ENVIRONMENTAL SCIENCE & POLICY 44 (2014) 164–173

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/envsci

Forest carbon accounting methods and the consequences of forest bioenergy for national greenhouse gas emissions inventories

Jon McKechnie [a,*], *Steve Colombo* [b], *Heather L. MacLean* [c]

[a] *Division of Energy & Sustainability, University of Nottingham, Nottingham NG7 2RD, UK*
[b] *Ontario Forest Research Institute, Ontario Ministry of Natural Resources, Sault Ste. Marie, Canada P6A 2E5*
[c] *Department of Civil Engineering and Department of Chemical Engineering and Applied Chemistry, University of Toronto, Toronto, Canada M5S 1A4*

ARTICLE INFO

Keywords:
Forest bioenergy
Life cycle assessment
AFOLU
Forest carbon
Wood pellets
Electricity

ABSTRACT

While bioenergy plays a key role in strategies for increasing renewable energy deployment, studies assessing greenhouse gas (GHG) emissions from forest bioenergy systems have identified a potential trade-off of the system with forest carbon stocks. Of particular importance to national GHG inventories is how trade-offs between forest carbon stocks and bioenergy production are accounted for within the Agriculture, Forestry and Other Land Use (AFOLU) sector under current and future international climate change mitigation agreements. Through a case study of electricity produced using wood pellets from harvested forest stands in Ontario, Canada, this study assesses the implications of forest carbon accounting approaches on net emissions attributable to pellets produced for domestic use or export. Particular emphasis is placed on the forest management reference level (FMRL) method, as it will be employed by most Annex I nations in the next Kyoto Protocol Commitment Period. While bioenergy production is found to reduce forest carbon sequestration, under the FMRL approach this trade-off may not be accounted for and thus not incur an accountable AFOLU-related emission, provided that total forest harvest remains at or below that defined under the FMRL baseline. In contrast, accounting for forest carbon trade-offs associated with harvest for bioenergy results in an increase in net GHG emissions (AFOLU and life cycle emissions) lasting 37 or 90 years (if displacing coal or natural gas combined cycle generation, respectively). AFOLU emissions calculated using the Gross-Net approach are dominated by legacy effects of past management and natural disturbance, indicating near-term net forest carbon increase but longer-term reduction in forest carbon stocks. Export of wood pellets to EU markets does not greatly affect the total life cycle GHG emissions of wood pellets. However, pellet exporting countries risk creating a considerable GHG emissions burden, as they are responsible for AFOLU and bioenergy production emissions but do not receive credit for pellets displacing fossil fuel-related GHG emissions. Countries producing bioenergy from forest biomass, whether for domestic use or for export, should carefully consider potential implications of alternate forest carbon accounting methods to ensure that potential bioenergy pathways can contribute to GHG emissions reduction targets.

* *Corresponding author*. Tel.: +44 0115 74 84435.
E-mail address: jon.mckechnie@nottingham.ac.uk (J. McKechnie).

http://dx.doi.org/10.1016/j.envsci.2014.07.006
1462-9011/

1. Introduction

Electricity generation from forest biomass offers the potential to reduce greenhouse gas (GHG) emissions relative to fossil fuel generation, while also addressing sustainability concerns such as non-renewable resource use, air pollutant emissions, and energy security. The flexibility of bioenergy as a potential alternative energy source for heat, transport, and electricity applications has led to its inclusion in national strategies for reducing GHG emissions and increasing renewable energy penetration (e.g., UK DECC, 2012). Risks associated with forest bioenergy production, in particular the impact on forest carbon sequestration and potential GHG emissions consequences, have been identified in several studies (e.g., Searchinger et al., 2009; McKechnie et al., 2011; Vanhala et al., 2013). Of particular importance to national GHG inventories is how trade-offs between forest carbon stocks and bioenergy production are accounted for within current and future international climate change mitigation agreements.

Under the United Nations Framework Convention on Climate Change, bioenergy systems straddle the Energy sector and the Agriculture, Forestry and Other Land Use (AFOLU) sector, with the latter accounting for terrestrial carbon stocks. To avoid double-counting, CO_2 emissions from biomass combustion are excluded from GHG accounting within the energy sector. Implications of these emissions on atmospheric GHGs are assessed indirectly through terrestrial carbon stock accounting under the AFOLU sector. Conventional life cycle assessment methods similarly do not account for biomass-based CO_2 emissions in the assessment of bioenergy systems. Life cycle studies commonly assume that these emissions are balanced by post-harvest biomass regrowth and thus do not contribute to atmospheric GHGs (e.g., Zhang et al., 2010). Research has highlighted the possible shortcomings of this accounting approach, as it risks omitting potentially significant carbon stock changes resulting from bioenergy production (e.g., Searchinger et al., 2008). Recent studies of bioenergy have developed integrated life cycle and forest carbon analysis methods to include forest carbon impacts within life cycle studies (e.g., McKechnie et al., 2011; Helin et al., 2012). Net GHG emissions, inclusive of life cycle activities and forest carbon impacts, are time dependent: forest carbon removals at harvest are compensated by forest regrowth, which occurs over a comparatively long timescale. Trade-offs between forest biomass-based bioenergy production and forest carbon stocks have been found to result in increased GHG emissions relative to fossil fuels lasting decades to more than 100 years (e.g., McKechnie et al., 2011; Ter-Mikaelian et al., 2011).

Lacking in prior applications of integrated life cycle/forest carbon analysis methods is a consideration of how trade-offs between bioenergy and forest carbon would be accounted for under climate change mitigation agreements and national emissions inventories. Accounting for forest carbon stocks within GHG emissions inventories is complex, due in part to the long-term consequences of previous management decisions and natural disturbances (Bottcher et al., 2008). Accounting rules have been proposed and prior studies have evaluated the implications of these rules on the assessed GHG emissions/sinks for managed forests (e.g., Bottcher et al., 2008; Ellison et al., 2011). Under the 2nd Commitment Period of the Kyoto Protocol, most reporting nations have chosen to measure forest carbon stock changes by first identifying a forest management reference level (FMRL) to define a dynamic, forward looking baseline to which future forest carbon stocks are compared (UNFCCC, 2013b). While alternate accounting methods can greatly impact assessed AFOLU emissions (Bottcher et al., 2008), implications of accounting methods on the emissions attributable to forest bioenergy have yet to be investigated.

The North American wood pellet industry has grown rapidly in response to demand in domestic and export markets (FBN, 2013), fuelled in part by initiatives in EU countries to implement biomass co-firing and repowering of coal generating stations to meet renewable energy and GHG emissions reduction targets. Alongside potential pellet sources in the US Southeast (e.g., Dwivedi et al., 2014), wood pellet export from Ontario, Canada, to international markets is developing as a supply chain (Rentech, 2014). It is thus important to understand the potential implications of wood pellet production and trade for producer country's national emissions inventories. The objective of this study is to investigate how forest carbon accounting approaches employed within the AFOLU sector might impact emissions attributable to forest bioenergy within national emissions inventories. We expand on existing life cycle and forest carbon analysis models to quantify AFOLU emissions resulting from forest bioenergy production under three alternative forest carbon accounting methods. This novel assessment approach is applied to a case study of wood pellet production from harvested forest stands in the Great Lakes – St. Lawrence Forest Region of Ontario, Canada. Life cycle GHG emissions are quantified for both domestic pellet consumption and export of pellets to a hypothetical EU consumer to compare implications for Canada's emissions inventory.

2. Forest carbon accounting approaches

Forest carbon accounting approaches are designed to quantify the impact of management (e.g., deforestation/afforestation; harvest/renewal) on atmospheric GHGs. Applied nationally, these approaches determine the net GHG emissions sink (or source) related to forests, a component of the AFOLU sector, for inclusion in national inventories. While forest carbon accounting approaches are not designed to assess the impact of a particular forest product, we adapt these methods, as described below, to better understand the implications of increased forest resource utilization for bioenergy production. Forest carbon accounting approaches have been described in detail elsewhere (e.g., Bottcher et al., 2008). A simple and general representation of changes in forest carbon stocks that would be accountable within national inventories, as either an emissions source or sink, can be presented by:

$$\Delta C_{acc} = \Delta C_{obs} - \Delta C_{base} \quad (1)$$

where ΔC_{acc} is the accountable change in forest carbon stocks over a set period of time, ΔC_{obs} is the observed change in forest