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Environmental impacts of combined milk and meat production in Norway according to a life cycle assessment with expanded system boundaries

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ABSTRACT

The environmental burdens from combined milk and meat production in Norway have been studied. A model of three typical farms was constructed to represent the three most important regions for dairy production in Norway (central, central southeast and south-west). Processes from cradle to farm gate were covered in the assessment, including all activities on the farm, along with the production of machinery, equipment, buildings, diesel, oil, fertilizer, lime, seeds, pesticides, detergents, plastic, silage additive, medicines and related transport. The results were given for the impact categories global warming potential (GWP), fossil depletion, freshwater ecotoxicity, freshwater eutrophication, human toxicity, marine ecotoxicity, marine eutrophication, ozone depletion, agricultural land occupation, photochemical oxidant formation, terrestrial acidification and terrestrial ecotoxicity.

To document the impact and to be able to compare the findings to results from previous studies, processes often excluded in literature were individually omitted from the assessment. The consequences of using alternative literature values for selected sub-processes were calculated and the sensitivity of the results to different parameter settings was evaluated by varying the parameter values ±50% of the default value.

GWP impacts of 1.5–1.6 kg CO_2-eq per kg energy corrected milk (ECM) and 17.7–18.4 kg CO_2-eq per kg carcass were calculated. By excluding production of machinery, buildings, medicines, detergents, seeds, fence and pesticides, the GWP impacts were reduced by approximately 8% per kg carcass and 9% per kg ECM. Compared to results from other studies, the GWP related to production of milk and meat was high in the present investigation. The validity of comparisons with other studies is however low due to differences in allocation and system boundaries.

1. Introduction

Worldwide concern about the environmental burdens and resource use efficiency of food production has been increasing, and there is special focus on the environmental impacts from animal husbandry based on ruminants (e.g. Janzen, 2011; Lesschen et al., 2011).

In order to quantify the resource use, emissions and other negative environmental impacts of this sector and to highlight goal conflicts when improvements are sought, a holistic analytical approach should be undertaken. Life Cycle Assessment (LCA) is the prevailing framework for

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environmental assessment of products and production systems that is widely used for this purpose. Several LCA studies of food production have been performed recently (e.g. Cellura et al., 2012; de Vries and de Boer, 2010; Milà I Canals et al., 2011; Saarinen et al., 2012; Virtanen et al., 2011).

The global warming potential (GWP) of milk and beef production has received increasing focus over the last years (Beauchemin et al., 2010; Flysjö et al., 2011a, 2011b; Lesschen et al., 2011). Other impact categories (i.e. abiotic depletion, eutrophication, acidification, photochemical oxidant formation, ozone depletion, terrestrial toxicity and land occupation) have been highlighted as well (Bartl et al., 2011; Castanheira et al., 2010; Cederberg et al., 2007; Fantin et al., 2012; Kristensen et al., 2011; Nguyen et al., 2010; O'Brien et al., 2012; Pelletier et al., 2010; Peters et al., 2010; Thomassen et al., 2008a, 2008b; van der Werf et al., 2009). When interpreting the results from these studies, it is important to be aware that most of the products are characterized according to the CML2 (2000) method while we applied the more recent and refined ReCiPe method (Goedkoop et al., 2012).

On-farm machinery, buildings and indoor mechanization are often left outside system boundaries when environmental impacts from agriculture are analyzed by LCA. The environmental impact from capital goods has been included in some recent publications, e.g. Blengini and Busto (2009), Frischknecht et al. (2007) and Møller (2010). All of these studies confirm that capital goods contribute significantly to the total impact of agricultural production systems. Of numerous studies on milk and bovine meat production, only van der Werf et al. (2009) consider both buildings and machinery, although Bartl et al. (2011) include machinery. Both studies address eutrophication and acidification in addition to GWP, and van der Werf et al. (2009) additionally include terrestrial ecotoxicity, non-renewable energy use and land occupation in their assessment.

Few Norway-specific cases exist in the peer reviewed literature of LCA studies of the agri-food chains, with the exceptions of the study by Eide (2002), which focused on the Norwegian dairy industry, and Roer et al. (2012) that investigated Norwegian grain production. National and even local environmental studies of agricultural productions are important both as benchmarks of various food pathways and for the development of future agriculture policies.

The combination of milk and meat production is a cornerstone in Norwegian agriculture both in terms of monetary value, employment and socioeconomic development in rural areas and for national food security. Its multifunctional roles legitimizes high rates of subsidies, high import toll on farm products and grants aimed at compensating farmers for challenging agro climatic conditions, topography and long transport distances. For these reasons, production units are kept small compared to most other European countries. In 2010, the average Norwegian herd size was 22 cows, and less than 6% of the herds exceeded 50 cows (TINE, 2011a). The national average milk yield is approximately 7300 kg ECM (energy corrected milk) (TINE, 2011a) and bulls are typically slaughtered within the age of 16–22 months.

The small scale structure, and the rather long indoor housing and feeding season demand large investments in buildings, indoor mechanization and outdoor machinery per produced unit. It might thus be hypothesized that the products are characterized by high scores in one or several environmental impact categories, especially when the manufacture of buildings, machinery and indoor mechanization are included in the analyses.

The objective of the present study is to improve the knowledge of the environmental burdens caused by Norwegian milk and meat production. The new, improved characterization method ReCiPe (Goedkoop et al., 2012) has been used for all calculations. The effects of excluding processes that are commonly omitted in the literature and the effect of basing sub-processes on different literature values have been calculated. A sensitivity analysis has been included to investigate the robustness of the study. Three model farms representing 'typical' Norwegian farms in terms of scale, yield, feeding regimes and localization are developed.

2. Methodology and case description

2.1. Case description

Three farms representative of combined meat and milk production in the Rogaland, Oppland and Nord-Trøndelag counties have been modeled. They are referred to in this study as 'southwest' (SW), 'central southeast' (CSE) and 'central' (C), respectively (Table 1). The basis and procedure for their construction are outlined in Section 2.3. The system boundary is the farm property. Still, production and acquisition of buildings, machinery and equipment, diesel and oil, fertilizer, lime, seeds, pesticides, fences, polyethylene and additives for silage production, detergents, medicines, sawdust, cow matrasses, concentrates and mineral supplement needed in the dairy farms are included in addition to field work processes, on-farm transport as well as animal feeding and management processes. Transport of major inputs from the outer boundary (i.e. fertilizers, lime, feed concentrates, sawdust, health care service) to the farm are accounted for, whereas transport of small consumable materials such as polyethylene netting and film, additives, detergents, and mineral supplements are not considered.

In SW, the farm is located on sandy loam 10 km from the North Sea, CSE on silty sand nearby a major waterway running 235 km south to the Oslofjord, and C on clay loam 10 km from the Trondheimsfjord. The soils contain 3–6% organic material in the plow layer, and the erosion risks are regarded as low, medium-high and medium, according to official classifications (The Norwegian Forest and Landscape Institute, 2011). The mean temperature during the growing season is 11–12 °C at all locations, and the season length, defined as the number of days with mean temperature of 5 °C or more, according to the 1961–1990 normal, is about 180, 165 and 210 days in C, CSE and SW, respectively.

Leys are plowed, limed and re-sown every 5th year with field management practice as illustrated in Fig. 1. At SW, the newly established sward is cut twice while the