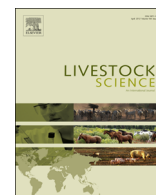




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Modelling cattle population as lifetime trajectories driven by management options: A way to better integrate beef and milk production in emissions assessment

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ABSTRACT

Methods to assess the consequences of mitigation scenarios on greenhouse gas (GHG) emissions in the cattle sector have been widely developed. A crucial issue of these methods is handling the co-products in emissions allocation. In the cattle sector, milk and beef production systems are closely interconnected because of the meat obtained from dairy culled cows and fattened surplus calves. To fully evaluate a change in the dairy sector, the change in the meat production induced should also be taken into account. With this objective, a national cattle population model was developed, based on three sub-models. The herd functioning sub-model represents the bunch of cattle trajectories generated by reproductive and finishing processes depending on breeds, production levels and finishing types. Assuming a steady state herd, the demographics sub-model represents the number of animals in age groups depending on trajectories length. The production sub-model represents the number of animals slaughtered or exported, the quantity of carcasses, milk and direct GHG emissions. The model was calibrated on French data. The simulation of a reference scenario reflecting the French situation in 2010 confirmed that the model allowed linking cattle trajectories, demographics and production of milk, meat and direct GHG emissions. Scenarios for the dairy sector were simulated to illustrate the potential of such modelling approach to evaluate direct GHG emission at the national level. The results confirmed that the interconnection between dairy and beef sectors can modify the benefit of strategies such as dairy intensification. Further, the results also demonstrated that the compensation between beef and dairy cattle to achieve production objectives lead to a change in the type of carcass produced due to differences between breeds and finishing strategies. Accounting for such differences allows deepening the evaluation of the consequences of GHG mitigation options.

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1. Introduction

While supplying 83% of the world milk production and 23% of the world meat production (FAOSTAT, 2010), cattle are pointed out as major contributors to climate change,

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through direct and indirect emissions of greenhouse gas (GHG). The cattle sector is facing both challenges of a growing demand for animal products, reduction of environmental impacts and resource consumption. The global demand for meat and milk is projected to double between 2000 and 2050 (Steinfeld et al., 2006). As many countries are engaged to reduce GHG emissions, they publish yearly national inventories to assess these emissions at national level. In this context, finding sustainable development strategies for the cattle sector is a key issue. As a result, methods for evaluating emissions associated with cattle products and production systems have been intensively developed.

A crucial aspect related with these methods is accounting for the interconnection between milk and beef production systems (Flysjo et al., 2012). A specific feature of dairy systems is the co-production of milk and meat, from surplus calves and culled cows. The meat produced by the dairy sector contributes to 57% of the world cattle meat production (FAO, 2010) and 35% of the French cattle meat production (Idele, 2011). When a process is related to different products, it raises methodological questions to distribute the environmental burdens link to the process (Weidema, 2001). This question of co-product allocation is crucial for a range of methods such as life-cycle assessment (LCA) or carbon footprint (CF). Dealing with it depends on the objective of the evaluation.

To assess GHG emissions of several co-products at farm level, the inputs and outputs of the system should be partitioned between the different co-products, as it is not easy to attribute emissions directly to each product. This co-products allocation can be based on the energy or protein needed for producing milk and meat (physical causality or biological allocation), on the economic value of the products at farm gate (economic allocation), on the edible protein content of the products (protein allocation) or on the total weight of milk and animals that leave farm gate (mass allocation). Allocation can be systematically avoided by using the system expansion approach. System expansion is defined as expanding the product system to include additional functions related to the co-products (from Weidema, 2001). This implies to model the change in the output volume of a co-product in one system and the need to account for an equivalent change in the others systems.

Depending on the method to handle co-products, the results of evaluation can greatly vary. Cederberg and Stadig (2003) found with LCA that the emission burden of milk (% of an evaluation with no allocation) was 92% for economic allocation, 85% for biological evaluation and 63% for system expansion. The result for CF evaluation reported by Flysjo et al. (2011) showed that 85–98% of GHG emissions were attributed to milk with allocation method while 63–76% were attributed to milk with system expansion. Including system expansion in emission assessment can strongly modify conclusions on the benefit of a strategy. Different studies (Martin and Seeland, 1999; Weidema et al., 2008; Zehetmeier et al., 2011) have shown that the benefit of dairy intensification is put into question if the compensation of meat production by beef production systems is computed. Intensification of milk production decreased

emissions per kg of milk produced, but the total emissions are not significantly reduced if the additional beef production from suckler cows necessary to maintain meat production is considered.

To fully evaluate the consequences of dairy sector scenarios on GHG emissions, there is a need to quantify their impacts on the beef sector. Quantifying such impact implies to quantify the substitution of meat from dairy systems by meat from beef systems. The quantity of meat substituted will depend on: (i) the national meat production objective (including both slaughtered and exported live animals), that is to say, how many meat should be compensated by beef systems to maintain the same meat production at national level and (ii) the factors that determine the quantity of meat produced by one head of cattle (such as the breed and the type of finishing), that is to say, by which type of animals the quantity of meat substituted is furnished. There is a need for a tool that converts the variation in meat produced by dairy cattle into variation in the beef cattle population and therefore in emissions inventory.

With this objective, we developed a cattle population model, named hereafter Cattle National POulation Model (CANAPOM) aims at (i) quantifying the compensation of meat produced by dairy cattle by meat produced by beef cattle to achieve the national production objectives for milk and meat (slaughtered and exported animals) and (ii) accounting for different ways of compensating for such quantity of meat (for instance, changing the breed composition of the cattle population, changing the productivity of a breed, etc.) in order to better evaluate the consequences on GHG emissions. From an overall point of view, consequences of scenarios should also consider the GHG associated with the inputs and the direct emissions of animals and manure as an LCA does. However, it is very complex to model at a national level and in a first step, a sector approach only considering direct GHG emissions of animals was considered, as it is done for national inventories. The substitution of the meat produced by dairy cattle by meat produced by beef cattle can vary in terms of types of slaughtered or exported animals (veal calves versus steers for instance), type of breed and production level, determining the quantity of product per head and further the quality of the meat produced.

In this paper, we describe the CANAPOM model structure and the verification of its behaviour for the French context. We then illustrate CANAPOM's application with simulations testing how changes in dairy breed milk production level and changes in the national milk production objective affect the cattle population and its direct GHG emissions.

2. Material and methods

2.1. Model overview

CANAPOM aims at simulating the lifetime trajectories of animals within the cattle population depending on management choices related to the breeds, their production levels and the finishing types. From this bunch of trajectories, CANAPOM computes the demographics of the cattle population and the production of milk, meat (slaughtered

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