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Research article

Determination of the carbon footprint of all Galician production and consumption activities: Lessons learnt and guidelines for policymakers

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ABSTRACT

Galicia is an Autonomous Community located in the north-west of Spain. As a starting point to implement mitigation and adaptation measures to climate change, a regional greenhouse gas (GHG) inventory is needed. So far, the only regional GHG inventories available are limited to the territorial emissions of those production activities which are expected to cause major environmental degradation.

An alternative approach has been followed here to quantify all the on-site (direct) and embodied (indirect) GHG emissions related to all Galician production and consumption activities. The carbon footprint (CF) was calculated following the territorial life cycle assessment (LCA) methodology for data collection, that combines bottom-up and top-down approaches. The most up-to-date statistical data and life cycle inventories available were used to compute all GHG emissions.

This case study represents a leap of scale when compared to existing studies, thus addressing the issue of double counting, which arises when considering all the production activities of a large region.

The CF of the consumption activities in Galicia is 17.8 $ktCO_2e$/year, with 88% allocated to Galician inhabitants and 12% to tourist consumption. The proposed methodology also identifies the main important contributors to GHG emissions and shows where regional reduction efforts should be made. The major contributor to the CF of inhabitants is housing (32%), followed by food consumption (29%). Within the CF of tourist consumption, the share of transport is highest (59%), followed by housing (26%). The CF of Galician production reaches 34.9 $MtCO_2e$/y, and its major contributor is electricity production (21%), followed by food manufacturing (19%).

Our results have been compared to those reported for other regions, actions aimed at reducing GHG emissions have been proposed, and data gaps and limitations identified.

1. Introduction

To address climate change, the United Nations Framework Convention on Climate Change (UNFCCC) has implemented several strategies for more than 20 years (United Nations, 1992). The first action must be the development and publication of national GHG inventories that serve as a basis for further actions (e.g., identification of hotspots and mitigation proposals). Spain, as a party to the UNFCCC, publishes periodically its GHG emissions inventory, which is further subdivided among the administrative regions of the country (i.e. the Autonomous Communities), which often have the competencies to develop subsequent policy measures (MAGRAMA, 2016b).

This study focuses on Galicia, an Autonomous Community located in the north west of Spain. Due to its location and climate, the studies that evaluate the effects of GHG emissions in northern Europe or the Mediterranean areas are not applicable, and the development of individualized studies are necessary (MAGRAMA, 2016a). As a result, the regional government launched several initiatives to measure the GHG emissions within the territory (Xunta de Galicia, 2009), to determine their effects on the climate and the ecosystems, and to propose mitigation and adaptation actions (Xunta de Galicia, 2010). So far, the available Galician UNFCCC inventories are based on the general Intergovernmental Panel on

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Climate Change methodology (IPCC, 2006), and thus only include the direct GHG emissions of those sectors which are expected to cause major environmental degradation, neglecting imported indirect emissions and many other small contributors. This means that the Galician GHG emissions are computed according to a producer territory-based approach.

In environmental accounting, there are two main approaches to allocate the environmental impacts linked to a region, the producer approach and the consumer approach (Peters and Hertwich, 2008).

Under the producer approach, a given region is responsible for all the on-site (direct) emissions that are directly generated within its borders. In practice, there are two types of borders considered: following the territory principle (including all the emissions occurring within a geographical area) or the residence principle (including all the emissions of resident economic units, even if these occur outside the studied territory) (Barrett et al., 2013). The former approach was applied in the Kyoto protocol, while the latter is applied in the European National Accounting Matrix including Environmental Accounts −NAMEA (Eurostat, 2016).

Under the consumer approach, a certain region is responsible for the upstream emissions of the products it consumes, regardless of where they happen. Thus, consumption-based emissions can be obtained from its direct, production-based emissions by excluding those emissions embedded in the exports and including the emissions embodied in the imports, also named indirect emissions (Peters, 2008). The consumer approach has achieved a wide diffusion in recent years, being applied in numerous studies at different scales (e.g. (Brizga et al., 2017; Dias et al., 2014; Ozawa-Meida et al., 2013)). The choice between the two accounting principles is not straightforward (Munksgaard and Pedersen, 2001), and both consumption-based and production-based approaches present disadvantages. Environmental policies based on the producer approach alone may lead to shifts in environmental pressures towards regions with less strict policies, and therefore to a global increase of GHG emissions (Caro et al., 2015), often referred to as carbon leakage. However, determining environmental impacts following the consumer approach requires complex, and often incomplete models (Lenzen et al., 2012), and it is also more difficult to pursue policies based on its results when compared to those of the production approach, since policies directed at lowering the environmental pressures across country borders are usually beyond the legislative competencies of national governments (Wilting and Vringer, 2009).

In terms of climate policy, assigning full responsibility to a certain agent (producer or consumer) is unlikely to be accepted (Marques et al., 2012), and it is argued that intermediate approaches could facilitate international agreement on global climate policy (Davis and Caldeira, 2010). Thus, several authors have proposed intermediate procedures where the responsibility is shared between the different agents of the supply chain based on different parameters, such as their carbon emissions (Bastianoni et al., 2004), value added (Lenzen et al., 2007), a combination of final expenditure and value added (Rodrigues et al., 2006) etc. Detailed descriptions of the available approaches can be found in Rodrigues et al. (2010) and Cadarso et al. (2012).

Considering a life cycle perspective (ISO 14040:2006), and thus including the direct and embodied emissions, can provide a more complete knowledge of the total environmental impacts that each region is ultimately responsible for (BSI, 2013; WRI et al., 2014). This can be done by computing its carbon footprint (CF), an indicator that allows expressing the total GHG in a single figure, stated as CO_2 equivalents (Carbon Trust, 2012). This indicator is intuitive and easy to understand by non-expert users, and it has been widely used in recent decades (Steen-Olsen et al., 2016; Weidema et al., 2008).

The CF has been frequently used in determining the environmental impacts of particular products obtained in Galicia, such as cheese (González-García et al., 2013), milk (Hospido et al., 2003; Iribarren et al., 2011a; Roibás et al., 2016), fish (Hospido and Tyedmers, 2005; Hospido et al., 2006; Vázquez-Rowe et al., 2014) or wine (Vázquez-Rowe et al., 2012; Villanueva-Rey et al., 2014), and even to a whole sector of activity: the fishing sector (Iribarren et al., 2011b). At this fine scale, a bottom-up approach such as the one offered by process-based life cycle assessment (LCA) is generally used (Peters, 2010). By contrast, there are numerous studies that propose to assess the final consumption CF of entire countries (Wiedmann, 2009). At this larger scale, the top-down approach, based on environmentally extended input-output tables (EIO), is widely used (Peters, 2010). EIO tables reflect the interactions among different sectors and relate environmental impacts to economic values. Studies at intermediate scales, such as those of cities, can also be found in the literature (Heinonen and Junnila, 2011; Lin et al., 2013; Minx et al., 2013). These studies adopt a hybrid approach, which combines both strategies looking to benefit from the high precision of process-based LCA (which identifies the particular process which is responsible for a certain environmental burden) and the calculation simplicity and the exhaustiveness (considering all sectors within a certain economy and thus excluding cut-offs) of EIO tables (Wiedmann and Minx, 2008; Wright et al., 2011). However, examples at intermediate scales (cities, subnational regions) tend to consider only one side of activities, final consumption of households or some specific production activities. The aim of this paper is to provide an exhaustive annual GHG overview of all production and consumption activities that take place within the region of Galicia, starting from the most recent data available. A hybrid approach based on territorial LCA is adopted (Loiseau et al., 2013). This case study focuses on a larger region than the previous applications of the territorial LCA methodology (Loiseau et al., 2013, 2014), although it is also conducted at a subnational level. This raises several methodological issues in terms of data collection and representativeness compared to many studies determining the CF of entire countries. In large regions such as Galicia, numerous local products are used again as raw materials within the same area. These inter-industry flows must be considered, and the double-counting issue is thus addressed in this paper.

2. Materials and methods

2.1. Description of the case study

Galicia is one of the 17 Autonomous communities that constitute Spain. Located in the North-West of the Iberian Peninsula, it is bordered by Portugal to the south, and by the Atlantic Ocean to the west and the north. The region has a population of 2,732,347 inhabitants, and a total area of 29,574 km^2 (IGE, 2015). The primary economic sector represents 5% of the Gross Domestic Product (GDP), the secondary sector 26% and the tertiary sector the remaining 69%. The importance of both the primary and secondary sectors is higher than in the rest of Spain, where primary represents 3% and secondary 22% of GDP (INE, 2014a). The Galician touristic sector is also an important source of income, representing 11.1% of regional GDP (Exceltur, 2014).

The region was chosen for several reasons: i) there are numerous Galician case studies that compute CF of specific products or activities, none for all regional production and consumption activities; ii) the territorial LCA methodology developed to collect environmental flows for all production and consumption activities has never been applied to other contexts than France and only to small areas; iii) the regional particular economic characteristics, where the primary sector −and especially the livestock sector,