. Sampling requirements for SOC stock in Australian grazing lands are yet to be explicitly quantified and an examination of a range of these ecosystems is required in order to assess the sampling densities and techniques necessary to detect specified changes in SOC stock and SOC pools. An examination of techniques that can help reduce sampling requirements (such as measurement of the SOC fractions that are most sensitive to management changes and/or measurement at specific times of the year – preferably before rapid plant growth – to decrease temporal variability), and new technologies for *in situ* SOC measurement is also required.

1b. Sampling design for the measurement of total soil organic carbon stock at Wambiana long-term research trial (full article in pdf format is supplied as attachment to report).

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Soil carbon stock in the tropical rangelands of Australia: Effects of soil type and grazing pressure, and determination of sampling requirement

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ABSTRACT

On-going, high-profile public debate about climate change has focussed attention on how to monitor the soil organic carbon stock (C_s) of rangelands (savannas). Unfortunately, optimal sampling of the rangelands for baseline C_s – the critical first step towards efficient monitoring – has received relatively little attention to date. Moreover, in the rangelands of tropical Australia relatively little is known about how C_s is influenced by the practice of cattle grazing. To address these issues we used linear mixed models to: (i) unravel how grazing pressure (over a 12-year period) and soil type have affected C_s and the stable carbon isotope ratio of soil organic carbon ($\delta^{13}C$) (a measure of the relative contributions of C_3 and C_4 vegetation to C_s); (ii) examine the spatial covariation of C_s and $\delta^{13}C$; and, (iii) explore the amount of soil sampling required to adequately determine baseline C_s. Modelling was done in the context of the material coordinate system for the soil profile, therefore the depths reported, while conventional, are only nominal.
Linear mixed models revealed that soil type and grazing pressure interacted to influence C_s to a depth of 0.3 m in the profile. At a depth of 0.5 m there was no effect of grazing on C_s, but the soil type effect on C_s was significant. Soil type influenced $\delta^{13}C$ to a soil depth of 0.5 m but there was no effect of grazing at any depth examined. The linear mixed model also revealed the strong negative correlation of C_s with $\delta^{13}C$, particularly to a depth of 0.1 m in the soil profile. This suggested that increased C_s at the study site was associated with increased input of C from C_3 trees and shrubs relative to the C_4 perennial grasses; as the latter form the bulk of the cattle diet, we contend that C sequestration may be negatively correlated with forage production. Our baseline C_s sampling recommendation for cattle-grazing properties of the tropical rangelands of Australia is to: (i) divide the property into units of apparently uniform soil type and grazing management; (ii) use stratified simple random sampling to spread at least 25 soil sampling locations about each unit, with at least two samples collected per stratum. This will be adequate to accurately estimate baseline mean C_s to within 20% of the true mean, to a nominal depth of 0.3 m in the profile.

Appendix 2 - Summary points regarding fractionation of soil samples for soil organic carbon as part of the national soil carbon research program (SCaRP)

http://www.clw.csiro.au/publications/science/2011/SAF-SCaRP-methods.pdf

- The national soil carbon program has adopted a modified version of a fractionation scheme proposed by Skjemstad et al (2004), which isolates particulate and mineral-associated fractions based upon size fractionation after sample dispersion, and then further isolates a resistant organic matter fraction dominated by charcoal present in the two physical fractions by use of solid-state 13C NMR spectroscopy. This fractionation scheme defines a particulate, humus and char fraction, which Skjemstad et al (2004) successfully substituted into the Roth-C modelling framework as measureable versions of the resistant plant material (RPM), humified OM (HUM) and inert OM (IOM) pools.

- Several improvements from the initial fractionation protocol have been made: operator variability in physical separation of size fractions is now reduced by use of an automated vibratory sieve shaker system (Massis et al 2010). Importantly, particulate C recoveries were found to be significantly greater using the automated method because less truly particulate material was being broken down and forced through the sieve. Second, it has been now recognized that the particulate fraction (>50 µm) can contain measureable quantities of char, thus charcoal content of both fractions is now determined and the quantities are bulked together to give the total char-C content.

- As the fractionation procedure is very labour and time intensive, 5-10% of the samples in the SCaRP project will be physically fractionated. These samples have been carefully chosen to span a range in OC content in each region, so that they can be used as an effective calibration set of samples for developing mid-infrared (MIR) spectroscopy-based calibration algorithms that will allow the content of SOC allocation to the particulate, humus and charcoal-like fractions to be predicted from the acquired MIR spectra. Each sample selected for fractionation goes through the fractionation procedure twice. The first time through, a 10 g sample is size fractionated and the carbon content of each size fraction is determined. The second time, this information is then used to determine how much of each of these two fractions, depending on their carbon content, need to be accumulated in order to determine the char content via 13C NMR spectroscopy