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Linking country level food supply to global land and water use and biodiversity impacts: The case of Finland

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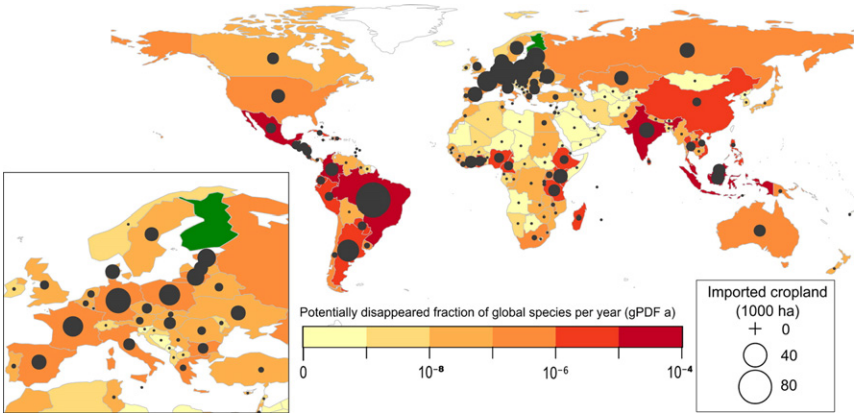
HIGHLIGHTS

- We present a study of the displaced impacts of the Finnish agricultural imports.
- We linked the imported land and water use to global biodiversity impacts.
- The consumption of imported food in Finland approximately doubled from 1986 to 2011.
- >90% of the biodiversity impacts related to food consumption were imported.

GRAPHICAL ABSTRACT



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ABSTRACT

The agricultural products consumed in Finland are increasingly grown on foreign farms. We analyze the Finnish imports of food and feed crops from 1986 to 2011 by products and by their geographic origin drawing a link to environmental impacts. The share of foreign crops consumed in Finland nearly doubled in the study period. The imports increased especially with commodities that could also be produced domestically. While the production of food increasingly shifted abroad, also the exports from Finland increased. >90% of the blue water of the Finnish crop supply came from foreign water resources. We map the results of land and water use together with their impacts on global biodiversity, and show that most of the land and water use related biodiversity impacts (>93%) associated with the Finnish food consumption are related to the imports and therefore taken place outside the Finnish borders. The use of multiple environmental indicators can help identifying products and spatial hotspots associated with the most severe environmental impacts of the Finnish crop imports contributing to a more holistic decision-making and the promoting of sustainable food consumption both domestically and globally.

1. Introduction

Global trade has dramatically affected the geographical patterns of production in relation to consumption (Peters and Hertwich, 2008).

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Regarding agriculture, trade makes it possible to meet countries' food demand by foreign production, while at the same time outsourcing environmental impacts. About 23% of all the food produced for human consumption is traded internationally (D'Odorico et al., 2014). The international trade of agricultural products continues to increase (Kastner et al., 2014a) promoting food availability in various parts of the globe (Porkka et al., 2013). However, the complex pathways of trade hamper transparent analyses of the effects of food production on land use, biodiversity and fresh water resources. The increase in trade affects virtually all efforts to promote sustainable agriculture and need to be ever more addressed in scientific research.

At the global scale trade contributes to a more effective global food system when food is produced in areas with higher resource use efficiency such as higher yields (Kastner et al., 2014a) or improved water productivity (Hoekstra and Chapagain, 2008). Higher productivity can, however, increase overall consumption levels if it means lower prices for products with elastic demand. Also, agricultural intensification often requires heavier use of fertilizers and pesticides that can have implications to the environment. Trade can as well be a way of displacing environmental impacts from consumers to producers (Meyfroidt et al., 2010). For example, over the period 1990–2008 the crop and livestock imports of the EU countries affected significantly the rate of global deforestation (Cuypers et al., 2013). Dependency on international trade impacts countries' food security and makes them more susceptible to disturbances outside their borders (Suweis et al., 2015). Land and water grabbing has emerged as a new way of globalized agriculture when countries and corporations acquire foreign land and the associate fresh water resources to sustain their food and biofuel consumption having implications to food security both in the producing and the exporting countries (Rulli et al., 2013).

Quantifying the implications of agricultural globalization is fundamental to understanding how to sustainably meet growing local and global food demands (MacDonald et al., 2015; Foley et al., 2011). Telecouplings (Liu et al., 2013) and land teleconnections (Yu et al., 2013) form the analytical framework to quantify the socio-economic and environmental interactions among coupled human and natural systems over distances. Teleconnections can be defined as the links between international demand and the local environmental impacts caused by the production of traded goods. There are various methods to assess the land and water embodied in international trade, and they can be divided into three categories, based on the input data (Bruckner et al., 2015). Environmental-economic accounting (input–output analysis) tracks embodied resources in monetary values and physical accounting uses physical quantities as their input value. Hybrid accounting mixes these two to form a combination of both. All methods include uncertainties and their results differ, even in the extent that the choice of method can impact the directionality of the results, e.g. whether a country is a net exporter or net importer of land use (Kastner et al., 2014b; MacDonald et al., 2015). Physical accounting enables higher levels of detail for crop and livestock products, allows specific allocation of land use to production based on the reported national yields and avoids distortions in value-to-weight ratios (Bruckner et al., 2015). The disadvantages of physical accounting are related to its limited ability to handle supply chains of highly processed products, especially from non-food sources, such as textiles.

Environmental implications of agricultural globalization can be assessed using various different metrics such as nutritional value, land use, irrigation water use or other ecological indicators such as, impacts to biodiversity. The choice of the metric can lead to divergent interpretations of trade relations and as a consequence contrasting policy suggestions, which highlights the importance of assessing multiple metrics (MacDonald et al., 2015).

This paper presents a national study of the displacement effects of trade based on physical accounting. An earlier study reported increased imports and exports between Finland and the global food markets over the period 1961–2007 (Sandström et al., 2014). Here we include data until 2011 and, more importantly, quantify the environmental impacts of the foreign crops consumed in Finland. Located in boreal northern Europe, Finland must cope with agricultural production at its climatic margins. Global trade can mitigate the climatic constraints and risks of the Finnish food system, but there are both advantages and drawbacks when increasing the dependency of foreign trade. One of the negative sides is the displacement of environmental impacts.

Previous studies have analyzed environmental impacts of Finnish imports using methods such as ecological or water footprint calculations (WWF Finland, 2012) or input-output models (Koskela et al., 2011; Mäenpää and Siikavirta, 2007) or a combination of both (Mattila et al., 2011). Sandström et al. (2014) described the development of imports and exports across the borders of Finland. However, none of the earlier approaches focused on the displaced environmental impacts taking into account the complex trade flows to trace the original production country of the imports consumed in Finland, which is the motivation of our analysis. In addition, this paper explicitly addresses land use, freshwater consumption and biodiversity impacts related to both land and water use in the production countries.

We focus on the agricultural products consumed in Finland including crops used as animal feed, and also including certain non-food crops, which contribute to the total cropland required. The objective of this paper is to present a country level case study and to investigate the development of agricultural imports over time, identify the domestic and foreign production regions for these products and analyze the environmental impacts caused by the production. The environmental pressure occurring at the production site is assessed with three indicator variables: first the area (in hectares) of cropland assigned to the Finnish food supply, second the quantity of fresh water used for cropland irrigation (= blue water), and third the biodiversity impacts caused by the land and water use in the production country.

2. Methods and data

2.1. Agricultural data

Our analysis is based on physical accounting. Estimates in tons were converted into estimates of resource use to illustrate the pressure on the environment related to the Finnish food supply. We use the information of agricultural trade of almost 450 secondary crop products converted into 132 primary products. In order to convert the processed products into primary products, conversion factors were used that were derived from the dry matter contents using standard factors of water contents (Haberl et al., 2007). Not all the products analyzed contribute to human food. For instance, some products were included such as flax, jute, manila, tobacco, rubber and palm oil that have also uses apart from food or feed. Detailed list of the primary crops included in the analysis can be found in Table S1. The method includes also the crops used for animal feed embedded in the animal products consumed in a country. The national level feed use data were obtained from the FAOSTAT commodity balances (FAO, 2016). A detailed description of the methodology to assess the feed use embedded in the animal products can be found from Kastner et al. (2014a). The input data are presented in tons of product that are available from the United Nations' Food and Agricultural Organization statistic database FAOSTAT (FAO, 2016) from 1986 to 2011.

2.2. Trade analysis

This method was developed by Kastner et al. (2011). The production of a country in this analysis is either consumed or exported. Analogously, the domestic consumption is supplied by domestic production or imports. The origin of agricultural products in the Finnish food supply was traced through trade matrices that are formed based on the information of the bilateral trade between Finland and the importing countries. Countries that report trade with Finland are not always countries