Carbon Dynamics in Organic Production Systems

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Abstract
Carbon accumulation and biological activity is being monitored for organic production systems of intensive vegetable production, broad acre arable farming, beef grazing and for uncultivated virgin soil at two depths (0-10 cm, 10-20 cm). The organic matter content and biological activity decreased with increasing soil depth. The total and bioavailable carbon levels, basal respiration and substrate induced respiration were higher under organic production systems than for virgin soil. All these values were higher for vegetable production than for the other two systems. The difference among organic production systems was more pronounced for basal respiration than for substrate induced respiration. The higher carbon levels and biological activity in soils under vegetable production is attributed to the copious application of organic compost to this system. Carbon dynamics of these systems will be monitored in the long term.

Key Words
Basal respiration, substrate induced respiration, organic farming, organic carbon

Introduction
In many countries including Australia and New Zealand, there has been increasing interest in organic production systems. In Australia, the growth in organic production is estimated at 15-25% annually and is expected to continue because of strong domestic demand and also because of Australia's ability to supply expanding markets overseas, especially in Asia (Alexandra and May 2004). While the economic prospects can be promising for Australian organic production, many growers face particular challenges due to high climatic variability, inherent low soil fertility soil and large distance between farm and input sources (Malcolm *et al*. 1996).

Organic farming systems are generally characterised by an ecological management system that aims to promote and enhance biodiversity, biological cycles (nutrient cycles) and soil biological activity (Kristiansen and Merfield 2006). Soil biological health is a central principle of organic agriculture and is vital to sustainable agriculture (Widmer *et al*. 2006). Soils under organic production systems are generally rich in organic matter and biological activity (Drinkwater *et al*. 1995; Marinari *et al*. 2006; van Diepeningen *et al*. 2006). However, this is not always the case with findings indicating no difference in soil biological activity between farming systems such as conventional, organic and biodynamic (Burkitt *et al*. 2007; Nachimuthu 2008; Penfold *et al*. 1995; Watson *et al*. 2002b). Soil biological properties were also strongly influenced by crop management practices rather than type of farming system as a whole (Nachimuthu 2008). Large quantities of organic compost are used in vegetable production systems in Australia including organic production systems as a source of nutrients and also to enhance the physical and biological fertility of soils (Chan *et al*. 2008; Wells *et al*. 2000). In contrast, the broad-acre organic production system receives low inputs and soil fertility levels decline so that the sustainability of the farming system is being questioned (Penfold 2000).

With this in view, an investigation was initiated to study the carbon dynamics on a fully certified organic farm in western Victoria which has multiple enterprises of intensive vegetable production, broad acre arable farming and beef grazing and uncultivated virgin soil. The aim of this study is to compare carbon accumulation and biological activity between these production systems in long term. The present paper discusses the preliminary findings of this study.

Methods and materials
Soil samples
Soil samples were collected at two depths (0-10 cm and 10-20 cm) from various organic production systems viz., vegetable production, broad acre arable farming and beef grazing systems and for uncultivated virgin soil during January 2009. The farms are located near Minimay, Victoria 36.72 ^{o}S, 141.18 ^{o}E. Soil is acidic with pH of about 5.5. Farms were converted to organic production system 5 years ago. The broad-acre area was pastureland until 2007. Three samples from each system were taken. The samples were air dried, ground and passed through a 0.2 mm sieve for the analysis of total and bioavailable organic carbon contents.

Organic matter and biological activity measurements
The total organic matter and bioavailable or easily degradable organic matter contents were measured by loss on ignition and dichromate oxidation methods (Blakemore *et al*., 1977)
Biological activity was monitored by measuring basal respiration and substrate induced respiration (respiratory response on the supply of glucose) (Anderson and Domsch 1978). Soil was broken in small clumps and stones, large invertebrate animals, stones and roots were removed before the soil moisture was adjusted to approximately 75% field capacity where microbial respiration is optimal. The moistened sample was incubated in air tight respiration jars at 25 ^{o}C for two days and then CO_2 evaluation was measured. These respiration rates were measured by trapping the evolved CO_2 from soil samples using 0.05M NaOH. The amount of CO_2 trapped was measured by back-titration with 0.03M HCl.

Sodium hydroxide solution has an affinity for CO_2. It is absorbed and forms sodium carbonate in solution.

$$2NaOH + CO_2 = Na_2CO_3 + H_2O \qquad (1)$$

This equation indicates that one mole of CO_2 combines with 2 moles of NaOH
The mixed solution of Na_2CO_3 and NaOH cannot be titrated directly with HCl because both would react. Barium chloride is added to precipitate the carbonate.

$$Na_2CO_3 + BaCl_2 = BaCO_3 + 2NaCl \qquad (2)$$

Because the solution in the flask remains alkaline until the end point is reached, the barium carbonate does not react with the acid. Thus the acid only reacts with the residual NaOH.

$$NaOH + HCl = NaCl + H_2O \qquad (3)$$

This equation indicates that one mole of HCl reacts with one mole of NaOH. Thus the moles of acid used for titration gives the moles of NaOH remaining after absorption of CO_2.

Results, discussion and conclusion
The organic matter content and biological activity as measured by basal and substrate induced respiration for the virgin soils and soils collected from various organic production system (Table 1) indicated that organic matter content and biological activity decreased with increasing soil depth which could be linked to the higher amount of organic matter available in top soil (Ge *et al*. 2010). The total and bioavailable carbon levels, basal respiration and substrate induced respiration were higher under organic production systems than virgin soil. These values were higher under vegetable production than for the other two systems. The level of activity and size of the microbial biomass may differ according to the management practices that have been used (Bulluck *et al*. 2002; Toyota and Kuninaga 2006). The organic production systems received off farm organic inputs such as organic compost and composted manure which could be the reason for higher biological activity than for virgin soil.

The substrate induced respiration was higher than basal respiration and there was a greater difference with land use in the later than the former, indicating that biological activity was limited by bio-available carbon in the soils. The higher substrate induced respiration than basal respiration indicates that the indigenous soil microbial population can readily adapt and multiply with respect to changes in soil environment such as addition of organic or inorganic amendments (Nachimuthu 2008). While the results are from an early phase of investigation and only the long term study will help us to state categorically which system is better, the observed difference or lack of difference in soil biological activity among different farming systems in this study might be attributed to the length of time the farms has been under organic management (Monokrousos *et al*. 2006; Zaller and Kopke 2004) together with the nutrient content and quality (Marinari *et al*. 2006; Shepherd *et al*. 2002; Stockdale *et al*. 2002) and quantity of organic matter added (Watson *et al*. 2002a). The increases in the accumulation of carbon and biological activity in soils under vegetable production in this study is attributed to the copious application of organic compost and composted manure to this system. This confirms the earlier findings that vegetable production system in Australia receive higher inputs to enhance soil fertility (Chan *et al*. 2008; Wells *et al*. 2000) and that there is large difference in soil carbon status between broad-acre and vegetable production systems.

Table 1. Organic matter content and biological activity for soils under various systems

Soil	Depth (cm)	Total organic matter (g/kg soil)	Bioavailable organic matter (g/kg soil)	Basal respiration (g CO_2/mg soil/min)	Substrate induced respiration (mg CO_2/g soil/min)
Virgin soil	0-10	2.38	0.82	8.91	23.3
	10-20	1.02	0.47	3.41	7.81
Vegetable	0-10	10.22	3.35	42.3	123.1
	10-20	7.28	2.11	34.2	87.5
Grazed beef	0-10	6.23	1.98	15.6	75.6
	10-20	2.12	0.89	7.81	17.6
Broad acre	0-10	4.21	1.14	11.2	35.3
	10-20	1.23	0.75	2.54	11.2

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