

## Influence of biochar on soil fertility, carbon storage and biomass in subtropical pasture: Results from a 3 year field study

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### Introduction

Prior to land clearing in northern NSW, Australia in the late 1800s, the highly fertile and naturally acidic red ferrosols supported tropical rainforests. Upon replacing these tropical rainforests with dairy pastures, soil productivity declined not only as a result of a decrease in organic matter and nutrient removal in forage but also because of an increase in acidity exacerbated by the frequent application of high rates of N fertiliser. As a consequence, it is a common requirement to apply lime to these soils in order to ameliorate the acidification associated with high N use and to sustain pasture productivity [1].

The use of N fertiliser to drive crop and pasture growth has been identified as a significant source of N<sub>2</sub>O emissions from soils. Urea is the main form of N fertiliser applied to annual ryegrass pastures in a subtropical environment. The direct carbon dioxide (CO<sub>2</sub>) and nitrous oxide (N<sub>2</sub>O) emissions from urea application to soils are estimated to be 3 t CO<sub>2</sub>-e t<sup>-1</sup> urea [2], with additional emissions arising during fertiliser manufacture and transport [3].

The application of lime to offset the acidifying effects of urea also results in greenhouse gas emissions, as CO<sub>2</sub> is released from the soil during the chemical dissolution of lime. Using the IPCC default value of 12% for lime applying 1 t lime to soil has the potential to directly emit 0.44 t CO<sub>2</sub>-e yr<sup>-1</sup> [2].

The subtropical dairy production system is thus characterised by a high demand for manufactured fertilisers and soil additives, and a corresponding level of both direct and indirect GHG emissions. New technologies for this system will need to demonstrate not only the capacity to improve productivity and fertiliser use efficiency but also reduce net GHG emissions.

A field site was established in 2006 to assess the benefits of biochar on pasture productivity, soil fertility and soil carbon storage. Twelve soil

amendments were formed by crossing 3 factors: 2 rates of fertiliser (nil and 276 units of N: 22P: 50K kg/ha/y, N applied to ryegrass only) by 2 rates of lime (nil and 5t/ha single application) by 3 biochar amendments (nil, beef feedlot manure biochar (FM) at 10t/ha and greenwaste (GW) biochar at 10t/ha single application). The experimental area was then direct-drilled to forage peanut (*Arachis pinto*) and oversown in autumn in 2007 and 2008 with annual ryegrass (*Lolium multiflorum*).

### Results and Discussions

Compared to nil amendments total ryegrass yield was increased 96% by applying NPK fertiliser, 14% by FM biochar application and 7% by liming. Addition of FM biochar with lime and fertiliser achieved the highest total yield of 16787 kg DM/ha which was 877 kg DM/ha above the nil biochar. The GW biochar did not significantly influence yield. Without fertiliser the FM biochar generally increased uptake N, P, K, Ca, Mg and Na compared to the GW and nil biochar.

In fertilised and limed plots, adding FM biochar significantly reduced the acidification rate at 3 years following trial establishment. Without lime, the FM biochar also gave significant increases in plant available P in fertilised and unfertilised plots at 3 years, and there was no effect of fertiliser application on available P at the rates applied (Table 1). It is clear the biochar amendment played a significant role in altering plant available P in this ferrosol.

There was no significant difference in either the soil microbial biomass, or soil enzyme activity following biochar amendment although significant differences occurred between seasons.

Soil (in the 0-75 mm profile) initially contained 4.7% C which increased to between 5.1- 5.4% following amendment with biochar. Over the 3 years, there was no significant accumulation in C in the controls without biochar, despite application of fertiliser and lime. The GW

biochar with farmer-practice fertiliser rates in the absence of lime resulted in the greatest accumulation of total soil C with 6.5% C found 3 years following the establishment of the trial (Table 1). In all treatments, the presence of GW biochar resulted in significant C accumulation.

Likewise, the FM biochar provided significant increases in combination with some other amendments, but this accumulation of soil C was not as great as with GW biochar. The positive priming effect previously reported [4, 5] was not observed in this field study.

**Table 1:** C and P content in field plots 6 months and 3 years following trial establishment

| Biochar                | NPK | Lime | Bray P        | C%     | C%    |
|------------------------|-----|------|---------------|--------|-------|
|                        |     |      | mg/kg<br>3yrs | 6 mths | 3 yrs |
| nil                    | nil | nil  | 6.9           | 4.7    | 4.8   |
| FM                     | nil | nil  | 13.0          | 5.1    | 5.5   |
| GW                     | nil | nil  | 6.7           | 5.2    | 5.9   |
| nil                    | nil | +    | 6.6           | 4.6    | 4.7   |
| FM                     | nil | +    | 10.1          | 5.2    | 5.5   |
| GW                     | nil | +    | 6.4           | 5.3    | 6.0   |
| nil                    | +   | nil  | 8.3           | 4.8    | 5.1   |
| FM                     | +   | nil  | 16.0          | 5.2    | 5.7   |
| GW                     | +   | nil  | 11.0          | 5.4    | 6.5   |
| nil                    | +   | +    | 11.3          | 4.7    | 4.9   |
| FM                     | +   | +    | 11.7          | 5.1    | 5.5   |
| GW                     | +   | +    | 14.3          | 5.1    | 5.7   |
| l.s.d.<br>( $p=0.05$ ) |     |      | 4.1           | 0.4    | 0.4   |

Increases in soil carbon storage were estimated to enable an offset against GHG emissions of 16 and 38 t CO<sub>2</sub>-e for the FM and GW biochar, respectively. These systems typically include application of N at rates of (600 kg urea y<sup>-1</sup>), with an initial application of 5 t ha<sup>-1</sup> lime. This would equate to around 1.8t CO<sub>2</sub>-e emissions ha<sup>-1</sup> y<sup>-1</sup> from urea and a total of 2.2t CO<sub>2</sub>-e emission from liming using published estimates [2]. Over the 3 year cropping cycle described here, the increase in C storage in the pasture soil offset emissions associated with N and lime application.

## Conclusions

Although the reason for increased soil C in our study was not fully explored, it is likely that increased biomass production with the FM biochar amendment resulted in greater soil deposition of C. Yield could not explain increased soil C with GW biochar amendment. In this case, the soil C increase may have been due to the stabilization of otherwise decomposable SOC by sorption to mineral and organic soil surfaces, occlusion within aggregates, and deposition in pores [6] which are inaccessible to microbial decomposers [7]. Work is continuing to identify the fractions of soil C that are responsible for this significant increase.

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