# Will stubble management and stubble load affect soil organic carbon under cropping in the high rainfall zone of Victoria?

**Penny Riffkin**[1] and Fiona Robertson[2]

[1] Department of Primary Industries, Hamilton, Victoria, 3300, Australia Email penny.riffkin@dpi.vic.gov.au
[2] Department of Primary Industries, Hamilton, Victoria, 3300, Australia Email fiona.robertson@dpi.vic.gov.au

## Abstract

We conducted a modelling study to predict the likely change in soil organic carbon (SOC) under crop production at Dunkeld, Victoria with different methods of stubble management. The site had recently been converted from long-term pasture to crop and SOC was 70 t C/ha in the top 30 cm. The RothC model was used to run 25-year simulations using different methods of stubble management (90% removed (e.g. burnt), 75% removed (e.g. baled), 25% removed (e.g. grazed) and 0% removed (e.g. mulched)) and a range of stubble loads (1, 3, 5, 7 or 10 t dry matter/ha per year). SOC declined where stubble loads were less than 5 t/ha regardless of how the stubble was managed. Where crop stubble loads were consistently high (e.g 10 t/ha), SOC was at least maintained regardless of the method of stubble management. Such high stubble loads of 10 t/ha required average grain yields of at least 5.4 t/ha with a harvest index of 0.35 to be achieved.

We also investigated the effect of different starting levels of SOC with an average annual stubble load of 5 t/ha. At low starting SOC (35 t C/ha), SOC increased under all methods of stubble management, whereas with high starting SOC (95 t C/ha), SOC declined regardless of the way stubble was managed. Growers are likely to have flexibility in the way they manage stubble from year to year providing consideration is given to maintaining average stubble loads over a number of years.

## Key Words

High rainfall zone, soil organic carbon, RothC, stubble management

## Introduction

High crop yields in the High Rainfall Zone (HRZ) of southern Australia result in stubble loads in excess of 10 t dry matter/ha. Heavy stubble loads can harbour pests and disease as well as impede machinery during sowing the subsequent crop and thus reduce crop yields and profits (Scott et al 2010). Growers in the HRZ manage stubbles by burning, grazing, mulching or by leaving them standing and sowing the next crop between the stubble rows. These options for stubble management may have consequences for soil organic carbon (SOC) levels (Chan and Heenan 2005). Chan et al (2003) suggested that, whilst conservation farming (stubble retention and reduced tillage) is likely to have little effect on soil carbon in lower rainfall areas of Australia, there may be potential to sequester soil carbon under conservation farming in higher rainfall areas (>500 mm annual rainfall) where biomass production is greater. However, little work has been conducted on the effects of stubble management on SOC in the HRZ of south-eastern Australia.

The importance of SOC for soil health is well recognised e.g. in providing energy and nutrients for biological processes and improving structural stability and water retention (Baldock and Nelson, 2000). Soils under long-term pasture are often high in SOC and their conversion to cropping can result in large losses (Robertson et al 1994: Tiessen and Bettany 1982).

Over the past 10 years in the HRZ of south-west Victoria, significant areas of pastures have been replaced by annual crops. The method of crop stubble management in this region may thus be critical in minimising the decline in SOC levels. We conducted a modelling study to better understand the effects of stubble management on SOC and test the hypothesis that SOC will decline in a cropping regime where stubble is removed. The study was conducted at Dunkeld, Victoria, on a site considered typical of the district and which had been converted from long-term pasture to crop the previous year. Four methods of stubble management were chosen by growers to be used to predict the change in SOC under different stubble loads and under different starting levels of SOC.

**Methods**

The model used in the study was RothC version 26.3 and 26.5 (Coleman and Jenkinson 2005) in Excel format as modified by Skjemstad et al. (2004). Climate, soils and stubble management data were used to parameterise the model. Monthly meteorological data (minimum and maximum air temperature, rainfall, potential evaporation, PE) were obtained from the SILO database (www.bom.gov.au/silo/, 2008) over years 1889-2008.

Soil organic carbon was determined in the top 10 cm (as is normal practice by growers in the district) from ten soil cores taken from an area of 170 $m^2$. To convert the 0-10 cm carbon concentration to the 0-30 cm equivalent in t/ha (the international standard for carbon accounting (IPCC 2006), the 0-10 cm concentration was multiplied by a bulk density of 1.2 $g/cm^3$ and the empirical conversion factor of 1.97 as proposed by Valzano et al 2005. The clay content of the soil (20%) and the initial carbon distribution among the various pools were assumed to be as measured on a similar soil at Hamilton (Robertson 2008). These were 64% humified organic matter, 18% resistant plant material, 14% inert organic matter, 1% each of decomposable plant material and slow decomposing biomass and 2% fast decomposing biomass.

Stubble management treatments were defined by growers and comprised 90% stubble removed (e.g. burnt); 75% removed (e.g. baled), 25% removed (e.g. grazed), and 0% removed (e.g. mulched),

*Study 1 –The effects of stubble load on changes in SOC over time*

Stubble loads selected by growers were 1, 3, 5, 7 and 10 t/ha per year calculated from wheat grain yields with a harvest index of 0.35 with a root:shoot ratio of 0.43 and a carbon proportion of 0.45 in the dry matter. The model run was taken over a 25 year period.

*Study 2 – The effects of starting SOC on changes in SOC over time*

Starting SOC values used were 35, 59 and 95 t C/ha representing the range of SOC levels in the district from soil tests conducted by growers. The model run was for 500 years with results presented up to 100 years, by which time SOC had reached 90% of equilibrium levels under all treatments.

**Results and Discussion**

*Study 1 –The effects of stubble load on changes in SOC over time*

Changes in SOC from the starting value of 70 t C/ha range from a 27% reduction for the 1 t stubble load for the burnt treatment to a 47% increase for the mulched treatment with a 10 t/ha stubble load (Figure 1). Under a burnt regime, the simulation showed that stubble loads of at least 10t/ha would need to be achieved in every year to maintain SOC levels at the starting level of 70 t C/ha. Such stubble loads would require grain yields of at least 5.4 t/ha for wheat with a harvest index of 0.35 each year.

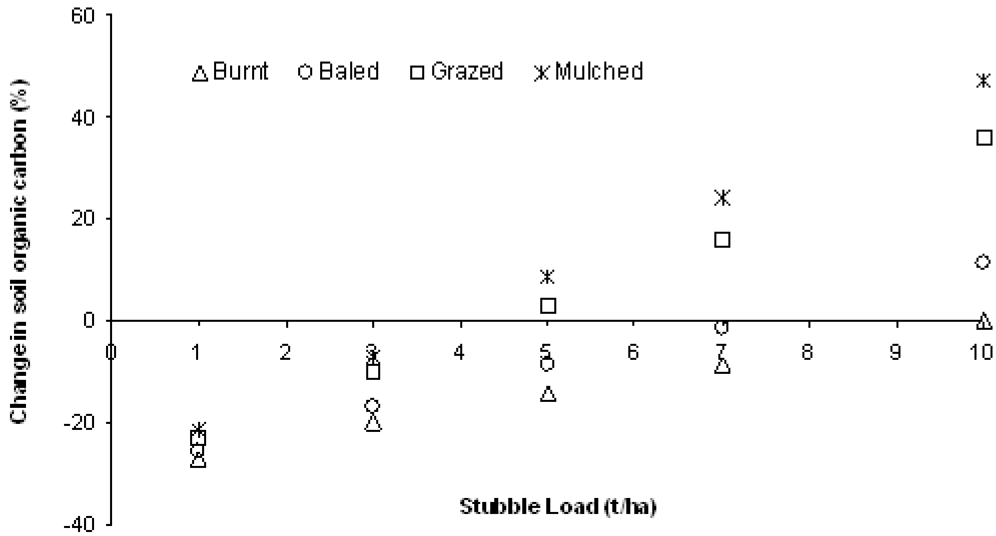


**Figure 1. Changes in soil organic carbon after 25 years from a starting level of 70 t C/ha (in the top 30cm) under four different stubble management regimes: 10% stubble retained (e.g burnt), 25% stubble retained (e.g. baled), 75% stubble retained (e.g. grazed) and 100% stubble retained (e.g. mulched). Modelled results use soil and historical climate data from Dunkeld, Victoria.**

Stubble loads of around 5 t/ha would be required under grazing or mulching at least to maintain SOC levels. Results suggest that, where loads are high in a particular year, growers may have flexibility in the way they manage stubbles and burning will not necessarily lead to a decline in SOC providing consideration is given to average loads over a number of years. It should be recognised, however, that other impacts of stubble load that may affect soil health and crop productivity such as soil erosion, pests and disease and nutrient availability are not specific inputs to the RothC model and should also be considered when deciding on a method of managing stubble.

*Study 2 – The effects of starting SOC on changes in SOC over time*

Soil organic carbon under stubble burnt or baled only increased where starting SOC was low (35 t C/ha). Soil organic carbon increased under both stubble mulched and grazed regimes (at least 75% of stubble retained) except where the starting SOC levels were high (95 t C/ha). The greatest increases in SOC relative to the starting level were at 35 t C/ha where stubbles were grazed or mulched (Figure 2).

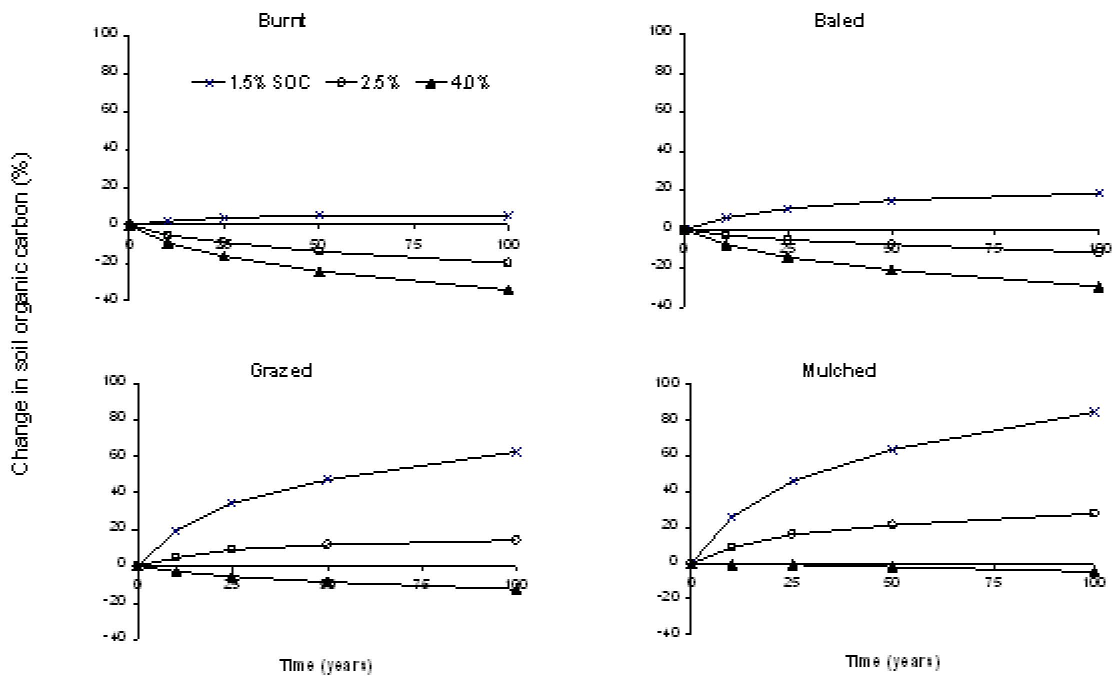


**Figure 2. Changes in soil organic carbon (% change) over time from three different starting levels, 1.5% (35 t C/ha), 2.5% (59 t C/ha) and 4.0% (95 t C/ha) under four different stubble management regimes; 10% stubble retained (e.g burnt), 25% stubble retained (e.g. baled), 75% stubble retained (e.g. grazed) and 100% stubble retained (e.g. mulched). Modelled results use soil and historical climate data from Dunkeld, Victoria.**

Loss of organic carbon from the soil was as high as 0.64 t/ha per year where starting SOC was 95 t C/ha and stubble was burnt. Gains of 0.65 t/ha per year were achieved from soils with the low starting SOC (35 t C/ha) and where 100% of stubble was mulched. SOC increased under all methods of stubble management at low starting SOC but decreased where starting levels were high. Soil organic carbon decreased under both burnt and baled treatments but increased when grazed or mulched where starting SOC was at medium levels (59 t C/ha) (Table 1).

**Table 1. Annual changes (t/ha per year) in soil organic carbon (SOC) in the top 30 cm under different starting SOC levels and stubble management regimes at Dunkeld, Victoria over a 25 year period with an average stubble load of 5t/ha.**

| Starting SOC | Burnt | Baled | Grazed | Mulched |
|---|---|---|---|---|
| 35 | 0.06 | 0.15 | 0.48 | 0.65 |
| 59 | -0.22 | -0.12 | 0.21 | 0.37 |
| 95 | -0.64 | -0.54 | -0.21 | -0.04 |

**Conclusions**

Results from this modelling study indicate that unless starting from a high SOC base, growers are likely to have flexibility in the way they manage stubble from year to year and still be able to minimise loss of SOC providing consideration is given to average stubble loads maintained over time. Increasing grain yields will result in more organic matter returned to the soil and reduce the risk of SOC decline. However, effects of stubble load which are not accounted for by the model such as soil erosion, pests and disease and nutrient availability need to be considered when deciding on an appropriate stubble management regime.

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**References**

Baldock JA, Nelson PN (2000) Soil organic matter. In 'Handbook of Soil Science.' Ed. ME Sumner) pp. B25-B84. (CRC Press: Boca Raton, USA)

Chan KY, Heenan, DP (2005). The effects of stubble burning and tillage on soil carbon sequestration and crop productivity in southeastern Australia. Soil Use and Management 21, 427-431.

Chan KY, Heenan DP, So HB (2003) Sequestration of carbon and changes in soil quality under conservation tillage on light-textured soils in Australia: a review. Australian Journal of Experimental Agriculture 43, 325-334.

Coleman K, Jenkinson DS (2005) A model for the turnover of carbon in soil. IACR - Rothamsted, Harpenden, UK.

IPCC (2006) IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4 - Agriculture, forestry and other land uses. Institute for Global Environmental Strategies for the Intergovernmental Panel on Climate Change, Hayama, Japan.

Robertson FA, Myers RJK, Saffigna PG (1994) Dynamics of carbon and nitrogen in a long-term cropping system and permanent pasture system. Australian Journal of Agricultural Research 45, 211-221.

Robertson F (2008). The potential for soil carbon sequestration in the Victorian Cropping Industry. Department of Primary Industries Victoria, Final Report MIS 08270.

Scott BJ, Eberbach PL, Evans J and Wade LJ (2010). EH Graham Centre Monograph No. 1: Stubble Retention in Cropping Systems in Southern Australia: Benefits and Challenges. Ed by EH Clayton and HM Burns. Industry & Investment NSW, Orange.

Skjemstad JO, Spouncer LR, Cowie B, Swift RS (2004) Calibration of the Rothamsted organic carbon turnover model (RothC ver. 26.3), using measurable soil organic carbon pools. Australian Journal of Soil Research 42, 79-88.

Tiessen H, Stewart JWB, Bettany JR (1982) Cultivation effects on the amounts and concentration of carbon, nitrogen, and phosphorus in grassland Soils.1. Agronomy Journal 74, 831-835.

Valzano F, Murphy B, Koen T (2005). The impact of tillage on changes in soil carbon density with special emphasis on Australian conditions. Department of Environment and Heritage , Australian Greenhouse Office, Canberra.