Biomass for bioenergy or biochar: which delivers greater climate benefits?

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1. Introduction:

Amongst the range of technology options for utilization of biomass to reduce greenhouse gas (GHG) emissions, pyrolysis is a technology that simultaneously produces renewable energy products (syngas and bio-oil) and a solid char that can be combusted for fuel, or alternatively used in environmental applications. When used as a soil amendment this char is known as biochar. Biochar has been shown to deliver various agronomic benefits (increased crop growth, reduced fertilizer requirements, disease resistance), and environmental benefits (reduced N leaching, and mitigation of GHG emissions) [1]. In terms of climate change benefits, the major contribution is from stabilisation of organic matter: biochar is resistant to chemical and biological decomposition. In soil, biochar is estimated to have a lifetime of centuries to millennia [2]. Also of major significance to GHG mitigation, biochar has been found to substantially reduce nitrous oxide emissions from soil [3].

It must be noted that the impacts of biochar vary widely: different feedstocks and pyrolysis conditions produce biochars with widely different properties, and results are also influenced by soil type and target crop. Besides the impacts listed above, additional climate change mitigation benefits can arise from avoidance of GHG emissions that would have resulted from conventional use of biomass, such as CH_4 emissions from disposal of greenwaste in landfill, or N_2O emissions from poultry litter composted and spread as fertilizer [4].

To inform decisions on utilization of biomass for biochar or alternative purposes, it is instructive to quantify the GHG impact of biochar systems in contrast with alternative uses of biomass, using a life cycle assessment (LCA) approach, confined to the single environmental impact category of climate change.

2. Concept and methodology:

LCA was used to assess the GHG emissions and sequestration across the biochar life cycle, including fossil fuel use in harvesting, processing, transport and application of biochar; indirect emissions such as from fertilizer manufacture; changes in soil and biomass carbon stocks; emissions of N_2O and CH_4 as well as CO_2. The net impact of biochar was determined by comparing the biochar life cycle emissions and removals with the applicable reference system, representing the conventional soil amendment and use of the biomass. Where the biochar production process produces an energy co-product, the conventional energy source is also included in the reference system.

Three feedstock sources were considered: greenwaste (GW), poultry litter (PL) and wheat straw (WS), and two pyrolysis temperatures: 450 and 550 °C. Two target crops were modeled: maize grown on the New South Wales north coast in a Ferrosol (Oxisol) soil, and wheat grown in the Northam district of Western Australia in a Tenosol (sandy) soil.

3. Results and discussion

The estimated impact on GHG emissions from utilization of biomass for biochar ranged from emissions reduction of 3.2 kg CO_2-e per kg biochar, for poultry litter biochar made at 550°C applied to maize, up to emissions increase of 1.2 kg CO_2-e per kg biochar for greenwaste biochar made at 450°C applied to wheat (Figure 1). Greater benefits were seen from application of biochar to maize than to wheat, due to the assumed lack of response of wheat to biochar, and due to greater emissions from conventional maize production compared with wheat, which are a function of the higher level of fertiliser inputs to maize, and the higher nitrous oxide emissions from the wetter climate in which it is grown.

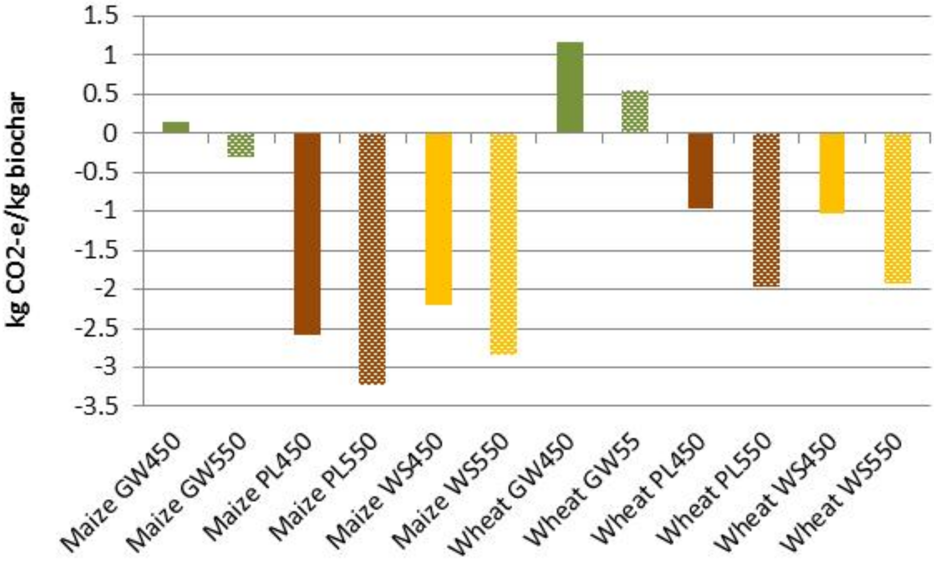

Figure 1 Net GHG emissions from application of 1 kg biochar in a maize or wheat cropping system

Between feedstocks, poultry litter and wheat straw biochars had similar impacts, though the factors contributing to emissions reduction differed: for poultry litter, there was substantial reduction in nitrous oxide emissions compared with using raw poultry litter as fertiliser; for wheat straw, the reduction in fossil fuel emissions from use of syngas for electricity generation was a significant contributor. For greenwaste biochar, stabilisation of biomass carbon was the major contributor to emissions reduction; reduced nitrous oxide and avoided fossil fuel emissions contributed similar, lesser benefit. Greenwaste biochar showed much lower net benefit compared with other biochars, and some greenwaste biochar scenarios actually increased emissions. The cause of this result was the alternative fate of greenwaste: if it would otherwise have been deposited in landfill, where little decomposition occurs [5], and if the methane generated was captured and used for electricity generation, then diverting greenwaste to biochar production was calculated to increase emissions. However, if the landfill had no methane capture then use of greenwaste for biochar was preferable. If the alternative fate of greenwaste was mulch or burning rather than landfill, then utilisation for biochar gave a strong advantage (Figure 2).

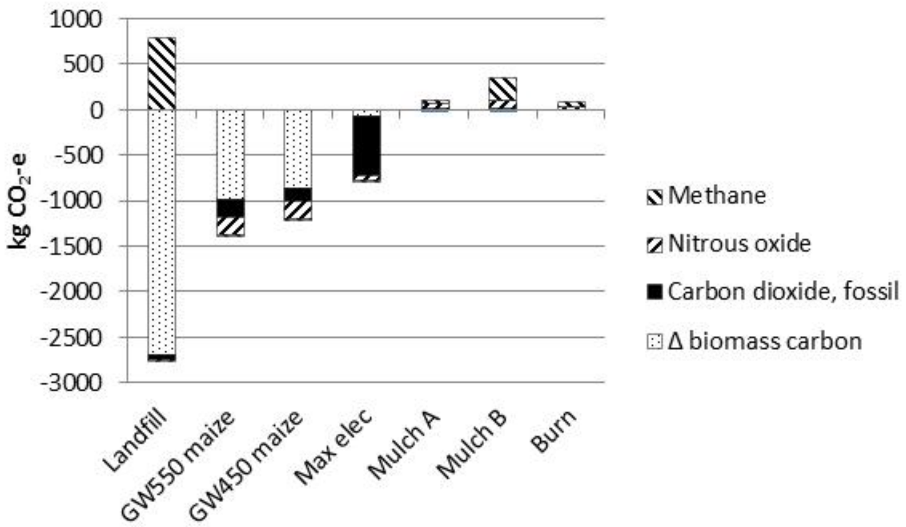

Figure 2 GHG impact of alternative options for the disposal of 1t greenwaste

Features of the biochar itself had a lower impact on the LCA results than assumptions about the reference system. Biochars made at higher temperature gave a greater benefit than lower temperature biochars, due to their greater stability and higher syngas yield during pyrolysis. The pyrolysis option that produced more electricity and less biochar was less attractive than high biochar yield options, however if the unit was deployed in a situation where the heat could be used directly, the "maximum bioenergy" scenario may become relatively more desirable.

Utilisation of biomass for biochar is estimated to give greater GHG emissions reduction than utilisation for bioenergy in some cases, but the wide variation in results between biochars and target crops, and the great sensitivity to the assumptions for the reference case, mean that LCA studies should be conducted for each specific situation in which biochar utilisation is being considered.

4. References

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