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Research article

A simplified approach to determine the carbon footprint of a region: Key learning points from a Galician study

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A B S T R A C T

On a previous study, the carbon footprint (CF) of all production and consumption activities of Galicia, an Autonomous Community located in the north-west of Spain, was determined and the results were used to devise strategies aimed at the reduction and mitigation of the greenhouse gas (GHG) emissions. The territorial LCA methodology was used there to perform the calculations. However, that methodology was initially designed to compute the emissions of all types of polluting substances to the environment (several thousands of substances considered in the life cycle inventories), aimed at performing complete LCA studies. This requirement implies the use of specific modelling approaches and databases that in turn raised some difficulties, i.e., need of large amounts of data (which increased gathering times), low temporal, geographical and technological representativeness of the study, lack of data, and presence of double counting issues when trying to combine the sectorial CF results into those of the total economy. In view of these of difficulties, and considering the need to focus only on GHG emissions, it seems important to improve the robustness of the CF computation while proposing a simplified methodology. This study is the result of those efforts to improve the aforementioned methodology. In addition to the territorial LCA approach, several Input-Output (IO) based alternatives have been used here to compute direct and indirect GHG emissions of all Galician production and consumption activities. The results of the different alternatives were compared and evaluated under a multi-criteria approach considering reliability, completeness, temporal and geographical correlation, applicability and consistency. Based on that, an improved and simplified methodology was proposed to determine the CF of the Galician consumption and production activities from a total responsibility perspective. This methodology adequately reflects the current characteristics of the Galician economy, thus increasing the representativeness of the results, and can be applied to any region in which IO tables and environmental vectors are available. This methodology could thus provide useful information in decision making processes to reduce and prevent GHG emissions.

1. Introduction

The average surface temperature of the Earth has risen since the mid-20th century, mainly caused by the anthropogenic increase in greenhouse gases (GHG) in the atmosphere (IPCC, 2013). This global warming phenomena is one of the most pressing environmental issues that humankind must address nowadays, as proved by the Paris Agreement (United Nations, 2015), a new global compromise aimed at holding global warming to well below 2 °C above pre-industrial levels (i.e. 1850–1900 (Hawkins et al., 2017)).

This study focuses on Galicia, an Autonomous Community located in the north west of Spain, and whose average temperature

List of abbreviations: GHG, Greenhouse gas; LCA, Life Cycle Assessment; CF, Carbon Footprint; IO, Input-Output; UNFCCC, United Nations Framework Convention on Climate Change; EIO, Environmentally extended Input-Output; PA, process analysis; LCI, Life Cycle Inventories; US, United States; SRIO, Single-Region Input-Output; NAMEA, National Accounting Matrix with Environmental Accounts; WIOD, World Input Output Database; HT, Housing and Transport; FGS, Food, Goods and Services; NACE, Nomenclature statistique des Activités économiques dans la Communauté Européenne; MC, MultiCriteria; EPRTR, European Pollutant Release and Transfer Register.

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has risen 0.20 °C per decade between 1961 and 2015, as found by a 2016 study of the Galician government, which evaluated data from 25 weather stations in the region (Xunta de Galicia, 2016). The regional government has the competencies to develop policy measures aimed at reducing and mitigating GHG emissions within the region (MAGRAMA, 2016), and it publishes periodic reports that present the GHG emissions of the region and evaluate their effects on the climate and the ecosystems.

The socio-economic characteristics of Galicia, in which the primary sector has traditionally been of high economic relevance, will affect the GHG emissions of the region. Regarding the production activities, the density of the bovine livestock sector (in heads per hectare) is 63% higher in Galicia than in the rest the country (Eurostat, 2017; IGE, 2015). Moreover, Galicia is one of the Spanish regions with the highest electricity production (producing 1.08 GWh/km^2 and doubling the Spanish average), but also one having a cleaner energy mix (in 2014, 60% of the electricity came from renewable sources in Galicia, while on an average Spanish region they only reached 43% (REE, 2014)). Finally, Galicians consume many products of animal origin (e.g., meat and milk consumption in households is respectively 21% and 15% higher than in the rest of Spain (INE, 2014)).

The GHG inventories published by the Galician government are downscaled from the Spanish inventories, published yearly by the Spanish government, as a party of the United Nations Framework Convention on Climate Change (UNFCCC). Thus, the Galician GHG inventories available only include the direct emissions that take place in the region, and may be subject to inaccuracies due to the downscaling procedure followed.

A holistic perspective, in which all the life cycle emissions linked to the region are accounted for, can provide a more complete knowledge of the total environmental impacts that the region is ultimately responsible for by identifying pollution transfers between territories, and lead to more effective decision making. To calculate the life cycle emissions of a certain region, three main approaches can be followed (Wiedmann, 2009a): i) a bottom-up strategy, based on process analysis (PA), in which the impacts of individual products are added up to obtain the total impacts of the activities of a certain area; ii) a top-down strategy, based on environmentally extended input-output tables (EIO), which reflect the interactions among different sectors and relate environmental impacts to economic values; and iii) a hybrid approach, in which both strategies are combined.

The total GHGs of both Galician consumption and production activities were calculated following a life cycle perspective (Roibás et al., 2017), and then combined into a single indicator, the carbon footprint (Weidema et al., 2008), expressed in CO_2 equivalents. To do so, a hybrid approach based on territorial LCA (Loiseau et al., 2013) was used. This hybrid methodology combines a bottom-up with a top down approach (based in the 2002 United States Environmental Input Output -US EIO- database), to evaluate the total environmental impacts of all the production and consumption activities that take place within a region. Territorial LCA applies a total responsibility approach (Eder and Narodoslawsky, 1999), in which all upstream activities related to local production and consumption are accounted for, whether or not they are located within the Galician region.

When calculating the CF of both the Galician consumption and production activities using territorial LCA, the authors encountered some limitations. Territorial LCA was initially designed to compute the emissions of all types of polluting substances to the environment (several thousand of substances including GHG) to perform complete LCA studies. This requirement implies the use of specific modelling approaches and databases that in turn raised some difficulties that seem to be worthless for computing only one category of impacts, i.e. carbon footprint. On the one hand, the suitability of using process LCA was questioned, due to the cut-offs that are inherent to that methodology, to the large amount of time invested in data gathering (which would hinder the replicability of the study in this or other regions), and to the need to fill certain data gaps (e.g. Spanish data was used when Galician data was unavailable). On the other hand, it was acknowledged that the use of an outdated US EIO database in a European study may have affected the geographical, temporal and technological representativeness of the study. Thus, it was concluded that further research involving different calculation approaches (i.e. different top-down approaches based on more suitable IO databases) should be carried out, both to improve the accuracy of the Galician CF results and to propose a simplified methodology to be followed in subsequent studies in this or other regions.

This paper presents the results of the aforementioned required further research, in which several methodological alternatives have been evaluated to determine the CF of the Galician production and consumption activities. The objective of this study is to improve the accuracy of the available CF results, while simplifying the methodology used for their calculation, in order to increase its applicability in subsequent studies in Galicia or other regions.

After this first introductory section, the study is structured in the following ones: the second section presents the different methodological alternatives used to determine the CF of both Galician consumption and production and the analysis grid built to compare them; the third section presents and discusses the results of these alternatives, proposes a recommended methodology for future studies, evaluates its quality and compares its results to those in the literature. The last section draws the general conclusions of the study.

2. Materials and methods

The aim of this paper is to reach a compromise between the high representativeness of the results and the simplification of the calculation procedure. This section describes the procedure followed to do so: several calculation alternatives are presented in the first subsection, and the criteria for their comparison are defined in the second one.

2.1. Description of the alternatives

The CF computation relies on combining activity descriptors with Life Cycle Inventories (LCI). The activity descriptors are economic values or physical quantities that describe the Galician consumption (e.g. the number of kilometres travelled by car, or the household expenditures in road transport), while the LCI relates these descriptors to a certain amount of GHG emissions. These LCI can be taken from two types of databases: PA databases such as Ecoinvent, or EIO databases, in which the LCI are a result of combining environmental vectors with input output matrixes.

This section details the methodological procedures followed to determine the CF of the Galician production and consumption activities. The first subsection presents the different sources of LCIs considered, and the following two include a more detailed explanation on how these LCIs have been combined with the activity descriptors to determine the CF of both consumption and production.

2.1.1. Overview of the LCI databases considered

This section presents the different LCI databases that have been considered to determine the CF of the Galician consumption and production activities. In the original territorial LCA approach