Stubble and carbon

What impact does stubble have on soil organic matter?

Retaining stubble does not necessarily increase soil carbon (C).
It increases undecomposed plant material (not humus) near the soil surface. Why?

- Stubble is mostly C and low in other nutrients (Nitrogen, Phosphorous, Sulphur)
- Humus, the stable nutrient rich form of soil organic matter (SOM), is what we are targeting
- Using stubble to build soil organic matter (SOM) requires addition of nutrients (N, P, S)
- Without sufficient N, P & S, as stubble decomposes, more carbon is released as CO_2 (a greenhouse gas) and less is converted to humus
- Humus contains C, N, P and S in predictable proportions; therefore
- We can calculate how much supplementary nutrient is required to convert stubble into humus

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What is Soil Organic Matter and Soil Organic Carbon?

Soil organic matter (SOM) and soil organic carbon (SOC) are often used interchangeably. But they are not the same thing.

Definitions

Soil organic matter (SOM) consists of plant or animal tissue in various stages of breakdown (decomposition), cells and tissues of soil organisms, and substances synthesized by soil organisms.

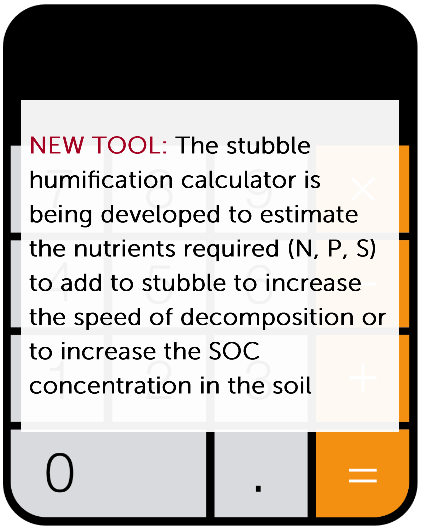
Soil organic carbon (SOC) is the carbon component of SOM.

Stubble residues are plant material that are carbon rich and generally nutrient poor (Tables 1 & 2).

Humus is a nutrient rich stable form of SOM produced by microbes.

We talk about SOC because it is easier to measure than SOM and there is a good relationship between SOC and SOM. % SOM = % SOC x 1.72.

It is SOM that can do wonderful things for soil (see below), not SOC per se



All organic matter contains, AT LEAST, carbon (C), hydrogen (H) and oxygen (O). Generally, three other key elements are also found in organic matter, and these are nitrogen (N), phosphorus (P) and sulphur (S).

Photo 1—standing stubble.

Soil Organic Matter as the basis of soil fertility

SOM is important for all aspects of soil health:

Nutrient availability. The humus component of SOM releases nutrients (N, P and S) as it decomposes which can be available for plant growth.

Soil structure and soil physical properties. SOM promotes good soil structure by holding the soil particles together as stable aggregates improving properties such as water holding capacity, water infiltration, gaseous exchange, root growth and ease of cultivation.

Biological soil health. As a food source for soil fauna and flora, which influence important functions such as nutrient cycling and availability, assisting root growth and plant nutrient uptake, creating burrows and even suppressing crop diseases.

Retaining crop residues in modern farming systems

1. Conservation cropping systems (no-till, stubble retention) can certainly build coarse soil organic matter (i.e. plant residues, particulate organic matter), maintain cover, protect soil structure and reduce erosion BUT at best will only maintain, rather than build stable soil organic matter (humus).

2. Maintaining adequate levels of humus is essential to ensure the structural stability of soils, and for the provision of nutrients (soil fertility), which will be soil type (texture) specific.

3. Retaining crop residues to try to increase SOM levels may not be the most important aspect of crop residue management for many growers.

So, growers need to ask the question:

What is the major benefit I am seeking from retaining crop residues?

Carbon sequestration in retained stubble farming systems has been examined on many long term trials world-wide. Several long-term studies have shown that burning stubble compared to retaining stubble or cultivation compared to using minimum tillage, has had surprisingly little effect on SOC levels. Cornelia Rumpel, a German scientist, compared burning and incorporation of wheat residues at a long-term field experiment in France. After 31 years, and even with such an obvious difference in residue returned to the soil, there was no difference in SOC levels. Y K Soon, working in Canada, compared complete residue removal and residue incorporated over a ten year period. SOC levels decreased in all treatments and there was no significant difference between treatments at the end of the study. Similarly, in a long term CSIRO trial at Harden, NSW, there was no significant difference in the SOC level after 28 years between late strategic burn or retaining stubble and cultivate or direct drill. More importantly, the SOC levels in all continuous cropping systems had declined from 1.3% SOC to 0.9%. Dr John Kirkegaard (CSIRO) also reviewed trends in wheat yield responses to conservation cropping in Australia by analysing data from 33 medium-term (3-5 years) and long-term (>5 years) agronomic experiments. The overall effect of cultivation was small (-0.18 to +0.06 t/ha), while stubble retention reduced yield in all regions (-0.31 to -0.02 t/ha). Merely increasing the amount of plant residue returned to the soil by retaining crop residues, compared to late burning or removal stubble, or switching from conventional cultivation to minimum tillage is NO guarantee that SOC, or crop yields will increase.

Residue management practices increase soil fertility in continuous cropping

Residue	C	N	P	S
Barley	10,000	138	19	33
Canola	10,000	171	32	98
Lucerne	10,000	444	40	56
Wheat	10,000	152	23	37
Mean plant residue	**10,000**	**235**	**35**	**49**
Humus	10,000	855	102	130

Table 1: Average quantity (units) of N, P and S per 10,000 units C for some crop residues, for soil organisms and for humus (dead organisms)

The most effective way to build stable soil organic matter (humus), nitrogen fertility and soil structure is by incorporating a well grown pasture phase into the crop rotation (Angus and Peoples 2012). However, in a continuous cropping system, where crop residues are the only source of C, sufficient nutrients (N, P, S) are necessary to maintain or build humus (Kirkby et al., 2016).

Crop residues are generally carbon (C) rich but relatively nutrient (N, P, S) poor, whereas humus is more nutrient rich *(Table 1)*. Although plant material decomposes to form humus, humus is primarily dead microbial biomass. The microorganisms (mainly bacteria and fungi) consume the dead plant material (crop residues, roots and root exudates) and thus the plant material "disappears". When the microorganisms die, the parts of their bodies resistant to decomposition (mainly the cell walls and cell membranes) become humus.

Dr Kirkby found that a maximum of 30% of the total carbon from stubble residues could be converted to humus (referred to as the Maximum Humification Rate of 30%). The remaining 70% of the carbon is used by the microorganisms for respiration and converted into CO2 (gas).

Fact: For every 10 tonnes of above ground crop residue (usually consists of 45% C), a maximum of only 900 kg of the crop residue C will be converted into humus C.

Post-harvest, farmers retaining stubble need to ask the questions ...

1. Am I trying to maximize the fertility from a given stubble load by converting the maximum amount of stubble to humus, plus ensure easier sowing? or

2. Am I trying to reduce stubble load for ease of sowing and convert a reduced quantity of stubble to humus at a lower cost?

Nutrient	Amount (kg)	Approx. price/kg nutrient	Approx. cost
N	85.5	1.10 (Urea)	$94
P	10	3.98 (Single)	$0
S	13	3.19 (Single)	$41
			$136
Note: Zero cost has been associated with the phosphorus component as 118kg single super/ha provided both P and S in the correct proportions.			

Table 2: Estimated potential value of N, P and S locked up with each tonne of humus-C

1. Convert maximum amount of stubble to humus

If the primary reason for retaining crop residues is to increase SOM levels (and therefore SOC), then incorporating stubble residues and adding nutrients to ensure the maximum humification rate of 30% would be the recommended option. This will increase the rate of decomposition of the stubble residues and convert the greatest amount of stubble to humus. To achieve this, incorporate stubble as soon as possible after harvest into moist soil with warm temperatures.

To sequester 1 tonne of soil carbon as humus requires 85.5 kg/ha N, 10 kg P and 13 kg S *(Table 2)*. As each tonne of humus-C "locks up" $136 worth of nutrients, careful consideration should be given as to whether increasing SOM levels will "pay for themselves". [The $136 worth of nutrients was derived using the most cost efficient mixture of fertilisers (combination of 186kg/ha of urea @46%N and 118kg/ha of single super @8.8%P and 11%S, with urea at $510/t and single super at $350/t].

FACT: The nutrients applied to the stubble are not lost, but do form a source of slow release nutrition for the newly emerging crop avoiding the "nutrient tie-up" which occurs when there is a lot of carbon rich stubble residue lying on the soil surface and low nutrients (N, P, S). However, plants using those nutrients results in a reduction in SOC.

2. Reduce stubble load for ease of sowing and convert some stubble to humus

If the farmer has a large quantity of stubble following harvest (i.e. a cereal stubble with grain yield ≥ 5t/ha and remaining stubble load of between 7.5-12t/ha), then one way to reduce the stubble load if soils are moist is to add nutrients at a humification rate of 20% and incorporate the stubble as early as possible following harvest after a good rainfall event. This will increase the decomposition rate of the stubble, increase soil fertility (but at a lower quantity than at 30% humification rate), reduce the amount of nutrients required and reduce the overall cost. To further reduce the cost, determine the nutrient concentration in the stubble and adjust accordingly.

Impacts of stubble retention, burning & cultivation on soil organic matter levels

Question: How much fertiliser do I need to add to the soil to decompose the stubble if it had a typical nutrient concentration of 0.7%N, 0.07%P, 0.07%S ?

At 20% humification rate: 49kg/ha of sulphate of ammonia at a cost of $29.20/ha (Figure 2).

At 30% humification rate: 99kg/ha of urea and 96kg/ha single super, cost of $83.90/ha (Figure 2).

Remember a 30% humification rate increases soil fertility but costs more. The cost could be significantly higher ($161/ha) if a different fertilizer mix was used (See appendix 1).

IMPORTANT: It MUST be emphasised that one is retaining organic matter, not C per se, and therefore the whole package (the C, N, P and S) must be accounted for in the correct ratio.

Different soils appear to have different capacities to increase SOM levels. Heavier soils appear to sequester C more easily than lighter soils and to also benefit most when the SOM levels do increase. Thus trying to increase SOM levels by retaining crop residues is not for all farming situations and not for all soils.

Stubble Humification Calculator

Stubble load (t/ha)	10				
Humification required (%)	20				
Stubble nutrient concentration (%)		C	N	P	S
		45.0	0.700	0.070	0.070
Extra nutrients required (kg/ha)			7.0	2.2	4.7
Fertiliser type 1	Granulock 15		14.3	12.0	10.5
Quantity of fertiliser to supply exact nutrients (kg/ha)			49	18	45
Fertiliser cost ($/ha)			$29.2		
Fertiliser and spreading cost ($/ha)			$37.7		

Fertiliser	Price ($/t)
Urea	$510
Gran Am	$450
DAP	$630
MAP	$630
Granulock 15	$600
Single Super	$350
Spreading Costs	$8.50

Stubble Humification Calculator

Stubble load (t/ha)	10				
Humification required (%)	30				
Stubble nutrient concentration (%)		C	N	P	S
		45.0	0.700	0.070	0.070
Extra nutrients required (kg/ha)			45.4	6.8	10.6
Fertiliser type 1	Urea		46.0	0.0	0.0
	Single super			8.8	11.0
Quantity of fertiliser to supply exact nutrients (kg/ha)			99	77	96
Fertiliser cost ($/ha)			$83.9		
Fertiliser and spreading cost ($/ha)			$92.4		

Fertiliser	Price ($/t)
Urea	$510
Gran Am	$450
DAP	$630
MAP	$630
Granulock 15	$600
Single Super	$350
Spreading Costs	$8.50

Figure 2: A screenshot of Dr Kirkby's stubble humification calculator to estimate the amount of fertiliser (N:P:S) that would need to be applied to a cereal stubble load of 10t/ha with a humification rate of 20% and 30% to decompose residual stubble.

OVERVIEW

- It takes a long time to either increase or decrease the SOC levels.
- A one off late strategic burn or cultivation to ensure that the following crop is not compromised by a large stubble load will not significantly reduce the SOC concentration.
- It costs to apply enough nutrients to appreciably increase SOM levels.
- The stubble humification calculator will be a useful tool to assist farmers determine what nutrients and the cost to increase SOC or decompose stubble quickly.

References:

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