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Producing oat drink or cow's milk on a Swedish farm — Environmental impacts considering the service of grazing, the opportunity cost of land and the demand for beef and protein

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ABSTRACT

There are plant-based alternatives to cow's milk that resemble milk in appearance and function, but differ nutritionally. These are associated with lower land use and environmental impact than milk. However, there are places where dairy herds contribute positively to conservation of high nature value pastures through their grazing. The dairy system also produces meat, but it can be questioned how much beef is needed/demanded. This study evaluated the environmental impact of production of oat drink in comparison with production of milk in terms of: i) the necessity for sufficient grazing animals in the landscape for biodiversity conservation; ii) different perspectives on the need for beef and protein; iii) the opportunity cost of land; and iv) the differing protein content of milk and oat drink. The climate impact, eutrophication and acidification potential and ecotoxicity impacts of a typical Swedish dairy farm were calculated and compared with those of the same farm when milk production was replaced by production of oat drink and three different alternatives to dairy beef: 1) beef from suckler herds; 2) chicken; and 3) plant-based protein. In all scenarios, the same area of semi-natural grassland was grazed. The opportunity cost of land use was included by producing bioenergy on spare land. The direct greenhouse gas emissions were considerably lower (16–41%) for all oat drink scenarios than for the milk scenario. When the bioenergy produced on the spare land was assumed to replace diesel, this substitution effect together with the carbon sequestration in soils cancelled out the direct emissions almost entirely when chicken or plant-based protein was produced instead of beef. The eutrophication potential was similar for all scenarios, while the acidification potential was 21–37% higher in the oat drink scenarios due to the need for handling increased amounts of digestate from bioenergy (biogas) production. This explorative study demonstrated great potential for reduced climate impact through production of oat drink instead of cow's milk, while still preserving grazing services for biodiversity conservation. However, for this to happen, incentives to manage semi-natural grassland need to be introduced, as such management is not an inherent effect of oat drink production. In addition, for the environmental benefits demonstrated in this study to come about, consumers must be incentivised to consume oat drink instead of milk and, to achieve the largest climate impact reductions, to replace some beef with chicken or cereals and legumes.

1. Introduction

Evidence is mounting that current food production systems are unsustainable in several ways and need substantial improvements (Godfray et al., 2010). Apart from production measures such as more efficient use of energy, fertilisers and water and closure of yield gaps (Burney et al., 2010; Foley et al., 2011; Mueller et al., 2012), changes in consumption patterns are also necessary, as the growing demand for more resource-demanding food products by the world's increasingly wealthier populations is cancelling out production-side efficiency gains (Bajželj et al., 2014; Foley et al., 2011; Smith, 2014). Meat and dairy are among the food products which cause most emissions of greenhouse gases and feeding crops to animals is considered inefficient, leading to large land and other resource requirements for feed production (Nijdam et al., 2012).

Milk and other dairy products are consumed in large amounts in a number of developed countries and consumption is rapidly increasing in other low and middle income countries (Gerosa and Skoet, 2012). There are several plant-based alternatives to cow's milk that resemble milk in appearance (Mäkinen et al., 2015) and can be considered partly functionally equivalent, i.e. a white drink to consume cold or warm with cereals, porridge, tea or coffee, or to be processed into different products resembling yoghurt, ice-cream etc. These plant-based substitutes for

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milk are water-soluble extracts of legumes, oilseeds, cereals or nuts. Although studies on the environmental impact of production of these milk alternatives are scarce, the results available indicate that e.g. the climate impact per unit weight of product from the production of these is considerably lower than for cow's milk due to the avoided emissions from animals, manure and feed production (Mäkinen et al., 2015). The avoidance of emissions from manure and feed production also leads to smaller contributions to acidification, eutrophication and water stress.

Apart from dairy production using considerably more land than the production of plant-based alternatives, its production differs in other fundamental ways that affect comparison of the environmental impact of milk and milk alternatives. One important aspect is that apart from milk, a dairy system also delivers several other outputs, of which two important products in a developed world context are beef and grazing services supporting various ecosystem services (Robert Kiefer et al., 2015). The multifunctional aspect of dairy production delivering both milk and meat is handled in current life cycle assessments through either: 1) allocation, in which the total impact from the milk production system is divided between the milk and the meat based on physical or economic relationships, and 2) system expansion, in which (most commonly) the impact from a pure beef production system is subtracted from the total impact of the dairy production system (Flysjö et al., 2011). Most studies use other beef as a substitute for the beef produced through dairy production, although one study considered that pork or poultry meat could replace some of the beef from dairy production (Flysjö et al., 2011). Depending on the function of beef for the consumer — as providing a sense of pleasure, as a status marker that only beef or other meat can provide or as providing protein and other essential nutrients, the beef from dairy production could be replaced by different types of meat, fish, cheese or plant-based protein sources made from legumes and cereals.

To our knowledge, the grazing services that animals in dairy production systems can provide have not been considered previously in quantitative environmental assessments of milk. In many countries, dairy cows and their offspring contribute positively to the conservation of high nature value pastures through their grazing, which prevents the areas from becoming reforested. Reforestation threatens the many meadow species that have adapted to the low-intensity agricultural management of grazing land carried out over hundreds of years (Hampicke and Plachter, 2010). In Sweden, 35% of the utilised biomass from semi-natural grassland is consumed by dairy cows and their offspring (Röös et al., 2015). Grazing is a service that does not inherently follow the production of plant-based milk alternatives but dairy cows are also not a prerequisite for pasture management, as these areas can be grazed by suckler herds, sheep or horses, or managed manually or mechanically (Carlsson et al., 2014) in parallel with the production of plant-based milk alternatives. Hence, a system that delivers both a plant-based milk alternative and grazing services could be designed in a multitude of ways.

The difference in nutritional quality between cow's milk and plant-based alternatives is another important aspect which needs to be considered in comparisons of the environmental impact of the two. Drewnowski et al. (2015) suggest a method to compare the environmental impact from different food products based on the functional unit of nutrient density instead of mass. The nutrient density score is calculated based on an algorithm to include some specific nutrients. However, the usefulness of this method when it comes to comparing individual food products can be questioned, as (Western) diets consist of hundreds of different food products and it is the contribution of all these to the nutritional profile of the complete diet that is of interest. For example, milk is an important contributor of protein, calcium and vitamins A, B_2 and B_{12} in the Western diet, but these nutrients can be supplied by a combination of fortified and plant-based foods (Craig, 2009). The nutrient content of plant-based milk alternatives differs between types of drink. Apart from soy drink, most are low in protein (oat drink 0.4–1% protein, rice 0.1–0.2%, almond drink 0.5% of protein) in comparison with cow's milk (3.3–3.4%) (Mäkinen et al., 2015). The fat and total energy content are also lower (Mäkinen et al., 2015), but can be compensated for by the addition of vegetable oil. As regards micronutrients, several milk alternatives are produced in fortified versions to be comparable to cow's milk. Therefore, the difference in protein content is one of the most important aspects to consider. However, protein consumption in most developed countries is well above the recommended level (Westhoek et al., 2011) and it could be argued that a general decrease in total protein consumption is needed to alleviate environmental pressures from the food system.

Most life cycle assessments of foods do not consider the opportunity cost of using land, i.e. alternative land uses and the cost for not using land for these other purposes. This was highlighted by Garnett (2009), who argued that considering the global constraints on land, the opportunity cost of rearing livestock instead of growing food for direct human consumption must be considered when assessing the sustainability of different foods.

Hence, the purpose of this study was to evaluate the environmental impact of production of a plant-based alternative to cow's milk, here oat drink from Sweden, and compare it with the environmental impact of production of cow's milk. This was done using a set of scenarios that considered: i) the necessity for grazing animals in the landscape for biodiversity conservation; ii) different perspectives on the need for beef and protein; iii) the opportunity cost of land; and iv) the differing protein content of cow's milk and oat drink.

2. Method

2.1. Overview and scenarios

In this study the environmental impacts of a typical fictional Swedish dairy farm (100 dairy cows) (the REF scenario) were calculated using a life cycle perspective. These impacts were compared with those of the same farm when dairy production was replaced by cultivation of oats and oilseed rape for production of the same amount of oat drink and three different alternatives to the dairy beef. These alternatives were: 1) beef from suckler herds (scenario BEEF), based on the assumption that beef could only be replaced by beef; 2) chicken (scenario CHICK), based on the current trend of increasing poultry meat consumption and decreasing beef consumption in the EU (FAO, 2015); and 3) plant-based protein, i.e. a combination of cereals and grain legumes (scenario PLANT) based on the increasing trend of vegetarianism, showing that plant-based protein sources are a valid substitute for meat among some population groups. The oat drink recipe came from the Swedish company Oatly. For the production of 1 kg of oat drink, 0.20 kg of harvested oats and 0.035 kg of rapeseed oil were needed, which yielded an oat drink with a fat concentration equivalent to that of average Swedish cow's milk (4.2% as it leaves the cow; Växa Sverige, 2013) and a protein content of 1% (Florén et al., 2013).

The farm consisted of 336 ha of agricultural land, of which 15% (49 ha) was assumed to be semi-natural grassland and the rest arable land. This ratio of semi-natural grassland/total agricultural land corresponds to the ratio for the whole of Sweden (SBA, 2013). Semi-natural grassland is currently the most threatened habitat in Sweden and its continued maintenance through low-intensity grazing, preventing reforestation or rewilding, is crucial for reaching national goals on biodiversity conservation (Eide, 2014). Hence, in order to consider the need for grazing livestock on semi-natural grassland, in all scenarios, including those in which no milk was produced, the 49 ha of semi-natural grassland was assumed to be grazed by cattle and some beef was produced in all scenarios.

To account for the opportunity cost of land, it was assumed that the land saved on the farm, i.e. not needed to produce feed or food, was used for grass–clover cultivation and the grass–clover biomass was used for biogas production together with manure (including straw used for