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Carbon footprints and land use of conventional and organic diets in Germany

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ABSTRACT

Organically produced food is often considered more environmentally friendly than conventionally produced food, and Germany is one of the most important and rapidly growing markets for organic food in Europe. However, the carbon footprints and land use of organic diets, and how they compare to conventional diets, have not yet been quantified. Using food consumption data from the German National Nutrition Survey II, and carbon footprint and land-use data from life cycle assessment studies of conventional and organic food products, carbon footprints and land use of conventional and organic diets in Germany were calculated for three consumer categories: men, women and their combined unweighted average. Conventional diets are defined as the average diet of consumers who do not buy organic food products; organic diets are the average diets of consumers whose food purchases include a large share of organic food products. Greenhouse gas emissions associated with land use change are not included. The carbon footprints of the average conventional and organic diets are essentially equal (ca. 1250 CO_2-eq cap^{-1} $year^{-1}$), while the land use to provide food is ca. 40% greater in the organic diet (ca. 1900 and 2750 m^2 of land cap^{-1} $year^{-1}$ in the conventional and organic diets, respectively). The average conventional diet contains 45% more meat than the average organic diet, which on the other hand contains 40% more vegetables, fruits, and legumes (combined). Animal-based food products dominate the carbon footprints and land use (ca. 70–75%) in both diets. The organic diet, in particular that of women, is more aligned with health-based dietary guidelines. Diet-related carbon footprints and land use can be reduced by shifting toward diets with less animal-based food products (other measures are also discussed). General conclusions about the overall performance of conventional and organic agriculture are not supported by this study since only carbon footprints and land use were assessed, while other important issues, such as biodiversity, ecotoxicity impacts and animal welfare, were not considered.

1. Introduction

To support global food production, 70% of the world's grasslands, 50% of the savannas, 45% of deciduous temperate forests, and 27% of tropical forests have been cleared or converted to agriculture since pre-industrial times (Foley et al., 2011). As a consequence, biodiversity and ecosystem services have been severely damaged (MEA, 2005). At present, global food production causes more than 25% of global anthropogenic greenhouse gas (GHG) emissions (Edenhofer et al., 2014) and uses around one-third of the global ice-free land area (Foley et al., 2011). In order to meet the targets of the 2015 Paris Agreement, GHG emissions need to be drastically reduced, not only from fossil fuels, but also, most likely, from agriculture (Bryngelsson et al., 2016). Also, in order to reduce biodiversity loss and protect ecosystem services, land saving measures are needed (Foley et al., 2011).

Organic agriculture is often considered more environmentally friendly than conventional agriculture, since chemical pesticides and synthetic fertilizers are not used. Germany is one of the most important and fast-growing markets for organic food in Europe

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(Schaack, 2016). In a recent survey, 8% of German consumers (5% of men and 12% of women) declared to buy the largest share of their food in organic supermarkets (BMEL, 2016a). The per-capita expenditure on organic food in Germany is also well above the EU-28 average (Statista, 2015), and the German "Ökobarometer" (eco barometer) suggests that the frequency and intensity of organic food consumption increased in the last decade (BMEL, 2016b). Whereas 17% of the German population declared to often buy organic food in 2008 (BMEL, 2008), this proportion rose to 24% in 2016 (BMEL, 2016b).

Life cycle assessment (LCA) is a method commonly used for quantifying the environmental impacts of food products throughout their life cycle (JRC, 2010). LCA studies show that animal-based food products generally have larger carbon footprints than plant-based food products, since they are less efficient at transforming energy and nutrients to edible products (Westhoek et al., 2011). LCA studies also show that food products from ruminants (e.g., beef, lamb, and cheese) have larger carbon footprints than other animal-based food products, due to lower feed-conversion efficiency of ruminants and emissions of methane from enteric fermentation (Gerber et al., 2013). Feed-conversion efficiencies largely influence both GHG emissions and land use demand. Therefore, land use associated with food products show similar patterns as carbon footprints (Nijdam et al., 2012).

Most LCA studies quantify environmental impacts of individual food products, but people eat whole diets consisting of different food products depending on cultural, demographic, and socio-economic factors. A diet perspective enables simultaneous consideration of social, nutritional, and environmental aspects. Carbon footprints and/or land use have previously been quantified for conventional "average national" diets in the Netherlands (Temme et al., 2014), France (Vieux et al., 2012), the United Kingdom (Berners-Lee et al., 2012), Denmark (Saxe et al., 2013), Ireland (Hyland et al., 2016), and Europe as a whole (Tukker et al., 2011), using different methods. The environmental impacts of specific diets, such as vegan and vegetarian diets, have also been assessed, see, e.g., Hallström et al. (2015) and van Dooren et al. (2014).

In Germany, the Max Rubner-Institut carried out the second German National Nutrition Survey (NVS II) from 2005 to 2007, with the objective to map food consumption and nutritional behavior of German citizens ages 14 to 80 (Heuer et al., 2015). Specifically, food consumption of different population groups were described, including those consumers who do not buy organic food (referred to here as conventional consumers), as well as those who buy a high share of organic food (referred to here as organic consumers). The data from the NVS II have been used to describe the food consumption of adults and specific population groups in Germany (Heuer et al., 2015); assess the environmental impacts of conventional diets and gender-related differences (Meier and Christen, 2012), and the environmental impacts of lacto-ovo vegetarian and vegan diets, as well as diets that follow dietary recommendations (Meier and Christen, 2013a).

However, the carbon footprints and land use of an organic diet, and how these compare to a conventional diet, have not yet been quantified. Yet, some studies, e.g., Krarup et al. (2008) and Knudsen et al. (2011), suggest that people who consume mostly organic food also eat less carbon intensive and land-demanding food products, e.g., meat, than the average consumer. Hoffmann and Spiller (2010) found that consumers with preference for organic food are also more likely to be vegetarians, but the diet-related environmental impacts were not quantified. Baroni et al. (2006) found that Italian consumers eating organic food have lower diet-related carbon footprints but higher land use, compared to consumers eating conventionally produced food. The assessed diets were however only hypothetical, planned by a dietician.

This study aims to assess and compare the carbon footprints and land use of conventional and organic diets in Germany, for three consumer categories: men, women and their combined unweighted average. To our knowledge, this is the first study that assesses carbon footprints and land use of organic diets using consumer reported food consumption data. Most studies on organic eating habits have so far focused on the reasons or motives behind consumption, without analyzing actual food intake or the associated environmental impacts (Bravo et al., 2013). Germany is a particularly interesting study object given the importance and scale of organic food consumption in the country.

2. Material and methods

In short, carbon footprints and land use of conventional and organic diets in Germany were calculated by combining food consumption data for men and for women from the NVS II, with carbon footprint and land-use data primarily from LCA studies of conventional and organic food products. Land use of organic plant-based food products was assessed using land use of conventional plant-based food products as a baseline, and multiplying with crop-specific yield-correction factors accounting for the relative yield differences in conventional and organic agriculture.

2.1. Food consumption data from the German National Nutrition Survey II

Food consumption data were obtained from the NVS II, see Chapter S1 in the Supplementary Material. NVS II was commissioned by the German Federal Ministry for Food, Agriculture and Customer Protection (BMELV) and carried out by the Max Rubner-Institut with the objective to map food consumption and nutritional behavior of German citizens ages 14 to 80. Nearly 20,000 German-speaking participants were selected to yield a representative sample and interviewed between 2005 and 2007 (Heuer et al., 2015). The NVS II represents the most comprehensive consumer reported survey on eating behavior in Germany with regard to its sample size, representativeness, and detail (Bravo et al., 2013).

The food consumption data used were collected by the diet-history interview method in which NVS II participants reported their consumption of meals and beverages of the previous four weeks (Heuer et al., 2015). In personal interviews, tableware models and an excerpt of the EPIC-SOFT picture book with different portion sizes (Slimani et al., 1999) were used to quantify the consumed amounts. Composite dishes, e.g., lasagna, were disaggregated into their constituent ingredients, such as beef, tomato sauces, pasta, etc., using standardized recipes from the German Nutrient Database 3.01. Sweets, bread, pastries, and soups and sauces were not disaggregated (Heuer et al., 2015). In the NVS II, food consumption data were also collected by 24-h recalls, but data from diet-history interviews contain more calculated food subgroups, and information about purchasing behavior concerning organic food is based on data from more participants. More information about the diet-history interview method is available in Chapter S2 in the Supplementary Material.

Of the NVS II participants, 13,074 (54% women and 46% men, aged between 18 and 80 years) were classified as either buyers (44.9%; n = 5875) or non-buyers (55.1%; n = 7199) of organic food (Eisinger-Watzl et al., 2015a). Based on purchasing frequency, buyers of organic food were further classified as intensive (5.1%), occasional (26.2%), or infrequent (13.6%) buyers of organic food (Eisinger-Watzl et al., 2015a). The subsets of NVS II participants classified as buyers or non-buyers of organic food represent the German population adequately (Hoffmann and Spiller, 2010).