Modèle d'estimation des émissions de méthane entérique prenant en compte la diversité des ressources alimentaires et la gestion du système (DREEM): étude de cas du pastoralisme dans le Sud de la France

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Enteric methane emission model considering diversity of feed resources and system management (DREEM): Case study of pastoralism in Southern Region of France

Methane prediction in sheep production systems in south of France

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Titre. **Modèle d'estimation des émissions de méthane entérique prenant en compte la diversité des ressources alimentaires et la gestion du système (DREEM): étude de cas du pastoralisme dans le Sud de la France**

Résumé. Les systèmes d'élevage de ruminants sont des sources importantes de gaz à effet de serre (GES) (Gerber et al., 2013). La mobilité est une excellente stratégie d'adaptation concernant la disponibilité et la variabilité annuelle des ressources fourragères, la possibilité d'augmenter la taille du troupeau et donc la productivité de l'activité. L'étude vise à estimer le méthane entérique (CH_4) de systèmes de production ovine en méditerranée, en particulier l'utilisation des ressources fourragères pastorales diversifiées, en utilisant un modèle de simulation (de la diversité des ressources fourragères et des émissions de CH_4, DREEM). Quatre cas ont été choisis représentatifs de systèmes contrastés et de degrés de mobilité, allant de faible (sédentaire) à très élevé (double transhumant). Les premiers résultats ont montré une relation négative entre la mobilité et les émissions de CH_4 concernant les systèmes les plus contrastés. Au niveau animal, les émissions de CH_4 entérique des brebis en systèmes sédentaires plus élevées. Ceci est principalement dû aux quantités ingérées et à la nature de l'alimentation. Toutefois, la gestion du troupeau, qui dépend de l'accès aux ressources et de leurs usages module ces résultats. Des améliorations méthodologiques sur la caractérisation de l'alimentation et un plus grand échantillon de systèmes sont nécessaires. Enfin, ces résultats doivent être analysés à l'échelle de l'exploitation grâce à des modèles de bilans économiques et de GES des systèmes agricoles (Benoit et al., 2010).

Mots-clés. Diversité alimentaire; Méthane entérique; Ruminants; Pastoralisme; Ressources alimentaires

Title. Enteric methane emission model considering diversity of feed resources and system management (DREEM): Case study of pastoralism in Southern Region of France

Abstract. *Ruminant livestock systems are significant sources of greenhouse gases (Gerber et al., 2013). Mobility is a highly adaptive strategy regarding availability and annual variability of forage resources, opportunity for increasing flock size and thus labor productivity. The present study aims at estimating enteric methane (CH_4) of French Mediterranean sheep farming systems, especially the use of diversified pastoral feed resources, using a simulating model (Diversity of feed REsources and Enteric Methane emissions, DREEM). Four case studies were chosen regarding contrasting farming and mobility in the French Mediterranean systems, from low (sedentary) to high (permanently transhuming) farming systems. First results showed a negative relationship between mobility and enteric CH_4 emissions as far as contrasting farming systems are concerned. At individual level, enteric CH_4 emissions from sedentary system ewes were the highest. This is mainly due to feed intake and feed characteristics. However, flock management, which depends on land use and ownership, questions these results. This methodology requires*

improvements regarding feeding characterisation and a larger farming systems sampling. Finally, these results have to be analysed at a global level by estimating total GHG emissions of the farm, according to economic and LCA models of farming systems (Benoit et al., 2010).

Keywords. *Feed diversity; enteric methane; ruminant; pastoralism; feed resources*

I – Introduction

Nowadays, livestock's contribution and impact on climate change and global warming are main focuses of animal scientists and many studies are dedicated to mitigate CH_4 emissions (Beauchemin et al., 2008; Doreau et al., 2014). Pastoralism and herd mobility, especially in sheep production system, may represent a good herd management practice to adapt to climate hazards. Indeed, climate hazards affects animal feed resources on a temporal and spatial scale and consequently mobility may represent a good strategy of mitigation and adaption to climate change (Vigan et al., in press). Several studies have shown that feeding levels (Sauvant et al, 2011) and physiological stages (Ramin and Huhtanen, 2013) are the main factors driving enteric CH_4 production in the foregut of ruminant at the animal level. In the literature, different methods for CH_4 cattle emission estimates exists based on mathematical or biophysical models (Kebreab et al., 2004; Sauvant et al., 2011), and empirical equations (Ellis et al., 2007). The DREEM model was built to estimate enteric CH_4 emission by sheep and further be combined with the OSTRAL model (Benoit et al., 2010) which can assess the impact of animal mobility on GHG emissions of sheep production system at the farm level (Vigan et al., 2015). The aim of the present study is to focus on impact of animal mobility on enteric CH_4 emissions by integrating feed diversity, feed quantity, feeding level and physiological stages of 4 pastoral sheep systems in South of France, using DREEM modeling approach.

II – Material & Methods

The DREEM (Diversity of feed REsources and Enteric Methane emissions) model was developed to estimate enteric CH_4 and subsequently to be connected, as a sub-model, to an economic and GHG balance model at the farm level (OSTRAL) (Benoit et al., 2010; Vigan et al., 2015). Enteric CH_4 is produced in ruminants' rumen and is related to feed intake and feed quality. Therefore several equations were chosen from literature data (Vermorel et al., 2008; Sauvant et al., 2011), in order to assess impact of feed nature, feed quality, feed quantity and feeding level from diets on enteric CH_4 emissions from sheep farming systems.

1. Enteric CH4 emissions equations used in DREEM

Four equations were chosen to estimate enteric CH_4 emissions from literature, one based on an inventory of French CH_4 emission of small ruminants (Vermorel et al., 2008) and three others from a meta-analysis of a large literature database on CH_4 emission from ruminants (Sauvant et al., 2011). These 3 equations were established from a large database (n= 1008 studies) from various feeding practices with high and low concentrate or forage percentages in the diet. This data base gathered many different diets. However, some specific diets (free rangeland) may not have been used to build these equations because to our knowledge no studies on CH_4 emission were performed on sheep fed free rangelands. Diets chemical composition, which are more sensitive to the evolution of the diet but hard to collect accurately, are needed for DREEM model equations. For intake calculations the parameter needed are the organic matter (OM), OM digestibility (OMd), gross energy (GE) and net energy (NE) contents in the diet, using national feed unit system.

2. Description of feed nature, quality and chemical composition of the diet in feeding calendar

Feed nature was registered along a feeding calendar compiling (monthly) a whole year of a farming system's management. In the context of sub-Mediterranean area, systems are specific and present large feed diversity (Lasseur, 2005). Each batch of animals, corresponding to different lambing seasons, in the farming system had a specific feeding calendar. Batches, constituted according to lambing seasons, were divided into four physiological stages: maintenance, reproduction, pregnancy, lactation. Feed nature could be detailed along 5 categories and was further characterised by plant species composition: concentrates, conserved forages fed to ruminant, temporary and permanent pasture, grazed crops and free rangelands. Chemical composition of specific rangelands from PACA region was approximated with chemical composition of pasture of experimental data from "La Fage" farm in French Larzac area (Hassoun et al., 2007).

3. Analysis of enteric CH_4 emissions of pastoral sheep farming systems

DREEM model was applied on four sheep farming systems from French Mediterranean area to estimate enteric CH_4 emission of all animal categories composing the flock in these farming systems during one year. This area is known as a pastoral one where a lot of farming systems move to Alpes Mountains or to the South of France in order to feed their sheep on common natural free rangelands areas. The choice of these four farming systems was based on the spatial and temporal mobility of their flock, for which a gradient of mobility was observed between farms and consequently a large diversity of feeding practices (Lasseur et al., 2005). The four farming systems were not from the same area within the chosen area, therefore mobility was only used as an indicator of feed diversity.

III – Results and discussion

The four sheep farming systems were characterised by different animal performances as described in details by Vigan et al. (2015). Herd flock size was similar between sedentary and simple transhuming farms (223 and 243 sheep, respectively) whereas, it was 3.6 and 8.2 times higher for double transhuming 1 and 2 farms, respectively.

The feeding management and the feed quality of the 4 farming systems are described (Table 1). Flock mobility is higher, both in summer and in winter, for double transhuming 2 farm as compared to other farms where mobility gradually decreased. Moreover, forages (rangeland and grazed pasture) proportion in feeding management is equal to 100% DMI per ewe in double transhuming 2 farm whereas proportion of conserved forages increased gradually in other farms. Small variations in feed intake were estimated between ewes of the four farms (from 498 to 567 kg DM/ewe/year). Whereas, feed quality estimated through OMd, was the lowest (58.5) for simple transhuming farm, intermediate (60.4) for sedentary and double transhuming 2 farm and the highest (64.1) for double transhuming 1 farm. Consequently, the amount of degraded organic matter (DOM) content in the diet (g/kg DM) was similar between the four farming systems (from 543.7 to 581.6 g/kg DM).

Table 1. Main characteristics of feeding management and feed quality of the four farming systems

	Sedentary	**Simple transhuming**	**Double transhuming 1**	**Double transhuming 2**
Rangeland (% of DMI/ewe)	43	57	28	84
Grazed pasture (% of DMI/ewe)	27	28	36	16
PCO[(1)] (%)	2.3	2.4	1.4	0.0
DMI (kg/ewe/year)	567	546	498	517

MOD g/kg DM	557.8	543.7	581.6	562.0

[1]PCO: proportion of concentrate:

Enteric CH_4 emissions from ewes, rams, female lambs and lambs represented 83%, 2%, 10% and 6% of enteric CH_4 emission of total flock, respectively (fig.1). Therefore, differences of enteric CH_4 emissions between farming systems were mainly due to their differences in flock size of ewes and to a lesser extent to feed quality (OMd) as the content of DOM (g/kg DM) in the diet of the 4 farms were similar. Emissions of lambs in the second double transhuming system accounted for 14.5% of enteric CH_4 emissions from the flock whereas emissions from other lambs explained 1.5 to 4.7% of enteric CH_4 emissions from the flock. This assesses the impact of feed quality and age at slaughter in this farming system management.

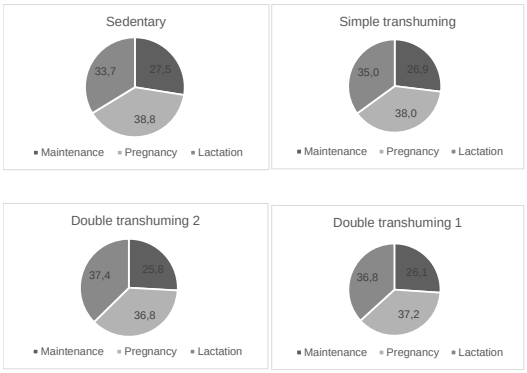

Fig 1. Contribution (%) of animal categories to enteric methane emissions from farming systems.

IV – Conclusion

This methodology needs improvements regarding feeding behavior (intake, digestibility) characterisation and a larger farming systems sampling. Finally, these results have to be analysed at a global level by estimating total LCA GHG emissions of the farming systems, thanks to economic and GHG models of farming systems (Benoit et al., 2010).

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