Modelling the national cattle herd to simulate meat and milk production and the greenhouse gas emissions inventory

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MODELLING THE NATIONAL CATTLE HERD TO SIMULATE MEAT AND MILK PRODUCTION AND THE GREENHOUSE GAS EMISSIONS INVENTORY

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ABSTRACT: Assessing the environmental impacts of cattle production raises the issue of handling the meat co-produced from milk production. The objective of the study was to develop a model of the national cattle herd in France that encompasses both meat and milk production and tests the effect of different technical orientations (breed, productivity and finishing type) on the direct greenhouse gas (GHG) emission inventory. The model was used to test dairy intensification (increase in Prim'Holstein milk yield), increased use of a dual-purpose breed (Normande) and beef intensification (increase in young bull and steer finishing types) under a scenario of constant milk and meat outputs. The results showed that dairy intensification slightly decreased GHG emissions when the number of calves per cow did not decrease (-2.03%). Using the Normande breed led to a slight increase in GHG emissions (+0.99%), except when veal production was replaced by beef production due to the dual purpose of this breed, which decreased GHG emissions (-4.01%). Finally, increasing the young bull finishing type led to the strongest decrease in GHG emissions (-4.66%), whereas increasing steer finishing was associated with a slight increase in GHG emissions (0.65%). This model demonstrated that inventory GHG emissions are more sensitive to the method of meat production than to dairy intensification.

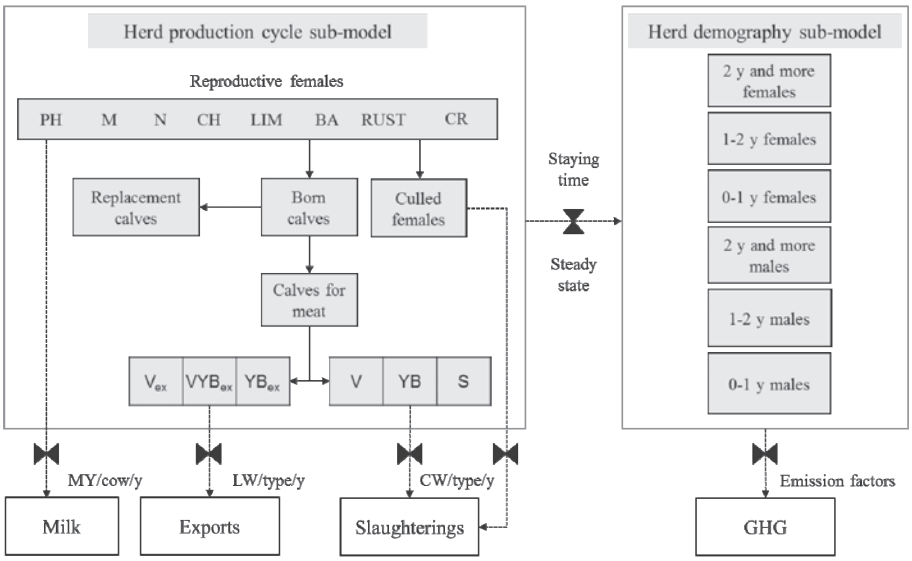
Keywords: GHG inventory, cattle, optimization, modeling, national herd

INTRODUCTION: Addressing the trade-off between the production objective and environmental impacts, especially greenhouse gas (GHG) emissions, is a major challenge for cattle farming systems. Animal intensification is often proposed as a solution. Although its efficiency has been demonstrated at the animal level, intensification results at aggregated levels are not clear. The way of handling the co-production of meat and milk by the dairy herd can modify the results of environmental evaluations (Cederberg and Stadig, 2003). Furthermore, at an aggregated level such as the country, the number of animals influences the GHG inventory. In the French context, interactions between beef and dairy herds are essential, since 35% of beef comes from the dairy herd. Our objective is to evaluate, with a model of the national cattle herd in France, the effects of different technical options on direct GHG emissions under the constraint of national production objectives. Technical options encompass the choice of breeds, their productivity and animal finishing types.

1. MATERIAL AND METHODS:

1.1. Model description: The model simulates the cattle population that satisfies constraints related to the production objective (milk and carcass weight) and national herd functioning and composition. Based on this cattle population, herd demography is simulated to compute the GHG inventory.

1.1.1. Herd production cycle sub-model: This sub-model (Figure 1) integrates 8 breeds of reproductive females that generate culled cows and calves, depending on parameters specified for each breed (numerical productivity, calf and adult mortalities, crossing rate and sex-ratio). Calves not kept for replacement are dedicated to meat production and diverted among different finishing types depending on a repartition matrix. They can be slaughtered as veal (V), young bull (YB) or steer (S) or exported alive as veal (V_{ex}), very young bull (VYB_{ex}) or young bull (YB_{ex}). The numbers of animals within each category (finishing type, culled or reproductive females) are combined with productivity parameters to compute national productions (milk, slaughtering and exports).



BA: Blonde d'Aquitaine; CH: Charolaise; CR: cross-breed; CW: carcass weight; LIM: Limousine; LW: live weight; M: Montbéliarde; MY: milk yield; N: Normande; PH: Prim'Holstein; RUST: Aubrac and Salers; S: steer; V: veal; V_{ex}: veal exported; VYB_{ex}: very young bull exported; YB: young bull; YB_{ex}: young bull exported

Figure 1. General description of the national cattle herd model.

1.1.2. Herd demography sub-mode: This sub-model simulates herd demography and GHG emissions based on the numbers of animals simulated by the herd production cycle sub-model (Figure 1). To compute the demography simply, we assumed a steady-state herd, which means that annual production remains constant over the years. To calculate the number of animals in each age class, the number of calves kept for replacement is combined with age at first calving, and the numbers of animals in each finishing type are combined with age at slaughter or export. Each age class is associated with an emission factor accounting for enteric CH_4 (adjusted for milk production with the equation of Vermorel et al., 2008) and CH_4 and N_2O related to manure management (CITEPA, 2012).

1.2. Simulations: The model is implemented with the GAMS software to perform optimization under constraints. Depending on the production objectives (milk, slaughterings and exports) and the input parameters specified for each scenario (herd functioning, productivity and staying time), the model predicts the number of reproductive females for each breed that satisfy constraints, the associated cattle population and the GHG emissions. Three contrasting intensification scenarios were

simulated (Table 1): i) dairy-herd intensification; ii) use of a dual-purpose breed and iii) beef-herd intensification. Simulations were performed with the same national production objectives (milk, slaughterings and exports) with a 1% tolerance. The reference scenario corresponds to the French situation in 2010.

Table 1. Model parameterization for the 6 scenarios simulated with the national cattle herd model, reflecting three types of intensification.

	REF	DI+	DI-	N100	N100V-	YB+	S+
Type of intensification	Reference	Dairy intensification		Dual-purpose breed		Beef intensification	
PH milk yield	7500	11500	11500	7500	7500	7500	7500
PH numerical productivity[1]	0.93	0.93	0.75	0.93	0.93	0.93	0.93
% N cows in the dairy herd	12	12	12	100	100	12	12
% N calves finished as veal (pure - cross-bred)	45 - 28	45 - 28	45 - 28	45 - 28	0 - 0	45 - 28	45 - 28
% of beef calves finished as YB	< 50	< 50	< 50	< 50	< 50	> 75	< 50
% of beef calves finished as S	< 50	< 50	< 50	< 50	< 50	< 50	> 70

[1] number of calves per cow; PH: Prim'Hosltein breed; N: Normande breed; YB: young bull; S: steer

2. RESULTS AND DISCUSSION:

2.1. Results: All simulations led to an optimal solution. The model found a cattle population that satisfied all herd constraints and French 2010 production objectives for milk (23.8×10^6 T) and for meat (1809×10^3 T of carcass equivalent, with 600×10^3 due to 1.44 M head exported alive). Scenario predictions (Table 2) are analyzed hereafter regarding the change compared to the reference scenario.

Table 2. Cattle population and GHG emissions simulated by the national cattle herd model for 6 scenarios, described in Table 1, reflecting three types of intensification.

	REF	DI+	DI-	N100	N100V-	YB+	S+
Cattle population (M head)	19.4	19.0	19.2	19.7	18.6	18.4	19.6
Beef cows	4.6	5.2	5.3	3.5	2.9	4.4	4.3
Dairy cows	3.4	2.6	2.6	4.3	4.3	3.4	3.4
Direct GHG emissions							
kg eq. CO_2/kg carcass	30.28	29.66	30.11	30.58	29.06	28.87	30.47
% REF scenario		-2.03	-0.56	0.99	-4.01	-4.66	0.65

Increasing PH milk yield (DI+) led to a decrease in the number of dairy cows (-0.8 M) and an increase in the number of beef cows (+0.6 M). Globally, both cattle population and GHG emissions decreased (-2.60%). When PH numerical productivity decreased (DI-), more beef cows were needed to achieve the meat production objective. Hence, the cattle population and GHG emissions decreased less than in DI+ (-0.56%). A 100% N breed dairy herd (N100) led to an increase in the number of dairy cows since this breed is less productive, and more cows are needed to achieve the milk objective. Even though the number of beef cows decreased, total cattle population increased, as did its GHG emissions (+0.99%). Finishing N calves as YB or S instead of V (N100V-) led to a decrease in cattle population (-0.8 M) and GHG emissions (-4.01%). Finally, increasing the number of YB (YB+) decreased both cattle population (-1.0 M) and GHG emissions (-4.66%). Conversely, increasing the number of S (S+) slightly increased the cattle population (+0.2 M) and the GHG emissions (+0.65%). YB and S had similar carcass weight, but S lives one year longer, thus increasing the number of animals in demographic categories.

2.2. Discussion: Results suggest that dairy or beef herd intensification led to slight effects on GHG emissions; they thus contrast with those of previous studies (Capper *et al*., 2008). This difference may come from assuming the beef herd increase compensates for the dairy herd decrease to ensure the same production objective (Zehetmeier *et al*., 2011). The apparent contradiction in intensification efficiency for mitigating GHG emissions highlights the importance of defining the organization level addressed and the system boundaries when evaluating environmental impacts. The effect of a factor at a given level cannot be simply extrapolated to other levels. Our results also show that finishing types have an impact on GHG emissions. Reducing finishing time reduces the number of animals in age classes and thus GHG emissions. However, such results should be nuanced in terms of carbon footprint; our model considered only direct GHG emissions and not emissions due to inputs. It will be necessary to link finishing types with their diets to evaluate the indirect emissions associated with a type of meat product.

CONCLUSION: The national cattle herd model quantifies the effects of different technical options on the national inventory of GHG emissions under a constant production objective. Results show that integrating the interactions between beef and dairy herds, through meat co-production, modifies the efficiency of animal dairy intensification as a GHG mitigation option, which could be cancelled by a reduction in numerical productivity. The results also highlight the potential interest of different finishing types in reducing GHG emissions.

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