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What prospective scenarios for 2035 will be compatible with reduced impact of French beef and dairy farm on climate change?

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ABSTRACT

The agricultural sector is being called upon to reduce its greenhouse gas emissions (GHG). A scenario approach was developed to explore the plausible futures of the French bovine sector and their impact on climate change. These scenarios encompass a Business As Usual scenario (S1-BAU) and alternative contrasting scenarios: (S2) cattle production increase to meet a high global demand under a liberal policy, (S3) refocus on internal demand within France, with an upmarket move to 'green' products, (S4) committed public policy to reduce GHG emissions. This paper analyses how key drivers of these scenarios (e.g. subsidies on investment, reduction of market risks, carbon tax, limitation of concentrate feed in animal diets) affect the evolution of production, economics, and environmental impact on climate change of typical French suckler cow and dairy farms, by means of simulations performed with a bio-economic model. To adapt their farming systems to the scenarios, farms can opt for variably intensive/integrated practices per animal and per unit land area. Some technological progress in animal production, crop production, and farm equipment is also modeled. Results show that in S1-BAU, milk production, net income and impact on climate change of dairy farms rise. Beef production and impact on climate change decrease slightly in suckler cow farms. Impact on climate change per unit of product decreases owing to higher productivity per animal and to a more integrated management of crop production. Alternative scenarios underline that reorienting public support toward farm investment would further intensify dairy farms and increase their income, but would reduce production and income of suckler cow farms and favor crop production (S2). Climate change impact per unit of product is more strongly reduced in S3 (organic farming with low feed concentrate) than in S2, but with a reduced production, particularly for milk. A carbon tax decreases emissions, but to the detriment of cattle production, especially suckler cow farms.

1. Introduction

The Paris Agreement (COP21, 2015) acknowledges the need to limit the global temperature increase to two degrees Celsius to avoid the worst climate impact. In all, 188 countries have committed to reducing their greenhouse gas (GHG) emissions, and have drawn up a roadmap. The French low carbon national strategy targets a reduction of 12% in agricultural emissions by 2028 relative to 2013 and of 50% between 1990 and 2050.[1] The agricultural sector makes up 19% of national emissions[2] (Citepa, 2015). With a population of 19 million cattle, beef and dairy production are the main contributors to agricultural sector GHG emissions (60% without carbon sequestration). The evolution of the bovine sector in the next 20 years will be crucial to meeting the GHG emissions target.

Over the last decade, many studies have analyzed the mitigation potential of specific technologies at animal level (Monteny et al., 2006; Doreau et al., 2011), farm level (Crosson et al., 2011; Nguyen et al., 2013) or at larger scales (Neufeldt and Schäfer, 2008; Smith et al., 2008; Havlík et al., 2012; Pellerin et al., 2013). However, the adoption of new technologies and levels of production are tightly intertwined with numerous factors such as the evolution of consumer demand, markets, policy, production organization and climate change. The prospective scenario approach combines different dimensions of the future: it is used to explore a highly uncertain future (Abildtrup et al., 2006; Audsley et al., 2006; Moss et al., 2010) by describing coherent, plausible future states of the world. The Intergovernmental Panel on Climate Change first developed the Millennium Ecosystem Assessment scenarios (IPCC, 2000; Carpenter and Pingali, 2005) to study climate

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[1] Law No. 2015-1491, http://www.gouvernement.fr/conseil-des-ministres/2015-11-18/l-adoption-de-la-strategie-nationale-bas-carbone-pour-le-cli.
[2] UNFCC: http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/8812.ph.

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change. Several studies have since used prospective scenarios to estimate the evolution of agriculture and its impact on climate change (Westhoek et al., 2006; Havlík et al., 2012; Grundy et al., 2016). In France, the Center for Studies and Outlook of the Ministry of Agriculture has developed four contrasting scenarios for the agricultural sector (Vert and Portet, 2010); several scenarios were also designed to reduce impact on climate change (De Perthuis et al., 2011; Vidalenc et al., 2013; Couturier et al., 2016). However, results for the cattle sector are aggregated. The Gesebov project (Gac et al., 2015)investigates the joint evolution of the dairy and beef cattle sectors for 2035 at farm and national levels, putting technology of production at the heart of the project. This paper focuses on the farm scale. It first simulates how some typical suckler cow and dairy farms would adapt their production to contrasting socio-economic contexts, taking into account some technological progress (higher milk yield, younger first calving, legume fodders, higher efficiency of fertilizer, milking robots, etc.). Secondly it assesses their impact on climate change. The simulations are run with the bio-economic model Orfee.

2. Materials and methods

2.1. Model overview

The bio-economic model Orfee (Optimization of Ruminant Farm for Economic and Environmental assessment) simulates French farms producing beef, milk, grass and annual crops (see Mosnier et al., XX, companion paper). It represents an annual farm production at equilibrium with a monthly level of disaggregation. Livestock and crop production, buildings and machinery are optimized under economic risks to maximize average net profit balances with standard deviation, with a weight of 0.5 (Fig. 1). These decisions are made under constraints related to animal feeding and herd demography; crop rotation, farmland; fertilizer needs; crop operations carried out with appropriate machinery; housing, milking and manure storage requirements; labor availability, and compliance with policy rules for entitlement to various public subsidies.

A large gradient of intensification and integration of beef and dairy farming systems is possible. Intensification per animal can be obtained by modifying the breed and type of animal (age at first calving, average daily gain, milk production) and its diet. Intake capacity, net energy and protein requirements are calculated on a monthly basis for each animal category using the Inra method (INRA, 2007). Different cropping intensities are defined for crops, from organic to intensive. Integrated cropping systems consist of reducing target yield simultaneously with favorable crop rotation in order to reduce input consumption. Fertilizer requirements take into account yield target, crop rotation and soil type using N mass balance equations. Integration between livestock and crop production can be obtained (i) by optimizing parturition periods and animal types to match animal needs with forage availability, (ii) by introducing grasslands and legume crops into crop rotation, (iii) by using manure to fertilize crops, and (iv) by feeding animals with on-farm forages and concentrates. In addition, machinery, buildings and labor are optimized, and include some trade-offs between level of equipment, workload, management possibilities and energy consumption. The number of worker units required is estimated considering an annual workload of 1900 h, and the 2010 minimum wage rate of 8.9€/h.

Two indicators of livestock production impact on climate change are calculated using a life cycle assessment approach to agricultural products from cradle to farm exit gate, with (CC-LULUC) and without (CC) carbon sequestration in grasslands. These indicators are computed at farm level and allocated to milk and meat production. A biophysical allocation, as applied in the French AGRIBALYSE® program (Koch and Salou, 2014) is used here to share the environmental burden of the systems between milk and meat. Three greenhouse gases contributing to global warming (CH_4, N_2O, CO_2) are aggregated by their global warming potential, and expressed in CO_2-equivalent (CO_2e). Values are those proposed by IPCC ((Forster et al., 2007), p212, 100-year time horizon): $CO_2 = 1$; $CH_4 = 25$; $N_2O = 298$. Methane (CH_4) emissions come from animal excreta and enteric fermentation estimated using a method that takes into account diet composition (Sauvant and Nozière, 2016). Nitrous oxide (N_2O) emissions are divided into direct emissions from manure management and managed soils, and indirect N_2O emissions that arise from volatilization of fertilizers and nitrogen lost via runoff and leached from agricultural soils. Carbon dioxide (CO_2) includes indirect input emissions and carbon sequestration.

2.2. Case studies

Four farm types were selected in the Inosys-Réseaux d'Élevage reference, which builds descriptions of typical farm types per region through a large network of commercial farms and expert knowledge (Charroin et al., 2005). The four types cross cattle production orientation with land characteristics: a dairy farm with permanent grassland only (DC_Grass) in Normandy (oceanic climate north-west of France), a dairy farm with temporary grasslands and annual crops (DC_Crops) in Pays de la Loire (west of France) (Table 1). Further details are provided in Tables 4 and 5 and in Appendices 2 and 3.

2.3. Scenarios

The scenarios simulated are based on the global scenarios defined for the project by joint expert groups of French researchers and persons working in the beef and dairy sectors. In these global scenarios,

$$\text{maximize } Z = \overline{NetProfit} + rav\sum_t (POS_t + NEG_t)/n$$

$$NetProfit = \overline{\overline{Net\ Profit}} + POS_t + NEG_t$$

Definition of net revenue

$$NetProfit_t = AnimalReceipt_t + CropReceip_t + AgriculturalPolicy_t - OperationalCost_t - StructuralCost_t - DepreciationFinancialCosts_t - LaborCost_t$$

OBJECTIVE FUNCTION

Where ***Z*** is the objective function, ***rav*** a coefficient of risk aversion, ***POS*** and ***NEG*** the positive and negative variation from average profit $(\overline{NetProfit})$,***t*** a subscript for the economic context considered, ***n*** the number of economic contexts

Fig. 1. Definition of the objective function within the Orfee model.