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Approaches to greenhouse gas accounting methods for biomass carbon

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ABSTRACT

This investigation examines different approaches for the GHG flux accounting of activities within a tight boundary of biomass C cycling, with scope limited to exclude all other aspects of the lifecycle. Alternative approaches are examined that a) account for all emissions including biogenic CO_2 cycling – the biogenic method; b) account for the quantity of C that is moved to and maintained in the non-atmospheric pool – the stock method; and c) assume that the net balance of C taken up by biomass is neutral over the short-term and hence there is no requirement to include this C in the calculation – the simplified method. This investigation demonstrates the inaccuracies in both emissions forecasting and abatement calculations that result from the use of the simplified method, which is commonly accepted for use. It has been found that the stock method is the most accurate and appropriate approach for use in calculating GHG inventories, however short-comings of this approach emerge when applied to abatement projects, as it does not account for the increase in biogenic CO_2 emissions that are generated when non-CO_2 GHG emissions in the business-as-usual case are offset. Therefore the biogenic method or a modified version of the stock method should be used to accurately estimate GHG emissions abatement achieved by a project. This investigation uses both the derivation of methodology equations from first principles and worked examples to explore the fundamental differences in the alternative approaches. Examples are developed for three project scenarios including; landfill, combustion and slow-pyrolysis (biochar) of biomass.

1. Introduction

1.1. Biomass lifecycle

The production and use of biomass typically involve very complex lifecycles that involves multiple input and output considerations to make a full assessment. Aspects such as nitrous oxide production from fertiliser use in biomass production and land use change have been shown to have large impacts on the net greenhouse gas outcomes of biomass activities [1,2]. For the purpose of focussing the scope of this investigation around the way in which biomass C cycling is accounted for, all other aspects have necessarily been excluded from boundary. It is intended that the methods developed through this work be applied within the context of complete LCA's that have far broader scopes and take into consideration all the necessary aspects of the biomass lifecycle, such as the use of fossil fuels, fertilisers, land use, etc.

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Definition of terms

$E_{biogenic}$	emissions forecast of GHG to the atmosphere via the biogenic method [kg CO_2-e/kg(dry) organics].
E_{stock}	emissions forecast of GHG to the atmosphere via the stock method [kg CO_2-e/kg(dry) organics].
$E_{simplfied}$	emissions forecast of GHG to the atmosphere via the simplified method [kg CO_2-e/kg(dry) organics].
$E_{i,j,k}$	emissions forecast of GHGs i,j,k released to atmosphere from the portion of organics decomposed to gas [kg CO_2-e/kg(dry) organics].
i	CO_2
j	CH_4
k	N_2O
m	mass of organic material at the start of the process [kg (dry)].
occ	organic carbon content of organic material at the start of the process [kg/kg].
d	mass fraction of occ that decomposes to gas as part of the short-term carbon cycle [kg/kg]·[kg/kg].
$a_{i,j,k}$	mass fraction of GHG component i,j,k in emissions released to atmosphere from the decomposition of organic material [kg/kg].
$M_{i,j,k}$	molar mass of GHG component i,j,k [kg/kmol].
M_c	molar mass of carbon = 12 [kg/kmol].
$WP_{i,j,k}$	Greenhouse warming potential of GHG component i,j,k.
C_i	C stabilised by moving carbon from the short to the long-term carbon cycle [kg CO_2-e/kg(dry) organics].
s	mass fraction of occ that is stabilised from the short to the long-term carbon [kg/kg].
A_{method}	emissions abatement calculated using a particular approaches method (biogenic, stock, simplified) [kg CO_2-e/kg(dry) organics].
E_{BAU}	emissions forecast for the business-as-usual activity [kg CO_2-e/kg(dry) organics].
$E_{project}$	emissions forecast for the project activity [kg CO_2-e/kg(dry) organics].
$\delta_{a/b}$	absolute difference in emissions forecast between approach method a and b [kg CO_2-e/kg(dry) organics].
$E_{a,b}$	emissions forecast calculated using approach method a and b [kg CO_2-e/kg(dry) organics].
$\Delta_{a,/b}$	difference in emissions abatement calculated between approach methods a and b [kg CO_2-e/kg(dry) organics].
$A_{a,b}$	absolute emissions abatement calculated using approach method a and b [kg CO_2-e/kg(dry) organics].
BAU	Business-as-usual emission forecast.
Project	Project emission forecast.
$r_{j,k}$	mass fraction of GHG component j,k in landfill gas converted to carbon dioxide by landfill management [kg/kg].
$f_{,j,k}$	mass fraction of GHG component j,k in landfill gas produced by landfill [kg/kg].
m_W	mass of organic waste [kg (dry)].
γ	biochar yield [kg biochar/kg biomass] (dry basis).
A_{stock} (modified)	emissions abatement forecast of GHG to the atmosphere via the stock method amended for accurate representation of abatement projects [kg CO_2-e/kg(dry) organics].
B_i	emissions forecast of CO_2-e of non-GHG's in the BAU that have been abated in the project and released as CO_2 [kg CO_2-e/kg(dry) organics].

1.2. *Inventories and abatement*

Internationally, the threat of climate change due to elevated levels of greenhouse gases (GHG) in the atmosphere has led to a desire to both understand the flux of GHG between carbon pools and the abatement of anthropogenic GHG emissions achieved by changing practises.

A GHG inventory, that sums emissions and removals can be compiled on a range of scales, from a household, project, organisation, to a country. Countries that are parties to the United Nations Framework Convention on Climate Change (UNFCCC) report annually on their GHG inventories. Increasingly corporations are including GHG inventories of their operations in annual reports and are required by regulation to report their inventory to governments [3,4].

GHG flux estimation methodologies are applied to calculate the net emissions of activities so that they can be appropriately incentivised or discouraged. To determine the mitigation value of abatement activities the emissions are compared with the "business-as-usual" baseline. Calculations according to agreed methodologies are used under voluntary or compliance emissions trading schemes, where abatement projects or activities need to be accredited, measured, monitored and verified to determine the number of offset credits generated[5].

1.3. *Biomass carbon cycling*

The short-term carbon (C) cycle includes the uptake of CO_2 from the atmosphere by photosynthetic organisms that convert it to organic C molecules in solid state. The growth, death and degradation of these C reservoirs, or the cycling of atmospheric C being taken up and re-released via biomass, occurs in a time scale that is highly dependent on the lifecycle and habit of the plant, ranging from days to centuries. This is, however, a short-term cycle relative to the formation of fossil C structures such as coal and oil that takes millennia.

Pathways exist for stabilising biomass C in long-term terrestrial reservoirs via directing short-term cycling biomass C into a longer-term C pool, such as occurs for coal and oil. One such pathway is through the formation of charcoal [6–9]. The highly aromatic chemical structure of the carbon in charcoal means that it is dense and recalcitrant to environmental degradation, similar to fossil coal. The growing