Is biochar carbon negative? Quantifying the climate change mitigation benefits of biochar

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Introduction

It is commonly claimed that biochar is a "carbon negative" technology. This claim needs to be justified through scientifically-rigorous assessment. Simplistically, "carbon negative" implies that the system removes more greenhouse gas (GHG) from the atmosphere than it releases. The appropriate metric for assessing carbon negativity is not so readily defined. Simple input/output ratios do not adequately reflect the mitigation benefit of a biochar system. Rather, it is necessary to document the whole life cycle GHG balance of biochar production and utilisation, and compare this with conventional practice.

Results and Discussion

The appropriate methodology for assessment of mitigation benefits of biochar is illustrated through a desk-top study in which the GHG balance of various biochar feedstocks applied to different cropping systems (biochar case) is compared with current practices (reference case) (Figure 1).

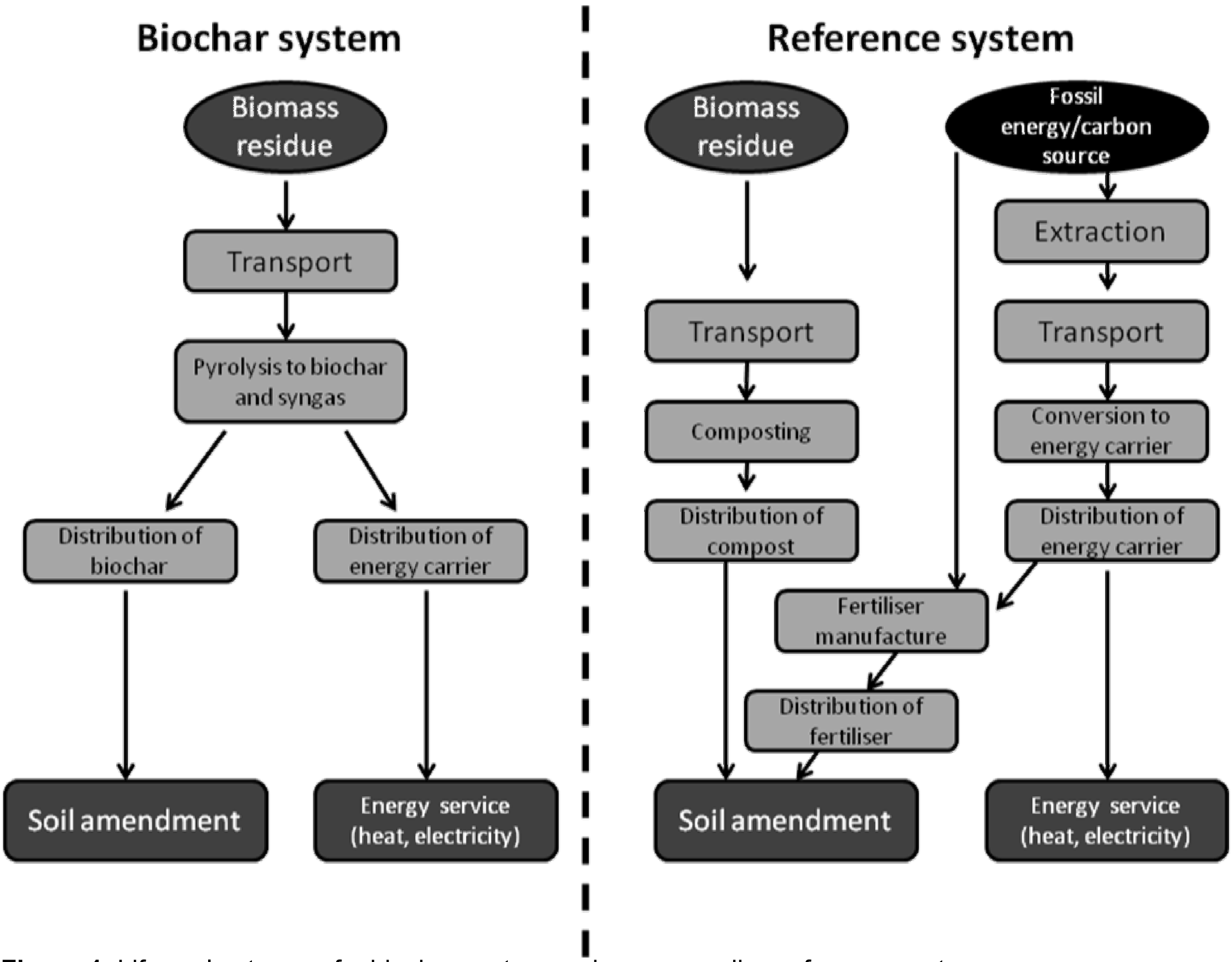

Figure 1. Life cycle stages of a biochar system and corresponding reference system

The emissions reduction benefit of biochar systems is calculated as the difference in net emissions between the biochar and reference cases.

For both the biochar and references cases the assessment should include:

- direct and indirect carbon stock change in biomass and soil;
- emissions of nitrous oxide and methane;
- crop yield, fertiliser and irrigation requirement;
- fossil energy use in plant construction, transport , processing, application of soil amendment, cultivation of crop, manufacture of fertiliser; and
- renewable energy generated.

Other elements that may be significant are timing of emissions and sequestration, and impact on radiative forcing of change in albedo.

It is important that the same “services” are delivered by the biochar and references cases. That is, they must produce equivalent energy output, generate soil amendment for the same land area, and utilise the same quantity of biomass.

In this example, the estimated net emissions reduction summed over 100 years for different biochar scenarios ranged from 1.7 to 3.1 t CO_2-e per t (dry) feedstock, equivalent to 1.3 - 2.0 times the CO_2-e of the feedstock.

The main factors determining emissions reduction were, in order of significance:

- emissions of methane and/or nitrous oxide avoided by diverting biomass from its conventional use;
- biochar yield and carbon turnover rate in soil;
- net energy exported and the energy source it displaces, determining displaced fossil fuel emissions; and
- nitrous oxide emissions from soil.

The result is highly sensitive to the assumptions in relation to these factors.

There is high uncertainty in many components of the analysis, particularly:

- emissions associated with landfilling of biomass in the reference case (the extent of decomposition and the proportion of carbon released as methane)
- the impact on nitrous oxide emissions
- the turnover rate of biochar under field conditions
- the longevity of the impact on crop yield and fertiliser requirement.

These aspects require further investigation to improve estimates of mitigation benefit.

In this example, the greatest GHG mitigation is obtained for the cases that utilise waste material that would otherwise be landfilled, and where biochar is applied to a horticultural crop with high fertiliser requirements. The benefit is lower for cases that divert biomass from its current beneficial use as fertiliser.

Conclusions

The net climate change benefit of biochar should be determined by comparison with the appropriate reference system, representing the conventional use of the biomass, and conventional energy source. A whole system, life cycle perspective is required, that includes indirect (upstream and downstream) emissions as well as direct emissions and sequestration. The desk-top analyses undertaken to illustrate the methodology demonstrate that use of biomass to produce biochar for utilisation as a soil amendment can lead to net negative emissions. Thus, it can be considered a “carbon negative” system. In fact, the magnitude of the net life cycle abatement can exceed the amount of GHG sequestered in the biomass, in situations where avoided emissions are substantial. The major contributions to mitigation vary depending on feedstock, target crop, and characteristics of the situation-specific reference system. The result is highly sensitive to the assumptions, and also to the reference system. Further research is needed to provide accurate data for estimation of mitigation benefit. Aspects of particular uncertainty are the turnover rate of biochar carbon under field conditions, and the impact of biochar on nitrous oxide emissions from soil. Care should be taken in generalising outcomes of life cycle GHG balance studies.

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