Managing soil biological decline during long-fallows in cropping systems

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Abstract
No-till farming in Australia has revolutionised the way many farmers crop. Some of the moisture retention advantages of no-till farming have resulted in a reduced reliance of in-crop rain as well as increasing yields and profitability. Less clear is the effect on biological properties.

Early results of a survey of the no-till cropping soils of the central west of NSW showed that most no-till cropping areas have lower soil carbon levels and lower microbial activity than nearby uncropped soils. This indicates that many no-till cropping soils may not be as sustainable as first thought. A long-fallow field trial was conducted on "Magomadine" near Coonamble NSW Australia using surface applied amendments (straw, compost, feedlot manure, biochar and zeolite) to investigate their effect on biological, chemical and physical soil properties. Early results are suggesting that the application of 10t/ha of straw can significantly ($P < 0.05$) increased soil moisture (24%), microbial respiration (50%), microbial biomass (21%), and mean weighted diameter of soil aggregates (75%). This research has highlighted the importance that high stubble residues have in improving these soil properties during a long-fallow.

Key Words
Mulch, soil health, amendments, cover crop.

Introduction
Soil health is the result of complex interactions between chemical, physical and biological soil properties. Biological activity is linked to increased levels of nutrient recycling, retention and release (Foissner 1999; Osler 2007), disease suppression (Deacon 2006; Hodda *et al.* 1999; Yeates and Wardle 1996) and higher aggregate stability (Tisdall 1991) resulting in greater moisture infiltration (Bissonnais, Renaux and Delouche 1995). There is a general interest by farmers to regain or improve the biological properties of their soils to maintain an ecologically sustainable farming practice.

Different agricultural management practices such as tillage, stubble management, crop rotation, and nitrogen fertilisation have the potential to change some soil biological properties such as carbon mineralisation and microbial biomass (Pankhurst *et al.* 1995). Despite the many benefits that no-till has on many soil properties it has inconsistent effects on soil biological properties (Bell *et al.* 2006; Simpfendorfer *et al.* 2001; Watt, Kirkegaard and Passioura 2006).

During an extensive study of cropping soils in northern Australia, Bell *et al.* (2006) found that no-till farming did not consistently raise the level of microbial biomass compared to near by uncropped soil. They postulated that the common practice of long-fallow may be detrimental to microbial populations. Long-fallow is a practice of stopping plant growth over a long period to allow moisture to build up for use by the following crop.

Holland and Coleman (1987) have suggested that surface applied amendments might improve several soil properties. Organic materials contain carbon which is an important food source for soil microbes. During a long-fallow there may be a reduction in organic material available as a food and energy source for microbes This paper will present early findings from a farm soil survey in central west New South Wales and from a field trial near Coonamble in NSW that may indicate the potential to improve biological properties that are reduced during a long-fallow.

Methods
Farm survey
Soil samples from the top 0-5cm were taken on 20 farms in the Central West NSW during 2008 and 2009. Physical, chemical and biological properties were analysed at the University of New England and the commercial laboratories at the Southern Cross University and the Lismore Soil Foodweb.

Field trial
A split-pot field trial was established on cropping soil on “Magomadine” Coonamble in northern NSW. “Magomadine” has a temperate climate with **latitude** 30.98°S and **longitude** 148.38°E. The trial site is situated on a clay loam vertosol with 16 treatments replicated three times. The 16 treatments were divided into four major treatments, three of which had either the equivalent of 10 t/ha of barley straw, feedlot manure or farm made compost surface applied to them while the fourth treatment did not receive any organic amendment. Each major treatment was further subdivided into 4 sub plots which received the equivalent of 6t/ha of biochar, 6t/ha zeolite, both 3t/ha biochar and 3t/ha zeolite or no amendment (control) as a surface application. The trial was sprayed with herbicides to simulate fallow and to investigate the influence of the amendments on soil biological properties during a long-fallow phase.

Microbial respiration and biomass methods:
CO_2 evolution from soil (70-75% field capacity moisture) was measured in an electronic respirometry system (Respicond III, Nordgren Innovations) at 20°C. Basal respiration rate was measured over 2 days and microbial biomass was determined by the Substrate-Induced Respiration method (Anderson and Domsch 1978). Samples for total soil fungi, total soil bacteria and soil nematodes were sent to the SoilFoodWeb laboratories at Lismore NSW for analysis.

Physical and chemical methods
Total carbon and Total nitrogen were measured using a mass spectrometer (Nitrogen/Carbon/Sulphur analyser Carlo Erba NA 1500). Colwell P was measured using a spectrophotometer (Biochrom Libra S11) at 630nm and CEC measurements were taken with an ARL 3560B ICP-AES (Inductively Coupled Plasma-Atomic Emission Spectrometer). Mean Weighted Diameter (MWD) was determined by dry sieving, weighing the aggregates retained by the individual sieves and calculated by using the formula

$$MWD = \sum_{i=1}^{n} x_i w_i$$

Results and discussion
The survey results indicated that cropping may generally lower respiration (up to 55%) and microbial biomass (up to 61%) in the top 0-5 cm of soil (Table 1) within the central west of NSW. The results also indicated that it is the fungal part of the microbial population that is most affected by cropping (Table 2) with values of total fungi lower by 49% on cropped compared to uncropped soil.

Table 1. Results of respiration and microbial biomass on 5 farms in Central West NSW during 2008 and 2009.

Land Use	Respiration ($mg\ CO_2$/hr/100 g DM soil)		Microbial Biomass (mg Microbial Carbon/100 g DM Soil)	
	2008	2009	2008	2009
Cropped soil	0.311	0.169	43.8	33.5
Uncropped Soil	0.687	0.327	111.0	61.4
LSD (P = 0.05)	0.262	0.120	32.4	19.4

Table 2. Results of a survey of 20 farms in Central West NSW during 2008 and 2009.

Land Use	Total Carbon (%)		Nematode (no./g DM soil)		Total Fungi (μg/g DM soil)	Total Bacteria (μg/g DM soil)
	2008	2009	2008	2009	2009	2009
Cropped soil	1.306	1.441	7.97	11.4	65.6	474
Uncropped Soil	2.166	2.469	10.04	4.0	128.7	488
LSD (P = 0.05)	0.258	0.313	3.56	4.8	30.1	90

These results indicate that the change in land use to cropping can have an adverse effect on both soil carbon and microbial populations. Bell *et al.* (2006) found similar results in southern Queensland. They found that a change from native grasses to cropping near Jimbour in Queensland reduced microbial biomass by 45%, microbial activity by 52% and total organic carbon by (55%) in the 0-5 cm soil layer.

Modern no-till farming practices involve spraying of weeds post harvest until the next crop is planted. This period of fallow can be five to seven months in between winter crops or as long as12-18 months in changing from a winter to summer crop.

Table 3. Effect of organic amendments on certain soil properties during a long-fallow phase in no-till cropping paddock near Coonamble NSW. Significant results (P = 0.05) are indicated by values being assigned different letters across treatments.

Parameter (0-5cm)	Straw	Compost	Manure	Control
Soil Moisture (%)	34.92a	29.19b	28.44b	28.14b
MWD (mm)	2.54a	1.44b	1.62b	1.45b
Respiration (mg CO_2/hr/100 g DM soil)	0.3607a	0.2628b	0.2516b	0.2393b
Microbial Biomass (mg MC/100g DM soil)	44.64a	40.78b	37.83b	36.92b
Soil pH	6.9	6.9	6.8	6.9
Total N (%)	0.12	0.13	0.13	0.12
Total C (%)	1.06	1.12	1.10	1.03
C:N ratio	8.9	8.8	8.5	8.4
Colwell P ppm	64	87	108	72
CEC (cmol/kg)	55	55	53	54
Sodium (cmol/kg)	2.16a	1.862b	1.613b	1.697b
Calcium (cmol/kg)	41	41	39	40
Potassium (cmol/kg)	3.9	3.7	3.9	3.8
Magnesium (cmol/kg)	8.7	8.8	9.1	8.7
Aluminium (cmol/kg)	0.0094	0.012	0.013	0.011

The results of surface applications of amendments on a long-fallow no-till farming paddock show that straw is superior to compost or manure in improving several soil parameters (Table 3).

Manure did significantly (P = 0.002) increase Colwell P by 49% but did not significantly increase the other physical and biological soil properties in this cropping soil during a long-fallow (Table 3). Rasool, Kukal and Hira (2008) found that application of manure at 20 t/ha to a maize crop increased MWD by 79% and water holding capacity by 21% in 0-15 cm soil layers. Altieri (1999) found that it did result in increased collembola populations and increased abundance and biomass of earthworms in cropping soils.

Compost in this research did not have any significant effect on the physical, chemical and biological properties (Table 3). This contrasts with findings by Adeli *et al.* (2007) that showed applying 6 t/ha of compost, in the form of broiler litter, three times over three years on a no-till farm significant increased phosphorus, total nitrogen, microbial biomass and structural stability in the 0-15 cm soil layer.

The straw at a rate of 10 t/ha in this trial resulted in a significant increase in soil moisture by 24% ($P < 0.001$), microbial respiration by 50% (P = 0.013), microbial biomass 21% ($P < 0.001$) and in mean weighted diameter of soil aggregates by 75% (P = 0.02). There was also a significant rise in sodium levels (Table 3). These results are similar to that reported in the literature on the effect of cover cropping on chemical, physical and biological properties (Price and Castor 2007; Blanchart *et al.* 2006; Wang *et al.* 2008).

The change in land management from open grasslands to continuous no-till cropping may have some downsides to some soil biological properties. The results from the soil surveys of the central west NSW have indicated that total carbon, microbial biomass and respiration seem to decline in cropping soils compared to near by grasslands. It seems that it is fungal rather than the bacterial populations that are most affected. This may be due to the reduction of surface mulch in cropping soils reducing food and energy sources for microorganisms.

Conclusion

The early stages of this research are indicating that while compost and manure had little effect on restoring certain soil properties, it is possible that high rates of straw (or stubble cover) is influential in raising the level of microbial activity and biomass, moisture retention and soil structure. It is important though to monitor the possible rise in sodium levels. Subsequent research will be investigating any differences between treatments when plants are actively growing. This early research is indicating that it is possible to raise the level of microbial activity and abundance in no-till farming systems when a long-fallow phase is used.

While most of the no-till farmers surveyed retain their stubble it appears that there may be a need to increase the amount of retained surface mulch to address possible soil biological decline. This research is suggesting that no-till farmers may be able to start improving several soil biological properties by concentrating on improving their stubble management and treating stubble as an asset. This may be achieved by stubble mulching of stubbles or the growing of cover crops and rolling them to produce thick mulch layers before entering into a long-fallow. This should result in the maintenance of soil quality, productivity and sustainability in no-till farming systems.

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