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Integration of ecosystem services into the carbon footprint of milk of South German dairy farms

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ABSTRACT

Allocation of greenhouse gas emissions (GHG) in Life Cycle Assessments (LCA) is challenging especially when multi-functionality of dairy farms, which do not only produce milk but also meat is considered. Moreover, some farms fulfill a wide range of additional services for society such as management of renewable natural resources as well as preservation of biodiversity and cultural landscapes. Due to the increasing degradation of ecosystems many industrialized as well as developing countries designed payment systems for environmental services.

This study examines different allocation methods of GHG for a comparatively large convenience sample of 113 dairy farms located in grassland-based areas of southern Germany. Results are carbon footprints of 1.99 kg CO_2eq/kg of fat and protein corrected milk (FPCM) on average if “no allocation” for coupled products is performed. “Physical allocation” results in 1.53 kg CO_2eq/kg FPCM and “conventional economic allocation” in 1.66 kg CO_2eq/kg FPCM on average if emissions are apportioned between milk and meat. Economic allocation which includes ecosystem services for society based on the farm net income as a new aspect in this study results in a carbon footprint of 1.5 kg CO_2eq/kg FPCM on average. System expansion that puts greater emphasis on coupled beef production accounts for a carbon footprint of 0.68 kg CO_2eq/kg FPCM on average.

Intense milk production systems with higher milk yields show better results based on “no allocation”, “physical allocation” and “conventional economic allocation”. By contrast, economic allocation, which takes into account ecosystem services favors extensive systems, especially in less favored areas. This shows that carbon footprints of dairy farms should not be examined one-dimensionally based on the amount of milk and meat that is produced on the farm. Rather, a broader perspective is necessary that takes into account the multi-functionality of dairy farms especially in countries where a wide range of ecosystem services is provided.

1. Introduction

Ruminants contribute more than 30% to global methane emission, with methane being a major greenhouse gas besides carbon dioxide (CO_2) and nitrous oxide (N_2O) (IPCC, 2007). Among the anthropogenic greenhouse gas (GHG) emissions, the dairy sector has a share of approx. 3%, which increases to 4% when meat products which are coupled with milk production are taken into account (Gerber et al., 2010). Carbon footprints for milk vary between 0.8 and 1.6 kg CO_2 equivalents (CO_2eq) in most studies depending on assumptions and methodology (Pirlo, 2012). But usually these studies focus only on milk production and to a minor extent on the coupled beef production. In fact, a dairy farm should be considered as a multi-functional system (OECD, 2001), where the emissions must be apportioned to the individual functions via allocation (Ekvall and Finnveden, 2001). These functions are: producing meat in addition to milk (Zehetmeier et al., 2012) and providing a wide range of additional ecosystem services (Bernués et al., 2011). The latter ones are typically non-market goods, but there is a willingness by society to pay for them (Bernués et al., 2014). Millenium Ecosystem Assessment (2005) refers to these additional functions as “cultural ecosystems services”, which include management of renewable natural resources, socio-economic viability of many natural areas (OECD, 2001) and preservation of biodiversity as well as of cultural landscapes (Plieninger et al., 2006). However, ecosystem services which are mainly

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provided by farms in less favored regions that keep cows on pastures (Bernués et al., 2011, 2005), have not been included into investigations of carbon footprints yet. Thus, increase in milk production intensity in more favored areas recommended by many authors from the climatic point of view would simultaneously result in displacement processes as well as increasing forest and bush vegetation in less favored regions. In contrast, more extensive milk production systems that are adjusted to such locations might at least partly prevent the above processes and provide ecosystem services as demanded by society (Bernués et al., 2005, 2014). Concerning this matter also Ripoll-Bosch et al. (2013) point to the multi-functionality particularly of pasture-based production systems and recommend their consideration in greenhouse gas balancing. This concerns all regions of the world where dairy farms provide such ecosystem services.

Therefore, a total of 113 South German dairy farms were selected for an empirical study investigating their carbon footprint in the economic years 2009 through 2011. The heterogenous sample included intensely managed dairy farms featuring high milk yields as well as very extensively, partly organically managed farms, whose income is generated by financial compensation for providing ecosystem services (preservation and forming of landscapes, preservation of species, etc.) besides milk production. The objective of this paper is to compare existing allocation methods of apportioning emissions between milk and meat (no allocation, physical and economic allocation, system expansion) (Cederberg and Stadig, 2003; Thomassen et al., 2008; Flysjö et al., 2011a) with a new approach integrating ecosystem services into economic allocation (Ripoll-Bosch et al., 2013). This approach takes into account the payments from the 2nd pillar of common agricultural policy of the European Union besides the sales of milk and meat. Considering the difficulties of estimating the value of ecosystem services, these payments can be seen as an indicator of ecosystem services of dairy farms and are intended to compensate farmers for income losses and costs for voluntary environmental protection measures (Ripoll-Bosch et al., 2013). Even in countries outside the European Union (eg. China, Australia, USA, Costa Rica, and Mexico) different payment approaches for ecosystem services have been implemented (Wunder et al., 2008; Sattler et al., 2013; Schomers and Matzdorf, 2013).

2. Description of methodology, system boundary and allocation of coupled products in milk production

The calculated greenhouse gas balances are expressed for each individual farm as a standardized carbon footprint (De Vries and De Boer, 2009), which can be regarded as part of life cycle assessment (LCA). A specially programmed Microsoft Excel spreadsheet was used for determining the carbon footprint in accordance with the directives of IDF (2010) and the Intergovernmental Panel on Climate Change (IPCC, 2006a, 2006b) and the SPSS software was used for statistical analysis. The three economic years were each consolidated as averaged mean values. The directives of IPCC (2006a) but also the database of the German Federal Environmental Agency "Prozessorientierte Basisdaten für Umweltmanagement-Instrumente (ProBas)" (Federal Environmental Agency, 2013) were used as database for the emission factors, because these values seemed most appropriate for the German farms studied. With over 8000 data sets, the database ProBas constitutes one of the most long-lasting and voluminous online databases among the freely accessible databases (Juric, 2009).

All gases were converted into CO_2 equivalents to achieve standardization. Furthermore, the global warming potential for an individual carbon footprint was modeled in view of the next 100 years as follows: 1 kg CO_2eq/kg CO_2, 25 kg CO_2eq/kg CH_4 and 298 kg CO_2eq/kg N_2O (IPCC, 2007).

The model applied to the greenhouse gas balance calculation takes into account all inputs of the farms with farm specific values including feed, diesel, electricity, mineral fertilizer, pesticides and the number of heifers supplied to the farm. The products milk, meat and ecosystem services as well as the associated emissions count as output. Only those areas were taken into account, which actually serve for dairy production including rearing of heifers whereas crops that bear no relation to dairy production remained unconsidered.

The approach "cradle-to-farm-gate" according to which the carbon footprints are only accounted for as far as to the milk tank is regarded as the system boundary of milk production, because the production phase has the greatest impact on the greenhouse gas balance (e.g. Cederberg and Stadig, 2003; Rotz et al., 2010; O'Brien et al., 2011; Yan et al., 2013).

The functional unit (FU) for carbon footprint is 1 kg fat- and protein-corrected milk (FPCM), which is standardized according to IDF (2010).

2.1. Options for dealing with co-products of milk production for carbon footprint calculation

The present paper compares the new approach of "Economic allocation including ecosystem services" with the following three existing allocation methods with an allocation factor as well as system expansion in order to determine the methodology-specific effects on carbon footprint results of dealing with coupled products:

(1) "No allocation": Total greenhouse gas burden of the production system is apportioned to the milk produced. This approach may be advantageous if delimitation of the products milk and beef appears to be unnecessary because the aim is to detect potentials of reducing overall emission (Flysjö et al., 2011b; Yan et al., 2011). Additional services of dairy farms next to milk production are not taken into account.

(2) "Physical allocation": IDF (2010) recommends physical allocation for the apportionment of emissions. This approach is based on the relationship between the cow's feed energy intake and its production of milk and beef. The emissions attributable to beef are deducted from total emissions based on animal weight of the specific breed. This allocation is calculated according to IDF (2010) using the following formula:

$$AF = 1 - 5.7717 \times R$$

where: AF = allocation factor milk

R = amount of beef (kg life weight)/amount of milk (kg FPCM)

(3) "Conventional economic allocation (milk + meat)": Conventional economic allocation is based on the economic relationship of milk and meat. The emissions were apportioned to the milk and meat prices (average values of three economic years 2009–2011) surveyed. The allocation factor for the apportionment of emissions was determined based on the relationship of the amount of milk and meat multiplied with their respective quantities. The average milk sales revenue in the sample during the three economic years