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Compost Use Mitigates Climate Change

FACT SHEET

It is well documented that preventing organic residues from going to landfill avoids methane emissions, and also preserves organic carbon and nutrients for beneficial use in land management and food production. It is equally well known that on-going use of compost improves physical, chemical and biological soil properties, and delivers a wide range of agronomic and environmental benefits. By supplying both stable and labile organic compounds, as well as plant nutrients and beneficial organisms, the agricultural and horticultural use of compost also supports climate change mitigation on two fronts:

1. **Removal of atmospheric carbon through soil carbon sequestration, achieved directly through storage of compost carbon, and indirectly through enhanced plant growth, which in turn contributes also to increased soil carbon levels;**
2. **Reduction of greenhouse gas (GHG) emissions, e.g. through reduced production and use of chemical fertiliser and pesticides, and through reduced irrigation.**

Preventing Methane Generation

In 2006/07, the Australian Organics Recycling Industry diverted at least 3.7 million tonnes of organic residues from landfill, comprising materials such as garden and food organics, wood & timber, biosolids, sludges, and the like. Diverting these materials from landfill and recycling them prevented the generation of methane equivalent to 4.28 million tonnes CO2-e, which is almost as much as what was recovered from landfill in 2007 (4.5 Mt CO2-e)

In addition, a minimum of 600,000 tonnes of manure and other agricultural residues were composted, which is recognised by the IPCC as superior manure management compared to deep litter or dry storage, let alone pit or liquid storage.

Declining Soil Carbon

The clearing of native land for agricultural use, particularly when it involves soil cultivation, results in considerable decline of soil carbon levels. It is estimated that soil carbon levels in Australia declined 30% to 60% after land clearing for cropping some 60 to 100 years ago. The rate of decline depends primarily on initial soil carbon levels, soil texture (clay content), rainfall and agricultural activities (Fig 1).

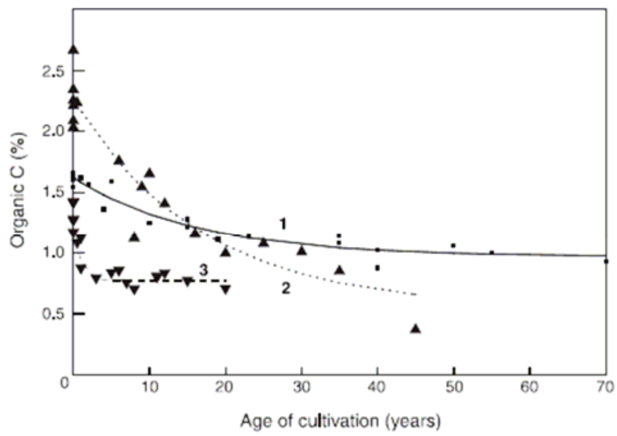

Figure 1 Long-term decline of organic carbon in three soils (top 10 cm) in Southern Queensland (Source: Dalal and Chan, 2001)

However, the decline of soil carbon is not a historic phenomenon – it still is widespread today as many soils have not yet reached new steady state carbon levels, and as agricultural production still intensifies.

Declining Soil Productivity

Soil organic matter (or carbon) levels are closely linked with soil fertility and soil productivity. Hence, declining organic matter results also in diminishing soil fertility, namely in less favourable soil physical characteristics, reduced water storage and availability, and reduced nutrient (N, P, K, trace elements) supply capacity.

Mineralisation of organic matter provides a constant slow-release nutrient source in natural and also agricultural ecosystems. Hence, declining soil carbon also delivered significant benefits: approx. 1,200 kg of N and 100 kg of P per hectare (at soil bulk density of 1.2 t/m^3) were released per one percentage point of carbon lost. Agriculture production benefited from this effect for a long time. However, increasingly unfavourable soil conditions and diminishing soil nutrient supplies due to organic matter decline resulted in growing needs for mineral fertiliser and other external inputs.

Using Compost is the Solution

Using compost has a two-fold benefit, as it is ideal for helping re-build soil fertility and re-plenish soil carbon and nutrient stocks, while at the same time helping mitigate climate change.

Compost contains macro and micro nutrients, a diverse microbial population, stable organic compounds (e.g. humic compounds), and also labile organic matter, which is an important source of food and energy for the soil food web. Hence, compost is not 'naked carbon', but rather 'humus in the making'.

The conversion of compost into humus continues after compost is added to soil. This means that the transformation of organic matter into microbial biomass, energy, CO_2 and stable organic compounds, i.e. humus, continues. Although this mineralisation process reduces the amount of compost carbon that remains in the soil, it also releases nutrients necessary for plant growth. Apart from soil type and agricultural activity, the degree to which compost carbon is converted into CO_2 depends on the type and age (maturity) of compost used, as well as on environmental conditions, primarily temperature and moisture. Research has shown for example that 17% of the total organic carbon added with garden and food organics compost was converted into CO_2 during a one-year period. This means that 83% of all carbon added with compost was still in the soil after one year.

Compost Use Sequesters Carbon

Many trials in Australia and overseas have demonstrated that on-going compost use increases soil carbon levels. However, there are very few longer-term trials that enable the modelling of carbon sequestration associated with compost use. Fortunately however, a considerable number of long-term (50 – 160 yrs) field trials in Europe and North America have demonstrated the benefits of farmyard manure in increasing soil carbon levels. In the short to medium term, a considerably higher proportion of carbon applied in compost is retained in the soil then when carbon is applied in manure. With manure, 5% to 20% of applied carbon is retained, while carbon retention for compost ranges between 10% and more than 50%. Hence, it can be assumed that compost is also considerably more effective in sequestering carbon in the long-term, than manure is.

While it is acknowledged that increases in soil carbon levels will diminish over time and be limited by new carbon equilibria, the current assumption that this point will be reached after about 20 years will have to be revised upward. Soil organic matter levels still showed linear increases after 9 and 12 years of continuous compost use (Figure 2). Over a 12-year period, around 1 tonne of carbon per hectare and year was sequestered for every 10 tonnes of dry matter compost (garden and food organics) applied per hectare. The sequestration of 1 tonne of carbon equates to 3,670 kg of CO_2-e abatement.

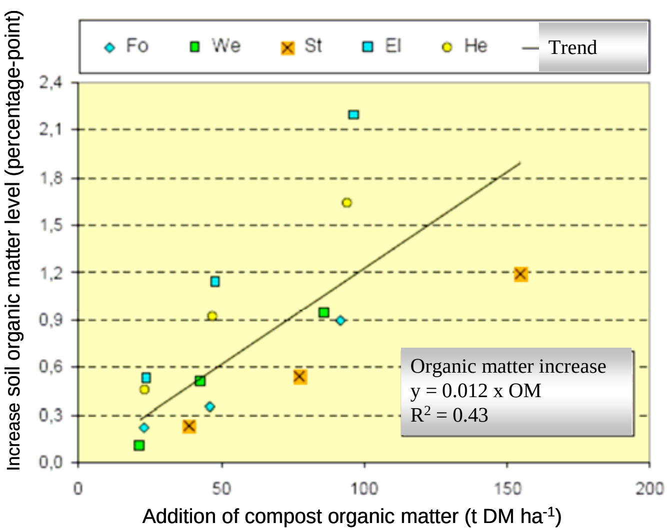

Figure 2 Effect of long-term (9 / 12 yrs) compost use on soil organic matter (0 - 30 cm) in five locations (Fo, We, St, El, He) in Southern Germany (Source: LTZ, 2008)

In line with this, a simple carbon sequestration model for compost use in European conditions predicts that a new equilibrium will be reached only within a time frame of probably 200 and 300 years for annual application rates of 10 and 15 tonnes per hectare, respectively (Figure 3). Annual application rates between 2.5 and 5.0 tonnes per hectare prevent further decline in soil carbon levels.

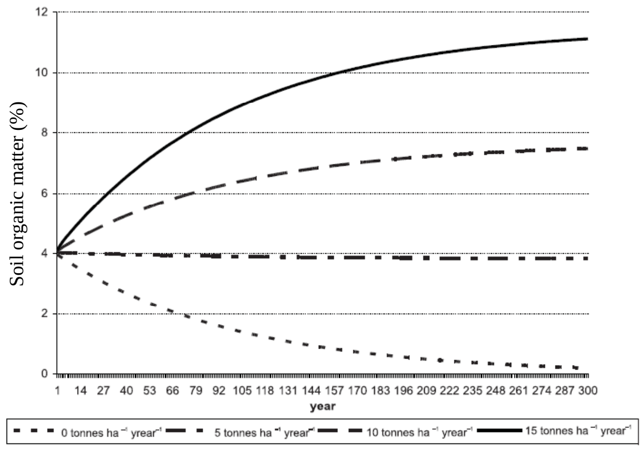

Figure 3 A simple carbon sequestration model for compost use (Source: Favoino and Hogg, 2008)

Based on available research data, it is estimated that 45%, 35% and 10% of carbon contained in mature garden organics compost is retained in the soil over 20, 50 and 100 year timer-frames, respectively. Hence, use of such compost at rates of 10 t DM ha^{-1} will be sequester carbon that is equivalent to around

- 5,000 kg CO_2-e over 20 years
- 3,500 kg CO_2-e over 50 years
- 1,000 kg CO_2-e over 100 years

Replacement of Mineral Fertilisers

The production of mineral fertilisers is quite energy and GHG intensive, particularly for nitrogenous fertilisers. The supply of plant nutrients through compost use allows for a reduction in using mineral fertiliser, and hence also a cut in GHG emissions caused by fertiliser production.

The degree to which this is achieved depends on factors such as nutrient density in compost, nutrient replacement efficiency, compost application rate and the global warming potential allocated to fertilizer manufacturing. If, for example garden organics compost (N: 1.1%, P: 0.2%, K: 0.55%) is applied annually at 10 tonnes dry matter per hectare, it could replace the use of approximately 44kg of N, 20kg of P and 55 kg of K from mineral fertilizer per year. If the use of urea and single superphosphate is reduced accordingly, emissions from fertilizer production will be reduced by around 180 kg CO_2-e. Savings are obviously considerably higher, if compost with higher nutrient concentrations is used, such as products that contain food organics, biosolids or manure. Also, while the above calculation assumes that plants utilise approximately 40% of nitrogen supplied with compost over four years, others (Favoino and Hogg, 2008) have assumed that this amounts to 100%, resulting also in markedly higher GHG savings.

Most nitrogen (> 90%) contained in compost is organically bound, and released slowly over time. Hence, if compost is applied regularly, soil nitrogen and phosphorous reserves will build up in parallel to increasing soil carbon levels. For each tonne of carbon that is stored in the soil, i.e. converted into humus, approximately 85 kg of N, 20 kg of P and 14 kg of S are stored also. These nutrients will be released slowly and become available for plant up-take at a later stage as the humus is mineralized. Over time, nutrient reserves will build up, so that probably 80 kg or more of N per hectare will be supplied annually from the soil nitrogen pool (Figure 4). This resembles farming conditions shortly after land clearing when soil humus levels were still high.

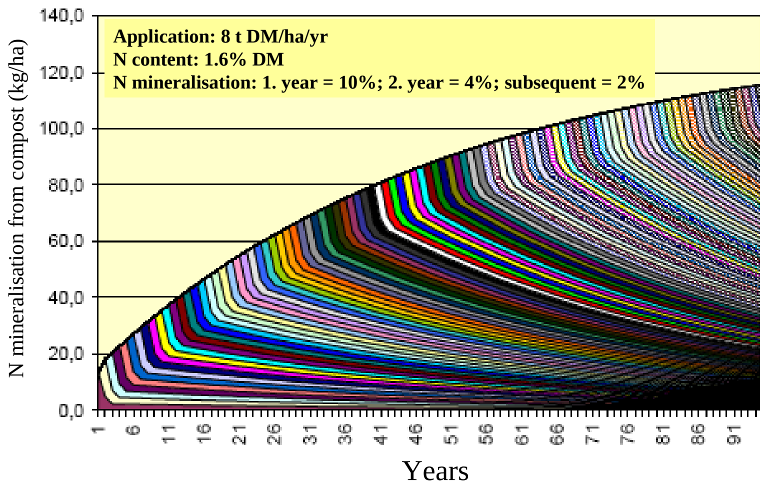

Figure 4 Increasing nitrogen mineralisation due to the long-term annual application of compost [8 t dry matter ha^{-1}] (Source: Amlinger *et al.*, 2003)

Reduction of Nitrous Oxide Emissions

Despite the fact that nitrous oxide (N_2O) emissions represent less than 10% of the mitigation potential from cropland globally, they can have a significant impact, as their global warming potential is almost 300 times higher than that of CO_2. Consequently, increased N_2O emissions from agricultural activities can negate substantial carbon sequestration gains.

The production of N_2O in soil is governed by available mineral nitrogen (both from soil and fertilisation), soil aeration, moisture (water filled pore space), temperature, dissolved and readily degradable carbon, and soil pH and salinity. However, the overarching determinants for N_2O emissions are nitrogen fertilisation, nitrogen use efficiency, and oxygen supply.

The effects of compost use on N_2O emissions are not yet clearly established, probably because compost has the potential to both reduce and enhance emissions. Generally speaking, compost has low nitrogen concentration (ca. 1 – 3% DM), and only a small proportion is present in mineral form (ca. 0 – 10% of total N). Hence, from that perspective, compost poses little risk of causing N_2O emissions. The soil aeration effect of using compost also helps to reduce N_2O release. However, on the other hand, improved soil water holding capacity and the supply of dissolved / readily degradable carbon might enhance N_2O emissions.

Other GHG Savings

The use of compost delivers a further range of other savings on GHG emissions, which are more difficult to measure and quantify. These savings include the following:

- Reduced energy use for irrigation, due to improved water storage and water use efficiency,
- Reduced need for biocides results in reduced GHG emissions associated with biocide production, due to improved soil and plant health,
- Reduced diesel use for soil cultivation, due to improved tilth,
- Increased carbon sequestration from higher biomass production, due to improved soil productivity,
- Reduced nitrogen loss that causes secondary N_2O emissions, due to lower nitrogen surplus and leaching,
- Reduced erosion that causes loss of nutrients and organic matter, resulting in secondary N_2O emissions and those associated with replacing lost nutrients.

Summary and Outlook

Apart from the prevention of methane emissions from landfill and the recovery of key carbon and nutrient resources, the use of mature garden organics compost at a rate of 10 tonnes dry matter per hectare results also in GHG abatement due to carbon sequestration and fertiliser replacement, which is equivalent to 5,200 kg CO_2-e over a 20 year time frame, 3,700 CO_2-e over 50 years and 1,200 kg CO_2-e over 100 years. In addition, there are other, unaccounted reductions of GHG emissions.

Hence, the use of compost

- can contribute to mitigating climate change,
- can help open a window of opportunity (20 – 40 years) to find other means (technologies) of reducing / mitigating emissions,
- is one of the fastest means of improving soil carbon levels,
- is ideally suited as mitigation measure in productive agricultural soils,
- fits easily into the Australian National Carbon Accounting System, and
- can attract carbon credits.

It is important to understand that using compost not only helps to sequester carbon and mitigate climate change, but also delivers many agronomic, environmental and societal benefits. Hence, composting and compost use must be one of the best options available for mitigating climate change, while also enhancing agricultural production.

References

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