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Review

Linking carbon stock change from land-use change to consumption of agricultural products: A review with Indonesian palm oil as a case study

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ABSTRACT

Numerous analyses have been performed to quantitatively link carbon stock change caused by land-use change (CSC-LUC) to consumption of agricultural products, but results differ significantly, even for studies focussing on the same region or product. This is due to the different focuses and interpretations of the links between direct drivers and underlying causes of CSC-LUC, which can be translated into differences in key functions, i.e. specific methods, algorithms and parameters embedded in the analysis. Using the example of Indonesian palm oil production (often associated with CSC-LUC), this paper carries out a meta-analysis of 12 existing studies, determines the different settings for the key functions embedded in consumption-based CSC-LUC studies and discussed their implications for policymaking. It identifies the underlying reasons of adopting different settings within the eight key functions and their advantages and trade-offs. Examples are the way of determining how deforestation is linked to oil palm, and the inclusion of non-agriculture and non-productive drivers in the accounting to weight their roles in CSC-LUC in comparison to palm oil consumption. Following that, the quantitative results from the selected studies were processed and harmonised in terms of unit, allocation mechanism, allocation key and amortisation period. This resulting in ranges of 0.1–3.8 and −0.1–15.7 tCO_2/t crude palm oil for historical and projection studies, respectively. It was observed that CSC-LUC allocated to palm oil is typically lower when propagating effects and non-agricultural or non-productive drivers were accounted for. Values also greatly differ when marginal and average allocation mechanisms were employed. Conclusively, individual analyses only answer part of the question about CSC-LUC drivers and have their own strengths and weaknesses. Since the context can be very different, using quantitative results from a single study for accounting purposes in policymaking is not recommended. Instead, insights from different studies should be combined, e.g. the relative role of logging and oil palm or the contribution to CSC-LUC in regional and global perspectives.

Contents

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1. Introduction

Carbon stock change as a consequence of land-use change (CSC-LUC) plays a significant role in global greenhouse gas emissions, contributing to 8–20% of annual global anthropogenic CO_2 emissions through deforestation, forest degradation and peat emissions (van der Werf et al., 2009). Deforestation as the major source of carbon stock loss has increased substantially in tropical regions, although afforestation, the major carbon stock gain, has increased in other regions like Europe and East Asia (FAOSTAT, 2016).

Many studies have focused on identifying direct drivers (also called proximate causes) of CSC-LUC, e.g. logging and agricultural expansion (e.g. Koh et al., 2011; Wicke et al., 2011). These direct drivers, especially human activities, are closely related to both local and distant underlying causes derived from social, economic, political, cultural and technological processes, e.g. changes in socio-economic environment, new land-use policies or consumption patterns (Geist and Lambin, 2002). Despite efforts to relate these underlying causes to CSC-LUC, it remains a challenge to provide quantitative indications (Azadi et al., 2010; Kissinger et al., 2012; Lambin et al., 2001; Xie et al., 2005). This is becoming more complicated with the shifts of carbon intensive activities from one region to another (i.e. carbon leakage), particularly in the form of export-oriented agricultural expansion (Ostwald and Henders, 2014).

A way to come closer to quantifying underlying causes is associating CSC-LUC with measurable consumption and trade patterns of land-use based products, i.e. consumption-based accounting analyses (Peters, 2008; Larsen and Hertwich, 2009; Davis and Caldeira, 2010). These analyses can be widely categorised as: (i) *historical* studies which examine the historical consumption of agricultural commodities in general and linking this to CSC-LUC (e.g. Yu et al., 2013), and (ii) *projection* studies, which examine potential CSC-LUC impacts of specific causes or drivers, including for example studies on indirect land-use change (ILUC) induced by biofuels (e.g. Laborde, 2011).

While both types of studies have different starting points (historical and future perspectives), they both contribute to the discussion of consumption-based land-use accounting. These studies generate a large amount of quantitative indications, but the results vary from one to another significantly. For historical studies, reviews (e.g. Bruckner et al., 2015; Hubacek and Feng, 2016; Schaffartzik et al., 2015; Wiedmann, 2016) have revealed the large discrepancies between quantitative results produced by different studies. For projection studies, reviews on ILUC analyses (e.g. Wicke et al., 2012; Warner et al., 2013; Ahlgren and Di Lucia, 2014) have also found that the land-use emissions projected for biofuels in different studies scattered in a wide range, even for studies that employed similar methods (e.g. computable general equilibrium models). A common finding from these reviews is that the differences in methods, algorithms and parameters are the main reasons for these differences. For communication, these sets of methods, algorithms and parameters may be collectively referred to as methodological 'functions', with key examples of such a function being the classification of land and products or the allocation mechanism.

The diversity of settings for these functions may be due to the different focuses and interpretations of the links between direct drivers and complex underlying causes of CSC-LUC, and may involve value judgements (Brandão et al., 2012; Creutzig et al., 2012). For example, it is possible to allocate certain CSC-LUC to vegetable oils in general assuming perfect substitutability (where the driver is the increased consumption of vegetable oils in general), while the other may consider the differences between oil crops (where the driver is the increased consumption of certain types of vegetable oil). The differences in key functions also affect the compatibility of datasets used for analysis, e.g. when different names and definitions of forest are used (Bruckner et al., 2015; De Rosa et al., 2016).

Indonesian palm oil, a largely export oriented commodity, has received a lot of attention among researchers, civil society and policymakers due to its role in CSC-LUC (Sheil et al., 2009). In 2006–2010, the carbon stock loss in Indonesia has contributed to at least 3% of global anthropogenic CO_2 emissions emission, for which oil palm expansion may be significantly accounted for (Agus et al., 2013; van der Werf et al., 2009). In addition to being an important food source, palm oil is also a major feedstock for chemical products and biofuel production. The role of palm oil in CSC-LUC (and its links to export) has been quantitatively evaluated in various manners through historical and projection approach (e.g. Henders et al., 2015; Laborde, 2011). Their quantitative results are often inconsistent, and some are even contradictory in their policy advises. Given that the reasons for discrepancy are not always made clear, this creates confusions among decision makers on both production and consumption side.

Existing literature reviews only examine either historical (e.g. Schaffartzik et al., 2015) or projection studies (e.g. Wicke et al., 2012), but have not compared them in terms of underlying functions and their settings. Strictly speaking, the quantitative results come from these two types of studies cannot be compared directly due to differences in starting point (similar to the issue of attributional and consequential life cycle analysis, see Creutzig et al., 2012). However, they share similar methodological functions, which can be translated into important policy implications. Comparison of, and possibly exchange between these two types of studies may help to account for arbitrary characters embedded within these key functions, and to explain differences between them. For example, if one wants to know how palm oil performed in the past and will perform in the future, the way of distributing CSC-LUC between palm oil and other drivers (e.g. logging and fire), which could involve arbitrary assumptions, needs to be first understood. Assessing the underlying functions helps to clarify the