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Enteric methane emissions 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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Abstract. Ruminant livestock systems are significant sources of greenhouse gases. Herd mobility is a highly adaptive strategy to increase food availability and to face annual variability of forage resources in harsh conditions. Herd mobility also gives the opportunity for increasing flock size and also the farm productivity. The present study aims to estimate enteric methane (CH_4) of French Mediterranean sheep farming systems, especially those utilising diversified pastoral feed resources, using a simulating model (Diversity of feed REsources and Enteric Methane emissions, DREEM). Four chosen case studies were representative of contrasted farming system and herd mobility in the French Mediterranean systems, varying from low (sedentary) to high (permanently transhuming) farming systems. First results indicate that CH_4 emissions (kg/year) of farming systems increase together with herd size and mobility. At individual level, enteric CH_4 emissions from sedentary system ewes were the highest, mainly due to feed intake and feed characteristics. This methodology requires improvements regarding feeding characterization and a larger farming systems sampling. Finally, these results have to be analyzed at a global level by estimating total GHG emissions of the farm, according to economic and LCA models of farming systems.

Keywords. Feed diversity – Enteric methane – Ruminant – Pastoralism – Feed resources.

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. *L'élevage de ruminants est une source importante de gaz à effet de serre (GES). La mobilité du troupeau est une excellente stratégie d'adaptation permettant d'augmenter l'accessibilité et parer à la variabilité annuelle des ressources fourragères en conditions difficiles. L'étude vise à estimer le niveau d'émission de méthane entérique (CH_4) de systèmes de production ovine en zone méditerranéenne, en particulier dans le cas d'utilisation des ressources fourragères pastorales diversifiées, ceci en utilisant le modèle de simulation DREEM (de la diversité des ressources fourragères et des émissions de méthane entérique). Quatre cas d'étude ont été choisis représentatifs de systèmes ovin méditerranéens français contrastés et avec différents degrés de mobilité, allant de faible (sédentaire) à très élevé (double transhumant). Les premiers résultats indiquent que les émissions de CH4 (kg/an) des systèmes ont augmenté en même temps que la taille et la mobilité du troupeau. Au niveau animal, les émissions de CH4 entérique des brebis en systèmes sédentaires sont les plus élevées et ceci est principalement dû aux quantités ingérées et à la nature de l'alimentation. 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 globale en estimant les GES de la ferme grâce à des modèles de bilans économiques et de GES à l'échelle des systèmes de production.*

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

I – Introduction

Nowadays, livestock's contribution and impact on climate change and global warming are important focuses of animal scientists and many studies are dedicated to mitigate CH_4 emissions (Beauchemin *et al.*, 2008; Doreau *et al.*, 2014). Pastoralism and flock mobility, especially in sheep production system, may represent a good flock 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.*, 2016). 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. In the literature there are different estimation methods of enteric CH_4 emissions in cattle production, 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.*, 2016). The aim of the present study was to assess the 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 and 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.*, 2016). Enteric CH_4 is produced in ruminants' rumen and is related to feed intake and feed quality. Therefore several equations were collected from literature data. Then the selection was based on their capacity 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. 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. Briefly, French Mediterraneen 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 four farming systems were not from the same area within the chosen area, therefore mobility was only used as an indicator of feed diversity. Mobility practices were characterized according to seasonal mobility: (i) sedentary flocks (sedentary); (ii) simple transhumance of flocks (flock moving in summer; simple transhuming); and (iii) double transhumance of flocks (flock moving in summer and winter, double transhuming 1 and 2).The technical and economical characteristics, during one year period, of these four farming systems were modeled by OSTRAL and are described by Vigan *et al.* (2016). Output data on animal performance, feed practices and farming management of these models were further used in DREEM model.

3. 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, 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 characterized by its components: 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).

III – Results and discussion

The four sheep farming systems were characterized by different animal performances as described in details by Vigan *et al.* (2016). 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 double transhuming 2, 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[2]	Simple[3] transhuming	Double[4] transhuming 1	Double[4] 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 on DM basis; [2]sedentary: sedentary flocks; [3]simple transhuming: simple transhumance of flocks (flock moving in summer); [4]double transhuming 1 and 2: double transhumance of flocks (flock moving in summer and winter).

Total enteric CH_4 emissions of the flock for sedentary, simple transhuming, double transhuming 1 and 2 farms were 2775, 2939, 10509 and 25875 kg/year, respectively (Vigan *et al.*, 2016). 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.

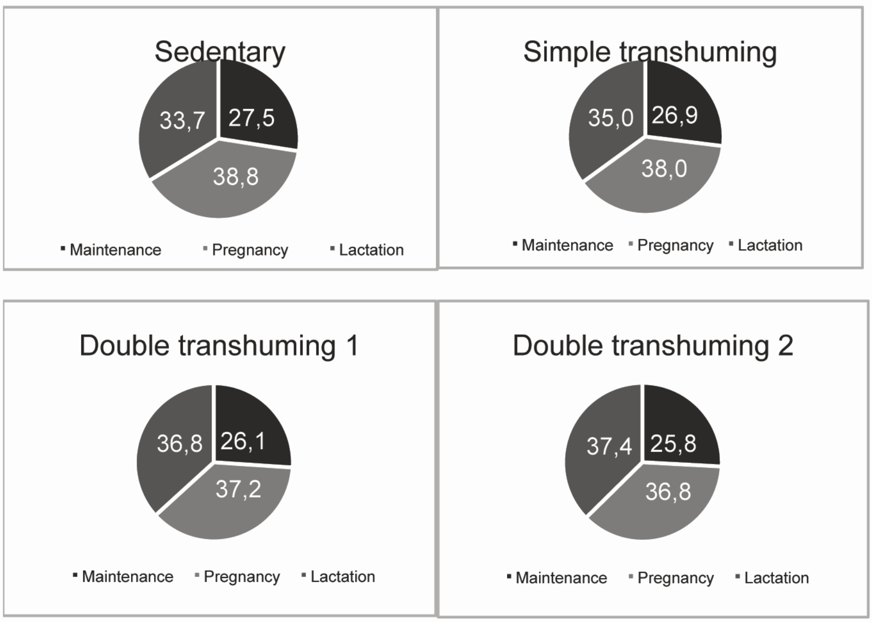

Fig. 1. Contribution (%) of physiological stages to enteric methane emissions from one ewe within a year.

IV – Conclusion

The methodology requires improvements concerning feeding behavior (intake, digestibility) characterization and a larger farming systems sampling. Moreover, these results have to be analyzed at a global level by estimating total GHG emissions of the farming systems (Gerber *et al.*, 2013) including other sources of GHG emissions as N2O and CO2, in particular these in relation with the use of inputs. Models developed at farming system scale including technical, economic and environmental performances can be useful for this (Benoit *et al.*, 2010).

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