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Food consumption and waste in Spanish households: Water implications within and beyond national borders

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ABSTRACT

The improvement of the sustainability of global food systems is a top priority. Many efforts have targeted the production side, yet managing food consumption demand, i.e., people's eating habits, might deliver important co-benefits from a land, water, and energy perspective. This paper focuses on assessing the water-related implications of food consumption and waste among Spanish consumers to discern possible policy recommendations. Specifically, we estimated the water footprint (WF) of the diet and associated food waste of Spanish households from October 2014 to September 2015, broken down by WF component (green, blue and grey) and its geographical origin. Our results showed that, for the analyzed period, the WF of food consumption in Spain is 52,933 hm^3, equivalent to 3302 liters per person and day. The consumptive fraction (green + blue water) of this diet-related WF accounts for 89%, while the remaining 11% (127 m^3 per person/year) is attributed to water quality impacts (grey water). The products that account for the largest share in the total WF are meat, fish and animal fats (26%) and dairy products (21%). Likewise, roughly 41% of the total WF linked to household diets is foreign, i.e., imported virtual water, and the main countries of origin are Tunisia, Portugal, and France. The WF of food waste accounts for 2095 hm^3, equivalent to 131 liters per person and day. From a policy perspective, several studies have highlighted that high water savings can be achieved by reducing food waste; in Spain, however, eliminating food waste at household level would reduce the Spanish food-related WF by only 4% (292 hm^3 of blue water and 1555 hm^3 of green water). In the light of these results, a shift back to a Mediterranean diet, in which fruits and vegetables account for a larger share of the food intake, would deliver greater water savings.

1. Introduction

Global food supply will need to increase by from 70% to 100% in the coming decades due to the increasing world population and rising living standards (Godfray et al., 2010). This poses a major challenge, as food production and consumption are one of the most important global drivers for both the environment and global health (Tilman et al., 2001; Tilman and Clark, 2014). This has turned the food "problem" (how much, what type, how or by whom food is produced) into a global concern in recent years (Garnett, 2014). People's eating habits have major implications for resource use, considering increased competition for land, water, energy, and other inputs in the future (Garnett et al., 2013; Tilman et al., 2001). Water competition leads to increasing water scarcity problems in many regions and river basins (Jalava et al., 2014; Wada et al., 2011), and water is now one of the major limiting factors of agricultural production (Yang and Cui, 2014).

Many recent studies have addressed the relationship between diets and associated water impacts. Some of these studies have compared average consumption patterns with vegetarian or low-meat diets to highlight the major impact that current eating habits have on water (Blas et al., 2016; Vanham et al., 2013a,b). Other studies have addressed the water footprint linked to shifts from recommended diets across various countries like the United States (Pimentel and Pimentel, 2003), Austria (Vanham, 2013) or Spain (López-Gunn et al., 2012). Different consumption patterns at city level in the Netherlands (Vanham et al., 2016a), Mediterranean region (Vanham et al., 2016b) or Nordic countries (Vanham et al., 2017) are another focus of research. Yet most of these studies address the composition of diets, focusing on dietary options sourced from recommendations by public health organizations and annual international statistics, like the Food Agricultural Organization's food balance sheets (FAO, 2001). Few studies have compared national data at household level in order to evaluate food consumption and provide results on current and realistic national dietary patterns.

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Besides, the need to assess global food waste in today's society has grown over the last decade. This has been partly driven by the need to link waste and global malnutrition and highlight its scale (Parfitt et al., 2010). Food waste can be defined as all losses occurring during any stage of the production chain or during consumption, including the household consumer level (Kummu et al., 2012). Food waste contributes directly to excess freshwater consumption (Hall et al., 2009). The importance of avoiding food waste and investigating at which stage of the chain this occurs are major issues. However, research has been scant so far. Available studies usually differ with respect to the part of the food chain on which they focus (Parfitt et al., 2010). Taking into account the entire food chain, some authors have estimated food losses ranging from 30% to 50% (Gustavsson et al., 2011; Lundqvist et al., 2008). This amounts to nearly 1.3 billion tons per year (Gustavsson et al., 2011). Alexander et al. (2017) show that most losses of biomass and dry matter occur before harvest at a rate of about 73% of net primary production across crop land worldwide. Finally, both consumer food waste and over-consumption add final losses of energy (42%) and protein (61%) in world food systems. Some authors also emphasize stark differences between developing countries, where food losses tend to occur at the beginning of the chain (agriculture and industry), and industrialized nations, where they tend to be at the wholesaling, retailing and consumption stages (Lundqvist et al., 2008; Parfitt et al., 2010; Ridoutt et al., 2010). At the post-consumer level (food waste on a household basis), a review conducted by Parfitt et al. (2010) found that there were few available studies (none in developing countries) and that the reported quantitative data were hard to compare because they were measured according to different methodologies and definitions. National assessments have been conducted recently in countries like Turkey (Pekcan et al., 2006), the Nordic countries (Gjerris and Gaiani, 2013), the USA (Jones, 2014; Koester, 2013) and the UK (Quested et al., 2012; WRAP, 2009). A few studies have focused on the food waste-freshwater savings ratio, albeit in global terms (Gustavsson et al., 2011; Kummu et al., 2012) or for individual products (Ridoutt et al., 2010).

Concepts like the water footprint (WF) or virtual water (VW) are useful for linking water resource use to food production (Vanham et al., 2013a). The WF of a product is the sum of all the water consumed across its entire value chain (Mekonnen and Hoekstra, 2011). A water footprint assessment (WFA) methodology has been developed over recent years to assess and identify options for water savings, raise awareness about water issues or develop better water management (Boulay et al., 2013). On the other hand, VW is the water used in the production of an internationally traded agricultural good. Therefore, it is a concept that links trade, food, and water (Allan, 2003). Water imported or exported to a given geographical region (e.g., a country) is the volume of VW associated with the trade of a particular product, that is, the volume of water used to produce a particular product, measured at the place where it was actually produced. The joint analysis of WF and VW of food consumption habits permits identifying the impacts both on domestic and non-domestic water resources, detailing the products' water consumption and WF components, and what proportion is wasted.

Accordingly, our research goal is to identify and analyze the food consumption and food waste patterns of Spanish consumers using household data for a one-year period (October 2014–September 2015). To trace the water impacts of Spanish households, this study also explores the origin of the consumed and/or wasted products. Besides, the study evaluates the WF of household consumption and food waste in order to evaluate water consumption and savings at a household level.

2. Materials and methods

Data has been collected using five main databases, which refer to food waste and consumption statistics, food import trade matrix, water footprint data for crops and animal products and Spanish national crop and food production. Table 1 summarizes and describes all the data sources used.

2.1. Food waste and consumption

The Spanish government has implemented the so-called "More Food, Less Waste" Program over the last few years in a significant effort to quantify all food waste in households, industry, and farm levels (Ministerio de Agricultura Alimentación y Medio Ambiente, 2015). The study was launched in late 2014, and has so far collected bi-yearly data for the following time series: autumn 2014–winter 2015, spring-–summer 2015, and autumn 2015–winter 2016. Only data for the first two semesters (October 2014 through September 2015) were considered for the purposes of this study, in order to have a complete one-year dataset, as the assessment was discontinued in October 2015. This database on food waste contains information on both raw and cooked food waste per household (kg/household and year) and was gathered from a sample of 4000 households of varying sizes and income per capita, distributed randomly across different parts of Spain. For 2000 households, information was collected by scanning each purchase made on a daily basis. Then households completed online questionnaires reporting how much and which type of products they had thrown away because of food degradation and/or spoilage over the previous week in order to quantify of food waste. The other 2000 households completed online weekly questionnaires (for the 52 weeks of the year) about all food products consumed at home or prepared for take-away by all members of the household (identifying sex, age and preparation method). Then they completed online questionnaires reporting the amount of food thrown away in order to quantify food waste. The information of the sub-samples was collected and added together, and the average waste per capita was calculated assuming an average of 2.51 members per household and a total of 17.5 million Spanish households (Ministerio de Agricultura Alimentación y Medio Ambiente, 2015).

Data on food consumption per household were also collected for the period October 2014–September 2015. Food consumption statistics were taken from the Consumption, Commercialization and Food Distribution: Household Consumption Database Program (Ministerio de Agricultura Alimentación y Medio Ambiente, 2016a). The goal of this survey is to study food consumption by households, restaurants and catering services in Spain based on consumer surveys. A sample of 8000 households (of different sizes and income per capita, distributed randomly across different parts of Spain) with an average household size of 2.69 members was surveyed. The data collection was based on daily note-taking on household food shopping, with a monthly sampling rate. The variables were collected by an optical barcode reader, which gave information about the product and amount purchased, the unit price and the type of establishment in which it was purchased.

Information on final 199 consumed and/or wasted products was collected by the authors from the two surveys. For ease of assessment, these food products were grouped into 10 different food groups: (1) meat, fish and animal fats; (2) dairy products; (3) oil and vegetable fats; (4) legumes and nuts; (5) cereals and potatoes; (6) eggs; (7) vegetables; (8) sugar and sweets; (9) fruits and (10) drinks, sauces and others. Products categorized as "others" are products that do not come under any of the above labels, like assorted prepared food, salt or honey.

2.2. Imported water and origin of food products

To estimate the volume of imported water resources embedded in Spanish household food consumption and waste i.e., VW, we relied on the global WF database of crops (Mekonnen and Hoekstra, 2011), and livestock products (Mekonnen and Hoekstra, 2012). Both databases provide average worldwide values for the green, blue and grey WF of all products (m^3/t or l/kg) for the time series 1996–2005. The WF is the result of the sum of three components: green, blue and grey water (Mekonnen and Hoekstra, 2011). The green WF refers to rainwater stored in the soils and directly evapotranspired by crops. The blue WF