Long term effect of stubble burning on soil carbon levels and wheat yield in southern New South Wales

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Abstract

In Australia, stubble burning and excessive tillage are the two major processes responsible for decline of soil organic carbon levels in the cropping soils and the resulting soil degradation problems. However, the relative importance of the two in controlling the soil organic carbon (soc) level and the long term impact on soil health/productivity are not known. The effects of wheat stubble burning as practised by farmers in south eastern Australia were evaluated in two agronomic trials in southern New South Wales. Three tillage passes under conventional tillage practice led to far greater loss than stubble burning. Loss of soil organic carbon attributed to stubble burning was 1.75 C t/ha (0-10cm) in the 19 years trial, equivalent to 23 % that the total loss. In the 5 years trial, no change in soc due to stubble burning was detectable. Changes in soil quality due to stubble burning included reduction in macroaggregate stability, increases in pH and exchangeable K. Averaged over 19 years, higher wheat yield of 0.15 t/ha was also observed under stubble burning. Research to identify conditions of stubble burning when soc loss is minimised is needed.

Media summary

Loss of carbon due to stubble burning is small (<1/4) compared to 3 passes tillage. However, changes in soil quality highlight further research needed to identify optimal burning strategies.

Key Words

Wheat stubble, tillage, cool burn, soil carbon sequestration, greenhouse gases, labile carbon

Introduction

In Australia, traditionally burning of wheat stubble has been popular with farmers for controlling disease and making planting easier. However, stubble burning and excessive tillage have been identified as the two major processes responsible for the decline of soil organic carbon levels and the resulting soil degradation problems observed in the cropping soils. The relative importance of the two in reducing soil organic carbon of the cropping soils is not known.

Burning of stubble can potentially result in changes in a whole range of soil physical, chemical and biological properties, including pH, soil organic carbon, nutrient availability, infiltration and microbial activities, with long term implications on sustainability (Walker et al. 1986). Recently, burning of stubble has also been identified as a significant emitter of greenhouse gases in agriculture and therefore stubble retention can be a way of increasing soil carbon sequestration and possible control of global warming (Lal et al. 1998). Better knowledge of the long term impact of stubble burning on soil carbon level, soil properties and crop yield is important for making better decisions on more sustainable management of stubble under cropping systems.

This paper reports the results of two field trials in southern New South Wales with factorial design where the individual tillage and stubble management effects and their interactions on soil organic carbon levels can be analysed. In addition, the resulting impacts on soil quality and wheat yields were also investigated.

Methods

Two field trials (Wagga Wagga and Temora) included in this investigation were located in southern New South Wales (Table 1).

Table 1. Background information for the two field trial sites

	Location	Rainfall , mm	Soil type	Trial duration, yr
Wagga Wagga	35^0 05'S, 147^0 0'E	554	Kandosol	19
Temora	$34^0$27' S, $147^0$32'E	535	Sodosol	5

Both trials were factorial experiments, completely randomised blocks with stubble management and tillage as main treatments. Stubble treatments included stubble retention (sr) and stubble burnt (sb). The tillage treatments were no-tillage (NT) (no cultivation prior to sowing) and conventional tillage (CC) (three cultivations). Cultivation was carried out to about 0.1 m using offset tandem disc harrows in the stubble retained treatments, and scarifiers in the stubble burnt treatments. A wheat-lupin rotation was practised at each trial site (with phased entry) and only the wheat stubble was burnt. Following the farmers' practice, 'cool burn' was carried out - stubble was kept on the soil surface after harvest for erosion protection during summer fallow and was burnt in autumn after significant break and only after fire ban was lifted.

Soil sampling and analyses

Composite soil samples were collected from the four stubble/tillage treatments from both sites, namely NT/sr, NT/sb, CC/sr and CC/sb. At each site, bulk density of the sampled layers was determined by the core method. At the time of sampling, Wagga Wagga trial was 19 years old whereas Temora trial was 5 years old. Total carbon was determined using a Leco[R] Carbon Analyser (Nelson and Sommers 1982). Water stable aggregation was determined using wet sieving method***.*** Percentage of water stable aggregate >250 µm (%A250) was calculated and used as a measure of macro-aggregate water stability of the soil. The <2mm soil fractions were analysed for pH and exchangeable cations following Raymont and Higginson (1992).

Wheat yields

Wheat grain yield of each plot was measured by cutting a 1.8 m strip in the centre of each plot.

Results and Discussion

Soil organic carbon

For the Wagga Wagga site, analyses of variance of total carbon levels indicated significant tillage and stubble effects but no interaction for 0-5, 5-10 and 10-15 cm layers. Soil carbon levels were significantly higher under no-till than conventional till and higher under stubble retained than stubble burnt. However, the differences were most pronounced in the 0-5 cm layer. For the Temora site, only a significant tillage effect in the 0-5 cm layer but not stubble effect nor interaction was detected. The magnitude of difference was much smaller than those observed at the Wagga Wagga trial for the same layer.

Table 2. Soil organic carbon storage in 0-10 cm layer (t/ha) under different tillage and stubble management in the two field trials (Wagga Wagga and Temora).

Tillage	Stubble	Wagga	Temora

NT	sr	25.4	22.3
	sb	24.1	23.0
CC	sr	19.9	20.5
	sb	17.7	20.9
$lsd_{tillage}$		1.5	0.8
$lsd_{stubble}$		1.5	ns
$lsd_{stubble*tillage}$		ns	ns

Total carbon storage to 10 cm depth results indicates significant tillage and stubble effects but not their interactions for the Wagga Wagga site (Table 2). The highest carbon storage was found in NT/sr (25.4 t/ha) and the lowest in CC/sb (17.7 t/ha). However, the magnitude of difference due to tillage (5.95 t /ha) was much higher than that due to stubble (1.75 t/ha). For the Temora site, total carbon storage was similar between stubble burnt and stubble retained. The present results suggest that burning of stubble results in much smaller loss in soil organic carbon when compared to three tillage passes. In the Wagga Wagga trial, soil organic carbon loss after 19 years of burning stubble was 1.75 t/ha and equivalent to only 22.7 % of total carbon loss detected in the CC/sb treatment when compared to NT/sr treatment. In the Temora trial, no loss of soil carbon due to stubble burning for 5 years when compared to stubble retention was detected. Differences between the two sites could simply be due to the different durations of the two trials (19 vs 5 years).

Soil quality

For the Wagga Wagga site, macroaggregagte stability of 0-5 cm layer was significantly affected by tillage, stubble as well as their interaction (Table 3a). The significant interaction indicated that stubble burning reduced macroaggregate stability under no-tillage but not under conventional tillage. For the Temora site, only significant tillage effect was found where no-till soil had significantly higher macroaggregate stability than conventionally tilled soil (Table 3b).

Table 3. Soil quality parameters under different stubble and tillage management practices in the (a) Wagga Wagga and (b) Temora field trials

Wagga Wagga (0-5 cm)

Tillage	Stubble	Total C, g/100g	pH	%A_{250}	CEC	Ca	Mg	K	Al
							cmol kg^{-1}		
NT	sr	2.29	4.78	46.6	6.56	4.45	0.99	1.05	0.07

	sb	2.12	5.00	35.7	6.50	4.12	1.04	1.34	0.00
CC	sr	1.67	4.70	38.2	5.15	3.06	0.76	1.15	0.20
	sb	1.49	4.93	33.1	5.06	3.06	0.81	1.12	0.09
$lsd_{tillage}$		0.14	Ns	2.2	0.49	0.50	0.07	ns	ns
$lsd_{stubble}$		0.14	0.15	2.2	ns	ns	ns	0.08	ns
$lsd_{stubble*tillage}$		ns	Ns	3.3	ns	ns	ns	0.11	ns

(b) Temora (0-5 cm)

Tillage	Stubble	Total C, g/100g	pH	$\%A_{250}$	CEC	Ca	Mg	K	Al
							cmol kg^{-1}		
NT	sr	1.83	4.98	57.4	6.41	4.57	0.77	0.95	0.09
	sb	1.91	5.13	56.9	6.61	4.39	0.81	1.26	0.06
CC	sr	1.55	4.77	46.3	5.15	3.44	0.58	0.88	0.21
	sb	1.60	4.80	45.1	5.48	3.56	0.71	0.96	0.20
$lsd_{tillage}$		0.13	0.10	3.6	0.84	0.57	ns	ns	0.05
$lsd_{stubble}$		ns	0.08	ns	ns	ns	ns	0.17	ns
$lsd_{stubble*tillage}$		ns	Ns	ns	ns	ns	ns	ns	ns

Stubble burning did not affect macroaggregate stability at the Temora site. Stubble burning significantly increased pH of both Wagga and Temora soils. For Wagga Wagga, an average increase in pH of 0.23 (4.97 for stubble burnt compared to 4.74 for stubble retained) was found. For the Temora soil, the corresponding increase in pH (0.09) was smaller. Furthermore, a significant higher level exchangeable K was found in the stubble burnt soil at both sites.

Wheat yield differences

Significant tillage and stubble effects but not their interaction on wheat yield were found at the Wagga Wagga site (Table 4).

Table 4. Average wheat yield (t/ha) under different stubble and tillage management practices in the two field trials

Tillage	Stubble	Wagga Wagga (1979-1999)	Temora (1977-2001)
No-tillage	Sr	3.7	4.2
	Sb	3.8	4.2
Conventional	Sr	3.5	4.3
	Sb	3.7	4.4
$lsd_{tillage}$		0.1	ns
$lsd_{stubble}$		0.1	ns
$lsd_{stubble*tillage}$		ns	ns

Average wheat yield was significantly higher under sb (vs sr) and NT (vs CC). An average higher wheat yield of 0.15 t/ ha was found under stubble burnt compared to stubble retained and under no-tillage as compared to conventional tillage over 19 years. In contrast, no difference was found amongst the different tillage and stubble treatments at the Temora site. The increases in pH and K were direct results of the production of ash due to burning of the stubble and together with the often associated higher level of mineral nitrogen have been attributed as the causes of higher yield observed after burning. The higher yield observed under stubble burning in the Wagga Wagga site could also be due to disease control and the removal of causes of poor early growth often observed under stubble retention (Kirgergaard 1995). More information is needed on the longer term effect of stubble burning on soil quality and sustainability of the practice. Given the observed changes in carbon and associated soil quality parameters in the 19 year but not 5 year trial, therefore there is a need for continual monitoring of on-going long term field trials. Turpin et al. (1998) found that the highest nitrate loss due to leaching occurred under no-till, stubble burnt, hence suggesting the timing of burning is critical. Research is also needed to identify conditions where the practice can be strategically used with minimal adverse effects and maximal benefits.

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