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Land embodied in Spain's biomass trade and consumption (1900–2008): Historical changes, drivers and impacts

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ABSTRACT

Population increase, the change in consumption patterns and a greater demand for biomaterials will continue to put pressure on the use of land over the coming decades, an increasingly scarce and degraded resource. Trade allows the environmental impact of consumption to be outsourced to third countries, although it also allows production to be located in more productive areas. The aim of this paper is to shed light on those processes by studying the land embodied in biomass trade and consumption in Spain with a long-term perspective. It seeks to analyse the main patterns of historic change, the drivers and impacts associated with the increase in demands for land associated with consumption and biomass trade. Spain has always been a net importer of land, especially since the 1960s, when trade experienced accelerated growth. In 2008, net imports stood at 6.5 Mha. Using decomposition analysis, we show that increases in yield could have absorbed the new demands derived from population increase; however, changes in consumption, particularly with regard to diet, have increased demand, requiring land usage to be displaced to third countries.

1. Introduction

Global trade growth has allowed production and consumption activities to become decoupled in an unprecedented way. Since the late 19th Century, and in a much more marked way following the Second World War, a growing proportion of the resources consumed are no longer sourced locally or regionally, but instead are imported from much further afield (Dittrich and Bringezu, 2010; Schaffartzik et al., 2014). These exchanges have allowed some territories to access resources not available locally, improving their development possibilities. For example, many European countries have escaped preindustrial economic constraints (Wrigley, 2016) thanks to direct and embodied coal imports from countries such as England (Kander et al., 2017). Similarly, England has been able to expand its industrial growth thanks to overseas imported resources, especially land-intensive ones (Pomeranz, 2009; Hornborg, 2007). However, there is evidence regarding the negative effects associated with global trade. In 2010, trade was responsible for 28% of global energy consumption (IEA, 2018) and 14% of greenhouse gas emissions (IPCC, 2014). Trade also enables environmental impacts to be outsourced to third countries. In this sense, some territories may promote unsustainable forms of consumption by shifting the environmental burden abroad. These phenomena usually occur due to a shortage of local resources, in order to avoid the associated impacts within national territory, or because the relative price of certain goods is cheaper in third countries, leading to the abandonment of local extraction or production. In this regard, notions of *telecoupling* or *teleconnections* have gained growing importance in a bid to explain how changes in consumption may have relevant impacts in remote areas (Friis et al., 2016).

Consequently, in order to analyse fully the impact of consumption, the impacts that are displaced to other territories must also be incorporated. Traditionally, indicators of environmental impacts have been estimated using production-based approaches (PBA), i.e. from a national production perspective. These approaches do not always properly reflect the environmental responsibilities of consumption. For this reason, consumption-based approaches (CBA), also known as consumption footprints, which seek to estimate consumption-related impacts, have become very important in the last few years (e.g. Peters, 2008).

One of the so-called planetary boundaries is the change in land uses

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(Rockström et al., 2009). Land is a limited and threatened resource. Both expansion and intensification of cropland areas represent one the major challenges to global sustainability, responsible for serious environmental problems (Foley et al., 2005; Vanwalleghem et al., 2017). Population increase, changes in consumption patterns -particularly the rapid increase in animal products in the diet-, and the expected growing demand of biomass for non-food purposes threaten to increase pressure and competition for biologically productive land (Tilman et al., 2009; Kastner et al., 2012, 2014; Bringezu et al., 2014).

In the last few years, motivated by these concerns, a large body of literature focusing on the study of national and global land requirements has emerged based on the CBA. The major goal has been to gain a better understanding of the patterns and drivers behind increasing land use and land intensification. There are different methodological approaches to estimate land demands or land footprints. Some only take into account the land area required to produce the biomass consumed or traded (e.g. Kastner et al., 2014); others include urban or industrial areas (e.g. Yu et al., 2013); whereas others still include the virtual demand associated with the use of fuels, either to capture emissions (e.g. Haberl et al., 2001) or the forest land area that liberates their use (e.g. Sieferle, 2001).

Most of these studies present two major gaps: Firstly, they tend to focus on short-term perspectives so that our understanding of how the land-demand transition has occurred remains obscure. As far as we know, just three studies provide long-term information: for Austria (Erb, 2004), Sweden (Neset and Lohm, 2005), and the Philippines (Kastner and Nonhebel, 2010). Secondly, they do not usually provide estimations including all biomass demanded. Most articles tend to separate forestland and cropland demands, and sometimes they only include demands related to food products.

This paper presents novel estimations for the land embodied in both biomass trade and biomass consumption in the case of Spain. It does not consider land demands potentially attributable to non-biomass product consumption, e.g. the land area required to palliate the effect of fossil fuel use or built-up areas for industrial production. The study spans more than one century, from 1900 to 2008. In the period studied, the Spanish economy underwent substantial changes. In the first three decades, a process of industrialisation and globalisation was underway, which was halted by the Civil War (1936-39) and subsequent Dictatorship (1939–75). From the 1960s onwards, new liberalising and industrialising policies were developed, which led to a rapid socio-metabolic transition. Several studies have pointed to the substantial changes that took place in the use of materials (Carpintero, 2005; Infante- Amate et al., 2015), biomass flows (Soto et al., 2016), water footprint (Duarte et al., 2014), nutrient flows (Lassaletta et al., 2014b) and energy balances (Guzmán et al., 2017). They all point to an accelerated socio-ecological transition from the 1960s onwards. Nevertheless, actual land demands associated with consumption and trade is a topic that remains unexplored, preventing us from developing a full understanding of the biophysical changes that occurred in the Spanish economy.

The research aims of this paper are: (i) To provide new evidence on the patterns of biomass consumption-based actual land demands, in the case of an industrialised Mediterranean country characterised by distinct productive and consumption patterns and by important socio-political historical transformations during the period analysed. (ii) To open the black box of land requirements per type of biomass. By breaking down biomass consumption into different categories (level of transformation, type of product, or final use of biomass) we are better able to understand functional changes of biomass, and therefore of land use, during the industrial socio-metabolic transition. (iii) To study the quantitative drivers of land use demand through a decomposition analysis in which we consider changes in population, consumption patterns and land productivity.

The rest of the paper proceeds as follows. Section 2 describes the methods and sources. Subsequently, the results are presented. Firstly, estimations are presented regarding land embodied in trade, distinguishing between different types of biomass; secondly, the main drivers of change are analysed; finally, the effects of considering domestic or foreign yields when estimating land embodied in imports are examined, which involves distinguishing between actual land embodied and domestic land saved by biomass trade. The paper concludes with a discussion on the patterns, drivers and consequences of historical changes in actual land demands in Spain as an example of an industrialised Mediterranean country.

2. Methods

There are two main methodological approaches to estimate actual land demand: One, based on Multi-Regional Input-Output databases, which mostly relies on monetary values; and the second, based on physical accounting approaches (also termed material flows accounting approaches), which relates consumption or trade in physical units (e.g. one kilogram of wheat) to the land required per unit for its production (e.g. hectares per kilogram of wheat) (Bruckner et al., 2015; Henders and Ostwald, 2014).

This paper follows the physical accounting approach. This approach not only enables a more direct and reliable estimation, but it is also the only option when dealing with historical case studies. On the one hand, land embodied in total biomass trade is estimated. On the other hand, based on apparent consumption, actual cropland demand is also calculated. In the latter case, calculations have only focused on cropland due to the limitations on providing an accurate value for forestland or grassland actually managed in Spain, especially in the last four decades when a high percentage is estimated to have been abandoned (see Soto et al., 2016). Twelve benchmark years are covered between 1900 and 2008, using 5-year averages. Estimations were performed using the steps below:

1) A database of biomass trade was constructed for the period analysed, including all biomass traded (also in processed products). FAOSTAT was used for primary and most of the processed biomass products from 1961 along with Spain's Foreign Trade Yearbooks for the rest of the time points.[1] Different sources in different historical periods register categories differently. For this reason, the resulting database is composed of over 500 items that are aggregated into 20 main categories: 12 primary products and 8 processed products (Tables S1 and S2 in Supplementary Material I, SM I).
2) Processed products were converted into primary product equivalents using conversion factors based on weight-based criterion (Bringezu et al., 2012; Noleppa and Cartsburg, 2014). Final conversion factors were estimated as follows:

$$CF = \frac{W_{pri}}{W_{pro}} \quad (1)$$

where CF is the conversion factor, W_{pri} is the fresh weight of the primary product used to produce the processed product, and W_{pro} is the fresh weight of the processed product. They have mostly been taken from FAO (2012) and USDA (1992).

1) Conversion of weight-equivalent trade into hectares relies on yield data. In the case of exports, this study uses Spanish agricultural yield taken from Soto et al. (2016). Yield information is available for 211 crops and 3 types of forestland areas (open forests, high forests, and coppice), aggregated into the 20 main categories cited above (yields of main crops can be found in Table S3, in SM I). In the case of imports, the most weighted products in trade were identified as well as the main exporting countries to compile country-specific yields in

[1] Available in http://datacomex.comercio.es/. Last consulted, October 10, 2016.