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A carbon accounting tool for complex and uncertain greenhouse gas emission life cycles

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ABSTRACT

Software applications for life cycle assessment of greenhouse gas (GHG) emissions have become popular over the last decade. Their objective is to provide insight into how GHG emissions could be reduced in the sectors defined by the UNFCCC. However, boundaries between these sectors are not closed and current tools are not designed to represent this complexity or to assess the numerous sources of uncertainties.

In this paper, we present CAT v1.0, software developed for managed forests in the LULUCF sector, but whose emission life cycle is linked to that of other sectors. While the structure of the software follows IPCC Guidelines, it also contains additional features such as an embedded Monte-Carlo error propagation technique and a user-friendly flux manager that allows for complex cradle-to-grave representations of the wood transformation industry. The flexibility of the software is illustrated through two case studies in northeastern France.

1. Introduction

Since the adoption of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, the accounting of anthropogenic greenhouse gas (GHG) emissions has become an international issue. Every year, the members of the UNFCCC that were recognized as industrialized countries in 1992, better known as Annex I countries, have to report their national GHG emissions in different sectors (UNFCCC, 2014): (i) Energy; (ii) Industrial processes and product use; (iii) Agriculture; (iv) Land use, land-use change and forestry (LULUCF); and (v) Waste.

Since 1995, the International Panel on Climate Change (IPCC) has published guidelines that establish the methodological basis for carbon accounting in all the aforementioned sectors. However, their implementation is not straightforward and can be hindered by numerous uncertainties, risks of carbon leakage and double counting (Fortin et al., 2012; Dong et al., 2013), affecting interpretations even for experts in this field (Shvidenko et al., 2010; Jonas et al., 2010). One reason is due to the fact that the boundaries between the five sectors are not closed, forming complex emission life cycles that are hard to represent and even harder to evaluate.

In the LULUCF sector, for example, the cost-efficiency and carbon balance heavily depend on the correct but complex integration between multiple lines of wood extraction, transportation, transformation and production, and the fossil CO_2 emissions that can be linked to the industrial processes sector. The production of biomass clearly interacts with the energy sector. Management of the harvested wood products after their useful lifetime belongs to the waste sector. All these interactions are hard to evaluate and decision-makers therefore need software-implemented carbon accounting tools to obtain an overall view of the big picture.

This increasing popularity of carbon accounting tools is not limited to the LULUCF sector. However, regardless of the sector, most of these tools show major limitations as to how emission life cycles can be realistically and easily represented, and to how the uncertainties associated with these complex life cycles can be assessed. With respect to uncertainty assessment, theory on the topic shows that the more complex and integrated the life cycle is, with cascading use and open/multi-loops operating at different scales, the greater the need for sophisticated error propagation methods will be (Groen et al., 2014). Among the 15 tools reviewed by Gentil et al. (2010) in the waste sector, uncertainty assessment was not even selected as a primary criterion of software evaluation, mirroring the fact that uncertainty assessment was applied in only 4% of the case studies (Laurent et al., 2014). Similarly, Whittaker et al. (2013) found that only one out of 11 carbon accounting tools used in the UK agricultural sector implemented some features for uncertainty assessment. In the LULUCF sector, where carbon accounting tools are even more abundant, Brunet-Navarro et al. (2016) reported 41 tools, with only 40% of them integrating uncertainty assessment features of any sort.

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1364-8152/

Software

Name CAT v1.0
Developer Mathieu Fortin, UMR Silva, INRA/UL/AgroParisTech, 54000 Nancy, France; E-mail: mathieu.fortin.re@gmail.com
Available since 2017
Hardware required No specific requirement
Software required Java 8
Availability Fully available at https://sourceforge.net/projects/lerfobforesttools/files/CAT/
Website https://sourceforge.net/p/lerfobforesttools/wiki/CAT/
License LGPL v3
Cost Free
Program language Java
Program size 7.1 MB

Regarding the realism of the life cycles represented, most carbon accounting tools are designed to provide the carbon balance over a regional supply chain or with a predefined generic structure representing the basic supply chain compartments, including extraction, transport, production lines, product use and end-of-life. Users can change the interactions between the components of the emission life cycle in only a limited number of carbon accounting tools. However, even in these few cases, the changes need to be hard-coded or implemented in a spreadsheet like in the CO2fix model (Schelhaas et al., 2004) or the COT module of REMSOFT™ (Cameron et al., 2013). All of this inevitably hinders the capacity of users to obtain a reliable uncertainty assessment and to avoid carbon leakages and double counting when dealing with these complex emission life cycles. It also distorts the big picture so that the cost and benefits of detailed disruptive technologies, management and policies that could help reduce GHG emissions through a better integration of the different sectors cannot be evaluated.

In this paper, we present CAT v1.0, a software platform that mainly applies to managed forests in the LULUCF sector, but also considers interactions with other sectors. The tool offers a user-friendly interface that makes it possible to represent complex emission life cycles inherent to managed forests. Moreover, the assessment of the carbon balance is supported by built-in Monte Carlo error propagation methods. CAT was initially developed as part of a larger forestry modeling initiative within the open-source CAPSIS platform (Computer Aided Projections of Strategies in Silviculture: see Dufour-Kowalski et al. (2012)), but its implementation has been improved to create a standalone application.

This paper is structured as follows: we first describe the architecture of CAT with its different carbon pools, as well as how uncertainty assessment and scenario comparisons can be carried out. A second section presents the Java implementation of the software and the user interface that enables the design and comparison of complex emission life cycles. We then showcase the modularity of CAT in a third section, based on two case studies in Lorraine, the largest forested region of France. Changes in the harvesting, production lines, diversity of products and end-of-life processes are suggested and debated at a regional level to support the cost-effective transition from fossil fuel to renewable energy, as well as the use of grow-and-bury strategies to improve the carbon balance of the region. We finally discuss the interest of CAT for future software in combination with previous initiatives and future challenges. The source code of CAT, the compiled application to reproduce the results of the case studies, and the basic technical services can be found at https://sourceforge.net/p/lerfobforesttools/wiki/CAT/ .

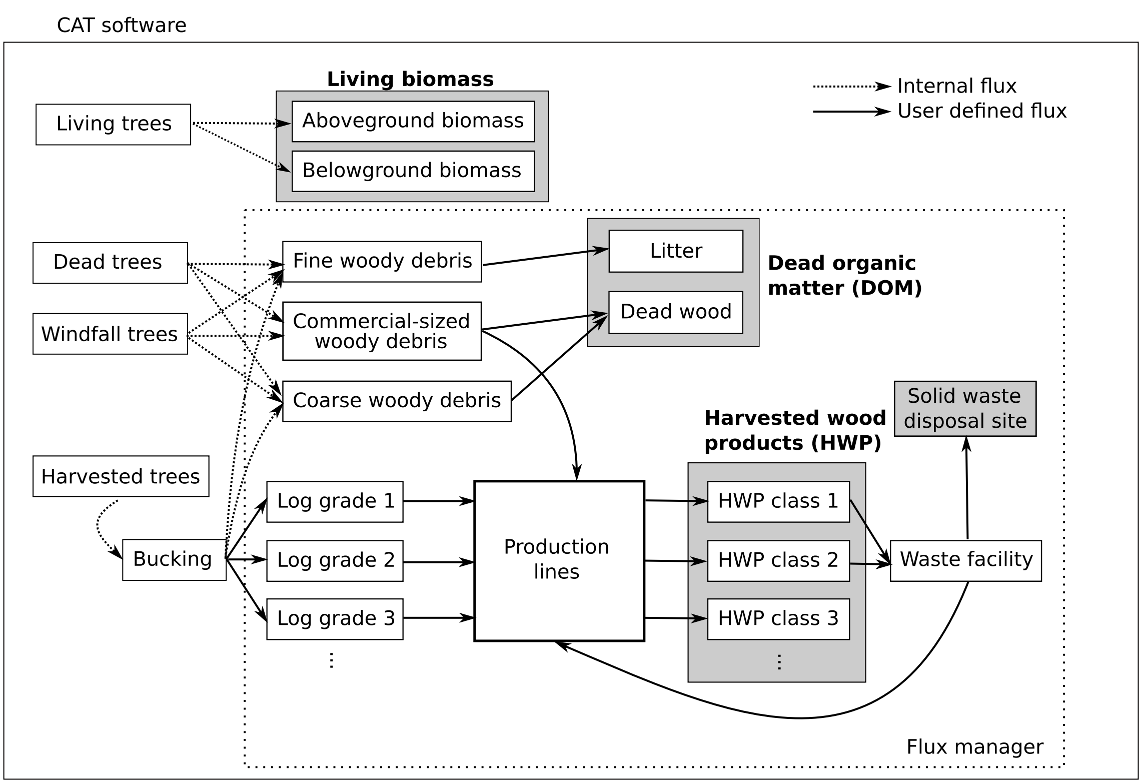

Fig. 1. Flowchart of CAT for the trees retrieved at a given time *t* of the growth simulation. The shaded boxes are the carbon pools. The waste facility implements recycling so that some harvested wood products (HWP) can be recycled after their useful lifetime. Note that the HWP of class 3 are deliberately assumed to oxidize after their useful lifetime. All solid line fluxes can be changed by the user. The internal fluxes are meant to avoid biomass leakage.