Paired-sites to engage farmers and understand soil organic matter and carbon

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Abstract
The emerging carbon economy is forcing farmers, their advisers and the research, development and extension community to better understand soil organic matter, soil carbon and the opportunities to better manage soil carbon for productivity and sequestration. National programs are developing detailed sampling and analytical protocols to measure changes in soil carbon and support carbon pricing mechanisms. However, a 'paired-site' approach has also been used to engage Queensland farmers and help them to better understand soil carbon processes, the impacts of their practices on soil carbon and its fractions, and so develop more informed ways to manage soil organic matter and carbon on their farms. Key impacts have been to help farmers recognise the dramatic affect of cropping on soil organic matter, the potential to rebuild their soils using perennial pastures, and the dangers of degrading their soil and its chemical fertility before commencing these pasture phases. With over 200 paired sites to date, the approach has been useful for more than extension alone. It has also provided a useful data set to benchmark the likely sequestration potential of key systems, professionally sampled soils for local calibration of emerging soil carbon testing procedures (e.g. MIR), and screening of sites for further more detailed soil carbon studies.

Key Words
Soil carbon, farmer engagement, action learning

Introduction
Soil organic matter is critical for healthy soils and sustainable agricultural production; it contains organic carbon that underpins many physical, chemical and biological soil processes in the soil, and a range of elements needed by both plants and soil biota (Hoyle, Baldock and Murphy 2011).

Farmers and scientists have long recognised these benefits of soil organic matter and included soil organic carbon analyses in commercial soil testing systems. However, dialogue about 'climate change' and the emerging 'carbon economy' in Australia appear to have renewed interest in better understanding soil organic matter (SOM) and soil organic carbon (SOC) levels, and how best to manage them on commercial farms.

Levels of SOC are the result of the balance between inputs (e.g. plant residues and other organic inputs) and losses (e.g. erosion, decomposition) in each soil and farming system (Hoyle, Baldock and Murphy 2011). Higher SOC levels are considered better and will be encouraged by maximising productivity (Bell and Lawrence 2009). However, these SOC levels typically decrease as native vegetation is removed for agricultural production; most dramatically when land is used for cropping (Dalal and Mayer 1986). Unlike many soil nutrients, critical levels of soil organic carbon are not defined for each soil.

National research programs are developing detailed sampling and analytical protocols to measure changes in soil organic carbon, understand the dynamics of different carbon fractions and so support the emerging carbon pricing mechanisms. Meanwhile, new policies and programmes (e.g. Carbon Farming Initiative) are encouraging farmers to sequester soil organic carbon and reduce their contributions to greenhouse gas emissions. Consequently, farmers, their advisers, and supporting research, development and extension (RDE) agencies are striving to better understand the principles of soil organic matter and make more informed decisions on how best to manage carbon on their farms.

These management decisions are likely to be unique for each paddock and property because the achievable soil organic carbon levels depend on the potential of each soil to protect organic carbon and the productivity of the underlying farming system (Hoyle, Baldock and Murphy 2011). Consequently, this paper reports on a workshop-based action learning (L) initiative (Revans 1997) to combine propositional scientific knowledge (P) and farmer experience with on-farm soil carbon testing to answer individuals farmer's questions (Q) about the impacts of land-use on soil carbon levels and practices to increase carbon in southern Queensland, that is; L = P + Q.

Methods

The general process described in this paper has been used with 25 groups and 250+ farmers in the last five years across Queensland and northern New South Wales. However, this paper describes the four basic steps of activities that have been used with most groups in southern Queensland since 2009:

Step 1. Clarifying the opportunity and expectations

Activities were conducted with existing farmer groups, such as Landcare and sub-catchment planning groups that had registered their interest in soil organic matter. Team members attended an initial meeting to provide a very basic understanding of soil organic carbon and the opportunity to do soil tests on participants' farms. This allowed each participant to make a more informed choice of paddocks to sample on their own farms; the paddocks of most interest to them personally, and so the ones from which they could learn the most.

Step 2. Testing each participants own paired-sites

Each participant nominated one paired-site comparison, and the project team stressed the importance of each pair being the same soil type so that the comparison would highlight the impact of their past land use and farming practices. The development history and paddock management was recorded for each site. Paddocks were sampled to a depth of 10 cm at 15 points, normally every three metres along a 45 metre tape to ensure representative samples across pasture sites. Samples were analysed for: Total Organic Carbon (Dumas) and Total Organic Nitrogen (Dumas); Walkley-Black Organic Carbon, Microbial Biomass Carbon, pH, Electrical conductivity, Colwell bicarbonate extracted Phosphorus and BSES Acid extracted Phosphorus. The Total Organic Carbon and Total Organic Nitrogen analyses were repeated within the particulate carbon fraction (53µm to 250µm) for many samples. However, the sites were not sampled for bulk density. While only Dumas organic carbon results are presented in this paper, the other analyses were covered in the discussion at workshops and contributed to the learning outcomes presented later in the paper.

Step 3. Conducting workshops

The workshop process was designed to integrate existing scientific understanding and farmer experience. Paired-soil tests from each participant's farm were designed to 'get farmers interested'; to engage them with their own data, not hypothetical examples; and to use the results to make real decisions on their future practices. The half-day workshops contained four sessions:

1. An introduction and discussion of soil organic matter and soil carbon principles and processes;
2. A paddock visit to understand the results of a group members paired-sites, usually native vegetation versus continuous cultivation;
3. A summary and discussion of collated results using charts of major land use contrasts, such as: timber cleared for native pasture; age of cultivation comparisons; continuous cultivation versus old crop land returned to pastures. After explaining the initial contrasts, the group were asked to what differences they expected and why…before looking at the actual results;
4. A brief session to ensure each participant understood their own soil carbon results and clarify any anomalous results;
5. A brief evaluation survey, followed by a discussion of participants' major learnings and the practices that they would change as a result of this information.

Step 4. Providing ongoing support

Finally, the project team and their networks provided some ongoing support for people to start changing their practices to increase soil organic carbon. This support was typically in association with their existing Landcare groups and specialist RDE projects on discrete technical issues (e.g. ways to increase the reliability of pasture establishment for people retiring old crop land to pastures).

Results and Discussion

The workshop process has been used with 100 mixed farmers across southern Queensland since 2009. A total of 212 sites have been assessed, including several comparisons of three different land uses. The average total organic carbon (0-10 cm) level was 1.4%, although this varied from 0.5% to 3.8%. The dramatic decline in organic carbon levels with continuous cropping was clearly illustrated to participants from a compilation of their own soil pairs comparing native vegetation (typically remnant Brigalow) and long-term cultivation (Figure 1) in the local area and regionally. Thirty years of continuous cropping reduced the mean total organic carbon levels on these soils from 3.1% to 0.9%, a significant decline in both organic carbon and its associated soil nutrients. For alternative land uses after development, there was a trend towards higher organic carbon levels under sown pastures than native pastures, including sites that had previously been under cropping (Figure 2). This is in line with expectations that sown pastures will have higher long term dry matter production than the native species that they have replaced. Farmers were particularly interested in the ability of sown pastures to increase soil organic carbon levels after a cropping phase, and the results show a significant increase in most cases (Figure 3).

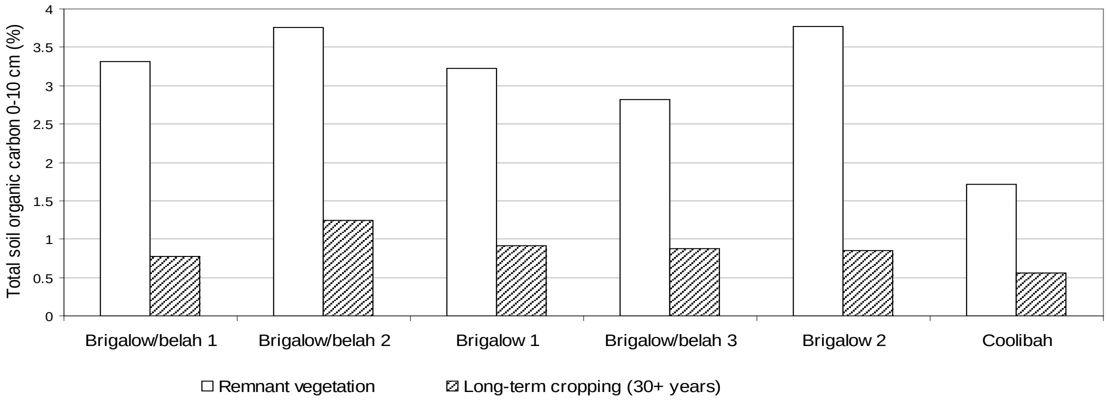

Figure 1. Total Soil Organic Carbon (Dumas %) in the topsoil (0-10 cm) of six paired sites under remanent vegetation (Brigalow) and long-term cropping in southern Queensland.

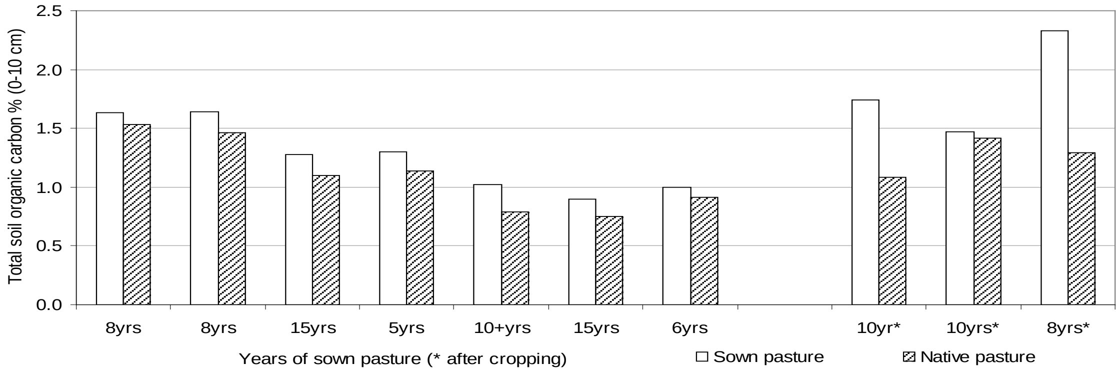

Figure 2. Total Soil Organic Carbon (Dumas %) in the topsoil (0-10 cm) of paired sites comparing sown and native pasture in southern Queensland, including sites following a period of cropping (*).

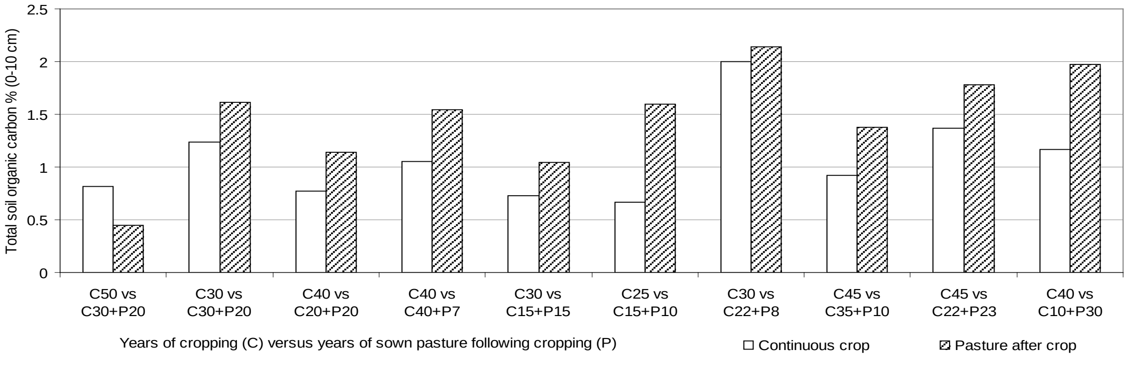

Figure 3. Total Soil Organic Carbon (Dumas %) in the topsoil (0-10 cm) of paired sites comparing continuous cropping and sown pastures after cropping in southern Queensland.

The introductory theory on accepted scientific knowledge (P) and examples of interest to answer each group's questions (Q) enabled most farmers to learn (L), that is, to understand their own soil test results and discuss the likely soil carbon levels of other scenarios tested. For example, the lack of clear differences between organic carbon levels under zero tillage and traditional cultivated systems, and the need for adequate soil nutrient supplies to support productive pastures that produce enough dry matter to rebuild old cropping soils was better understood. This understanding was reflected in participants' self-assessment of their 'learnings' from the activity. The highest rated 'learnings' were:

Gaining knowledge on;

1. How management/practices affect my soil carbon levels
2. Soil carbon and what it does in mixed farming systems
3. Climate change and variability

Building skills to;

1. Better manage soil organic carbon on my farm
2. Increase the sustainability of my farming practices

When asked an open-ended question on their biggest learning;

1. Soil organic carbon/matter, its fractions and processes (32%)
2. Soil carbon levels under different practices (24%)
3. How to lift soil organic carbon (12%)
4. Carbon credits/trading (5%)

Since testing, many farmers have been interested in using sown pastures to rebuild soil organic carbon and its associated nutrients in their more marginal cropping land. However, many of these soils have been degraded by continuous cropping, with low soil nitrogen and phosphorus levels. While low nitrogen levels may be partially overcome with the incorporation of pasture legumes, the persistence and productivity of these legumes and their subsequent nitrogen supply is likely to be severely limited by phosphorus levels that are highly deficient across much of the marginal dryland cropping land of southern Queensland.

Conclusion

These results and the continuing interest from farmer groups to undertake paired-tests to compare soil organic carbon levels on their own farms are encouraging. The process has helped participants better understand soil organic matter and organic carbon, has provided a useful local data set and general benchmarks to compare land use impacts on soil carbon. The professionally sampled soils from a range of scenarios have subsequently been used to help calibrate more detailed fractionation analyses in research laboratories for the national research effort, although the lack of soil bulk density measurements limits the data's value for carbon accounting. However, the interest generated and the impact of the activities of participants learning clearly shows the value of professional extension processes that use real (not hypothetical) on-farm data to engage participants and support them to develop informed on-farm strategies for their own farms.

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