Integrating pastures into farming systems – soil health and the benefits to crops

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Introduction

'Soil health' and 'carbon sequestration' are now commonly used terms in Australian agriculture. They are prominent in the title and program of this conference, and this paper deliberately introduces them together. While soil health and how pastures can improve the soils in our farming systems are the focus of this paper, it is the potential carbon sequestration under pastures that underpins many of these improvements. Consequently, this paper proposes a structure to understand and assess soil health in our farming systems, provides some examples of how pastures contribute to better soil health, and presents some recent data that show the potential for pastures to improve soil carbon levels across the grain farming systems of Queensland.

What is soil health?

For us, a 'healthy soil' is a soil that is fit-for-purpose and does not limit production beyond the limitations of its inherent soil properties and climate. As long as the land use is sensible, a healthy soil is one that continues to do what you want it to…with a minimum of fuss. However, just what makes a soil healthy? What does a healthy soil do? What does it provide for our crop and pasture plants?

To help answer these questions, we propose 10 basic functions that a healthy soil provides to plants in our farming systems. These functions provide a way to think about soil health and to understand the physical, chemical and biological interactions in our soils. Soil health is more than soil biology. It is the interaction of the physical, chemical and biological properties that makes a soil healthy and maintains profitable and sustainable farming systems. Our farming practices affect these physical, chemical and biological properties to determine how our soil behaves (Figure 1). For example, we can improve many of these soil functions by introducing productive pastures to our current farming systems.

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Physical functions of a healthy soil

Healthy plants need water. We need to get water into the soil and store it for future use, and we need the soil to support healthy roots that can then access soil water and nutrients. Pastures can make a big contribution to these physical functions, especially by providing cover that improves infiltration and reduces erosion, and by increasing the soil organic matter that builds soil structure to maintain infiltration and keep soils aerobic.

The effects of ground cover are well known and the level of erosion declines exponentially as soil cover increases up to about 40% (Figure 2). Perennial pastures that maintain cover all year and do not require lengthy fallows with high soil moisture levels are perhaps the best way to increase infiltration and reduce erosion in our systems. The direct impacts of increased organic matter are also important, even if this is less well known (Figure 3). As labile C increases, rainfall infiltration improves and runoff/erosion is reduced.

Chemical functions of a healthy soil

Water remains the major limit to both crop and pasture production in most of Australia. Yet plants still need a healthy soil chemical environ-

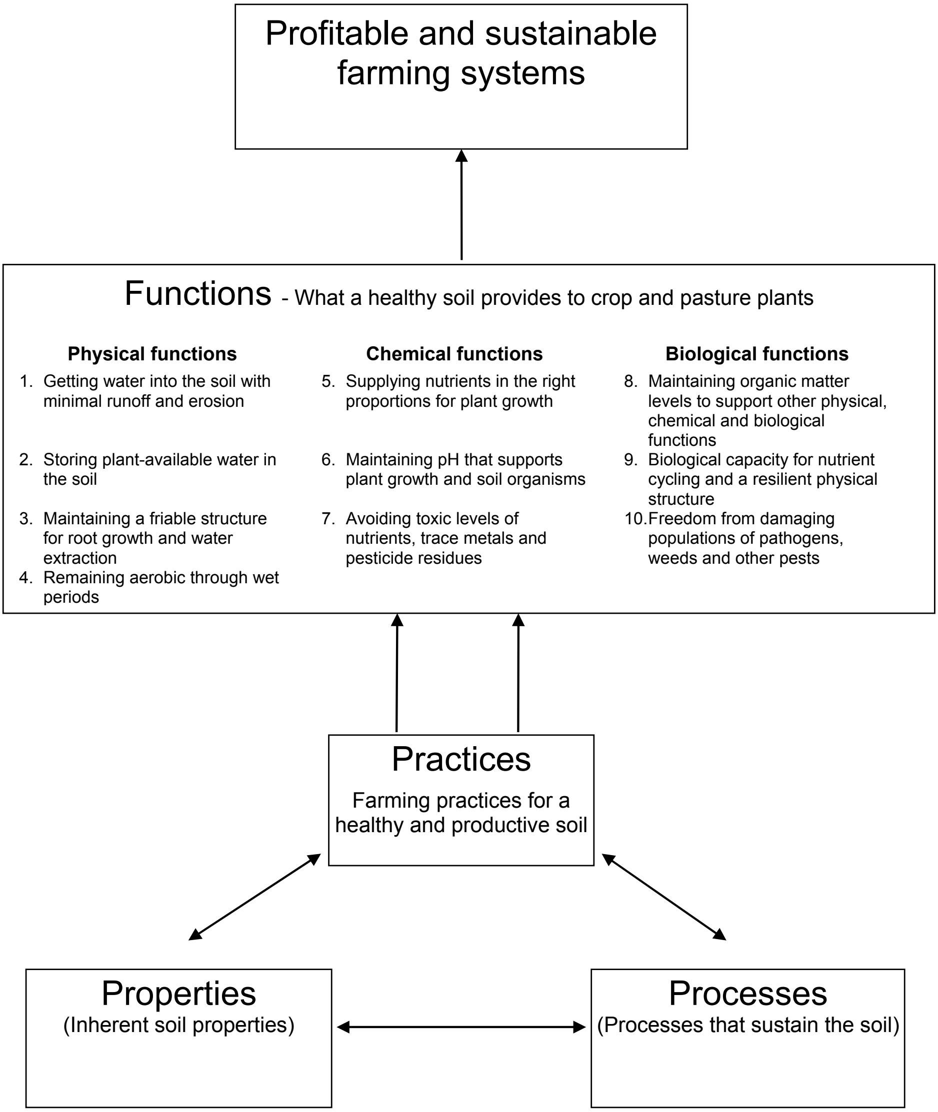

Figure 1. Ten functions of a healthy soil.

ment to best use this water and maximise production. To do this a healthy soil must supply the 15 essential key nutrients in the right proportions for plant growth. As the harvest of grain and biomass removes many nutrients (*e.g*. phosphorus, potassium), soil levels will decline unless they are replaced with fertilisers. Use of pastures will not replenish these nutrient reserves unless the pastures are fertilised. However, the supply of other nutrients (*e.g*. nitrogen) also declines, as continuous cropping depletes soil organic matter reserves from which they originate (Figure 4). Consequently, soils used for grain production typically require nitrogen fertiliser after about 30 years of cultivation, and often pulse crops are grown to reduce the nitrogen fertiliser needs.

Many mixed farmers have also used forage legumes such as lablab, medic and lucerne to improve the nitrogen status of their soils. These are good options but, with the possible excep-

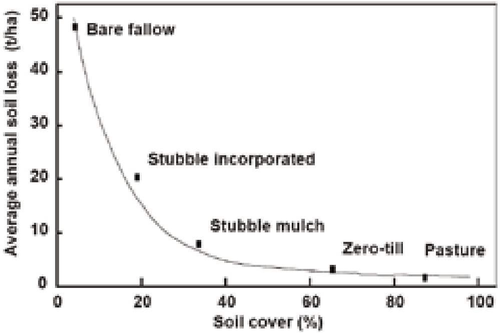

Figure 2. Effects of level of soil cover on erosion of soil.

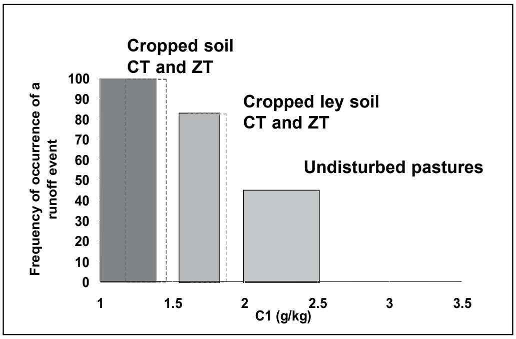

Figure 3. Effects of soil organic matter level on water infiltration and runoff/erosion.

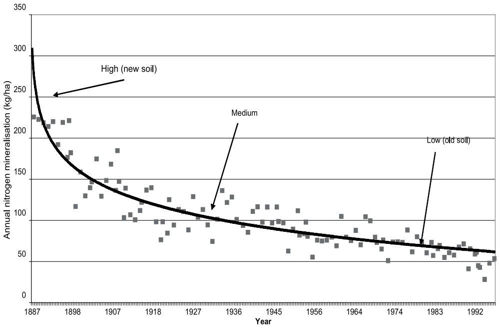

Figure 4. Effects of duration of cropping on level of soil N mineralisation.

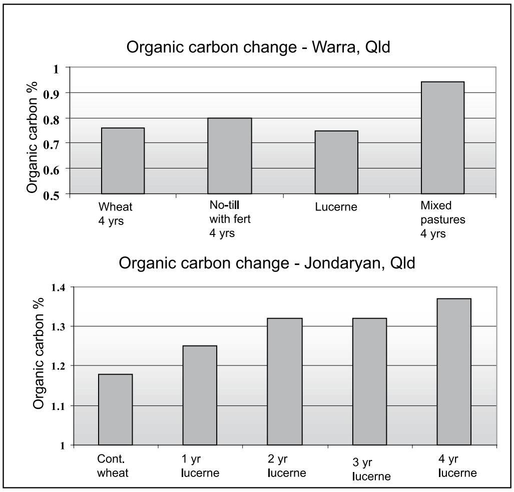

Figure 5. Effects of different cultural practices on soil organic carbon levels.

tion of lucerne, provide only short-term relief, as they rarely have much impact on total soil organic matter levels (Figure 5). Fortunately, mixed grass-legume pastures can both fix atmospheric nitrogen and rebuild soil organic matter levels. This option will become more attractive, especially on soils with physical constraints (*e.g*. hard-setting), as the challenges of climate change and rising oil costs drive fertiliser prices higher.

Finally, a healthy soil maintains a pH that can support plant growth and avoids toxic levels of nutrients, trace metals and pesticides. Again, increased soil organic matter helps 'buffer' soils to reduce acidification and can bind toxic nutrients such as aluminium to stop them becoming toxic.

Biological functions of a healthy soil

Soil health is more than biology. However, soil biology, and especially soil organic matter, is critical as it drives many of the other processes that keep soils healthy and productive. In the rest of this paper we will introduce the basic concepts of soil organic matter and some local data on the potential to sequester carbon with pastures. Later speakers will explore soil organic matter, soil carbon and carbon sequestration in much more detail.

Carbon sequestration for a healthy soil

It may be too hot and too dry to sequester enough carbon on our cropping soils to make money out of carbon trading. We may sequester some carbon, but the cost of measuring any change is greater than the gains we can make at current prices. Yet, we have seen that sequestering carbon will improve the health of our soils. Soils with high organic carbon levels are more fertile and more capable of responding to good seasons. This will be important in managing climate change, especially as our soil carbon levels normally decline with continuous cropping.

Soil organic matter and carbon

There is no critical level for organic carbon in our soils…more is usually better.

One tonne of soil organic carbon represents 1.7 tonnes of soil organic matter. Most grain cropping soils in Queensland and northern New South Wales contain 0.5-2.5% total organic carbon in the top 10 cm of soil. That represents 5-25 t/ha of organic carbon, or 8-40 t/ha of organic matter!

Be careful when measuring soil organic carbon and use only accredited laboratories. Big errors in measuring organic carbon and claims of huge rates of carbon sequestration have been mistakenly made by people failing to account for naturally occurring calcium carbonate in our soils. This inorganic carbonate is included in total soil carbon measures and failure to correct for it will suggest rates of soil carbon sequestration that really are just ‘too good to be true’.

The quality of soil organic carbon

Expect to hear about 3 main types of soil organic carbon in the future: the labile ‘particulate’ fraction, which breaks down over years to provide food and energy for microbial activity; the ‘humus’ fraction, which breaks down over decades to release nutrients such as nitrogen; and the ‘resistant’ charcoal fractions, that break down very little over centuries. Results from 200+ cropping soils in north-west NSW, that were analysed as part of the ‘Healthy Soils for Sustainable Farming’ project, showed that particulate carbon averaged 26% of the total organic carbon, while naturally occurring charcoal averaged 13%. Mike Bell’s paper (Bell and Lawrence 2009) will further explore the contributions of these fractions and the big role that pastures can play in their long-term management.

Soil organic carbon under grain and cotton crops

The recent ‘Healthy Soils’ project helped people across Queensland and northern NSW assess the quantity and quality of their soil organic carbon. For example, 240 people have compared the organic carbon of their main cropping soil with that in a reference soil of pasture on their farms. The examples in Figure 6 show that most of our long-term cropping soils have lost a considerable amount of the soil organic carbon that they had under native vegetation. This decline of 5-10 t/ha of soil organic carbon (or 8-17 t/ha of organic matter) reduces the soil’s ability to support biological activity and supply nutrients such as nitrogen to our crops. As a guide, each 0.1% change in soil organic carbon on a soil test (or 1.7 t of good-quality soil organic matter) may contain up to AUD 200 worth of nitrogen, phosphorus and other nutrients.

The cost of replacing these nutrients highlights the capital value of our soils and the contribution our soil organic carbon makes to profitable farming. This decline is not the ‘end of the world’, but it means our soils will be less resilient and we have less margin for error in managing infiltration and storing soil moisture, crop nutrition and soil-borne pests. For example, we will need to get our nitrogen fertiliser right, or put more on during the growth of the crop when seasons are good.

Why does soil organic carbon decline with cropping?

Soil organic carbon levels usually decline from their native levels when we grow annual grain or cotton crops because:

- Annual crops produce less dry matter than perennial native systems. Our fallows store only 20-25% of the rainfall. Most of our rain is lost as evaporation and grows little that contributes dry matter back to the soil.
- Cultivation breaks up soil aggregates and exposes organic carbon to decomposition.
- Erosion removes surface soil that is rich in organic carbon.
- Fallowing to retain soil moisture keeps the soil moister, which leads to more decomposition of soil organic carbon over summer than native systems that keep the soil dry.

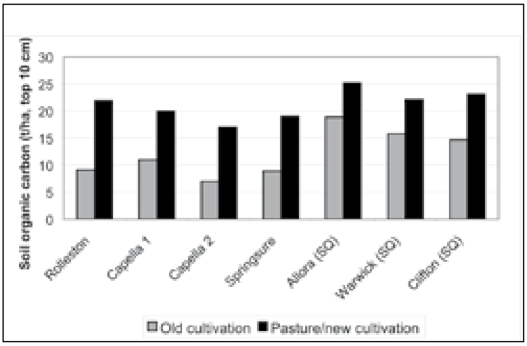

Figure 6. Soil organic carbon levels under crops and pastures at sites in central and south Queensland.

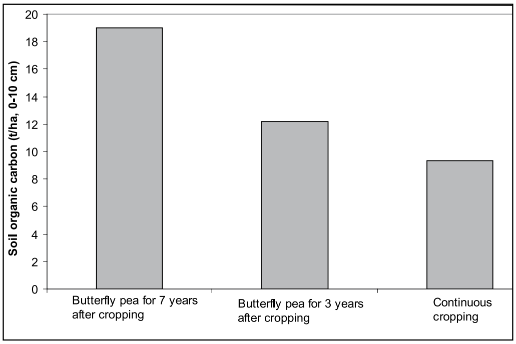

Figure 7. Soil organic carbon levels under grass-butterfly pea pastures compared with continuously cropped soil.

- Crop species break down faster and have less extensive root systems than native species.
- We harvest and remove product for sale.

Soil organic matter levels will reach a new lower 'equilibrium' under cropping, where the dry matter inputs equal the continuing decomposition of organic matter by soil biota. The amount of dry matter returned to the soil is a key driver of soil organic matter declines in Australian cropping systems. Hence, regular burning, removal of residues for feed, or harvesting whole plants for biofuel will lead to a lower soil organic matter than maintaining stubble with zero tillage and using fertilisers to grow higher-yielding crops.

Ways to increase and maintain soil organic carbon

Soil organic carbon levels will increase if organic carbon is added at a faster rate than the microbes are breaking it down. The microbial populations then increase and provide more benefits to our crops. However, these higher populations break down more organic carbon and so it gets harder to maintain these high levels. We have to keep adding the extra carbon to maintain the system. We can maximise the amount of dry matter returned in cropping systems by growing as many good crops as we can, maintaining our stubble, and never burning or baling stubbles. Green manure crops help but break down very quickly and so we have to keep using them to maintain levels. We can also add charcoal or other 'Char' products. While they lift the soil carbon levels, they are relatively inert and do little to improve the soil.

Research confirms the best strategy to build soil organic carbon is to grow perennial pastures that have extensive root systems and produce more dry matter. Data from the 'Healthy Soils' project again shows what is possible. For example, Figure 7 shows the steady improvements in total soil organic carbon from 3 years and 7 years of a mixed pasture of grass and butterfly pea near Emerald. These pastures showed similar proportional increases in total nitrogen and microbial biomass, and these nutrients will be of great value to future crops.

Conclusion

The use of pastures in cropping systems will depend on the profitability of grazing and how it compares with grains. In mixed farming systems, a good pasture can lift the more labile soil organic carbon fractions that will later break down and benefit subsequent crops. However, remember that the increase in soil organic carbon depends on how much dry matter is produced, and poor pastures will be of little benefit to either your soil or future crops. Therefore, grow good pastures to maximise the benefits and continue to use current best practices such as zero-tillage to maintain soil carbon levels for as long as possible when you return to cropping.

References

Bell, Mike and Lawrence, David (2009) Soil carbon sequestration – myths and mysteries. *Tropical Grasslands*, **43**, 227–231.