Integrating livestock health measures into marginal abatement cost curves

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Summary

Improving livestock health offers both private and social benefits. Among the potential social benefits is a reduction in the greenhouse gas (GHG) emissions arising from livestock production. Reductions in emissions intensity (the amount of GHG produced per kilogram of meat, milk or eggs) may occur, as improving health can lead to improvements in the parameters that emissions intensity is sensitive to, such as (for ruminants): maternal fertility and abortion rates, calf and lamb mortality rates and growth rates, milk yields and feed conversion rates. However, improved health is not yet widely recognised as a GHG mitigation measure due, in part, to difficulties in reliably quantifying the financial and GHG effects of disease control options. This paper discusses how the GHG effects of disease control can be quantified and included in a marginal abatement cost curve (MACC). To illustrate some of the challenges, it draws on the experience of including health measures in the most recent (2015) agricultural MACCs in the United Kingdom.

Keywords

Climate change – Cost-effectiveness analysis – Greenhouse gas mitigation – Livestock health.

Introduction

The related global 'grand challenges' of climate change and food security have focused attention on the productivity of agriculture (including the external costs of production). The importance of agricultural greenhouse gas (GHG) emissions varies considerably between countries, for example, within the Organisation for Economic Co-operation and Development (OECD) on-farm methane and nitrous oxide account for 8% of total GHG emissions, but this ranges from 2% in Japan to 46% in New Zealand (1). Particular attention has been paid to livestock, which have been estimated (on a life-cycle basis) to account for 14.5% of global anthropogenic GHG emissions (2). Livestock therefore has an important role to play in meeting the global emissions reduction targets that have been defined under the United Nations Framework for Climate Change.

There are many ways in which livestock emissions can be reduced (or mitigated or abated) (for an overview and examples see Hristov *et al.* [3]). In theory, improving livestock health could provide a way of improving farm productivity (and profitability) while reducing emissions intensity (EI), i.e. the amount of GHG produced per kilogram of meat, milk or eggs. This apparent win-win situation has led to questions about the overall economic return on animal health surveillance and the cost-effectiveness of health interventions compared to other emissions mitigation measures. However, it has been argued that: 'Simulation results seem promising, but reliable quantitative estimates of the mitigation potential of improved health will require more research' (3). This lack of robust evidence is one of the reasons that livestock health had not (until 2015) been integrated into any of the marginal abatement cost curves (MACCs) developed for agriculture (although there is one study [4] that constructs MACCs for livestock health measures only). For example, when presenting the MACC for Irish agriculture, the authors explained that livestock health was 'likely to be included in future iterations of the MACC for Irish agriculture, when more detailed information is available on their overall extent and impact' (5). The omission of livestock health is important, as MACCs influence the development of national GHG mitigation strategies.

This paper provides an overview of what MACCs are and how they can be used to inform mitigation policy. It then provides a brief explanation of how improving livestock health could impact on GHG emissions, and cites some studies that have investigated this. A case study is provided describing how sheep and cattle health was integrated into the latest agriculture MACCs in the United Kingdom and some of the challenges faced.

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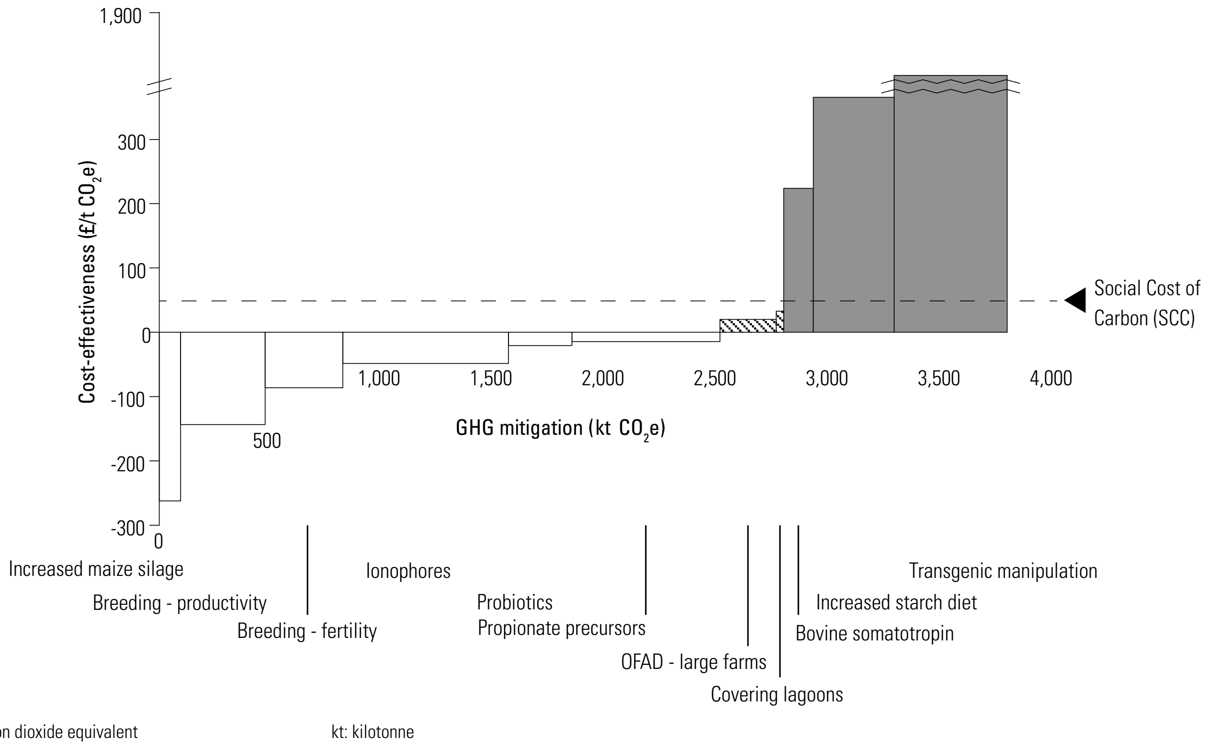
Identifying economically efficient mitigation measures

The global and national public policy challenge can be defined as a need to reduce GHG emissions at least cost to society. In agriculture, emissions can be reduced in many different ways, such as improving crop agronomy or using breeding to increase livestock productivity, with a recent review identifying 181 ways of reducing emissions *on-farm* (6). Further reductions may be achieved *pre-farm* by reducing the emissions arising from the production of inputs such as fertiliser and energy, and *post-farm* by improving the efficiency of processing and distribution. In addition to these supply-side measures, further mitigation may be possible via demand-side measures that seek to change the food people consume, and how they consume it (see [7] for further discussion of demand-side approaches to mitigation). Policy-makers are therefore faced with a bewildering array of mitigation measures. Applying certain criteria can help to make sense of this by identifying a subset of measures more likely to form successful mitigation policies. For example, measures can be appraised in terms of their technical feasibility, potential uptake and economic efficiency. Appraising technical feasibility requires clarification of a measure's potential unintended consequences and how its mitigation effect varies. Predicting uptake requires an understanding of how widely a measure could be applied in practice and the extent to which different policy approaches could be used to encourage its adoption. Finally, economic efficiency raises the question of whether the total economic (i.e. monetary and non-monetary) benefits of the measure are greater than the total economic costs, and whether or not the measure achieves mitigation at a lower financial cost than alternatives.

MACCs are often used to examine the economic efficiency of mitigation measures. In a MACC, the marginal cost of reducing pollution (i.e. the cost of reducing pollution by one additional unit) is plotted against the level of pollution, enabling the MACC to show how the marginal cost of reducing pollution increases as the level of pollution decreases. There are different approaches to deriving MACCs, with a broad distinction between 'top-down' partial equilibrium modelling approaches (e.g. [8]) and 'bottom-up' cost-engineering approaches (e.g. [9]). The former enable some of the economic welfare effects of mitigation to be captured (for example, changes in market share and impacts on ancillary industries), while the latter are generally capable of accommodating more measures and can be developed to be more regionally specific in terms of applicable measures. MACCs based on bottom-up cost-engineering approaches are more often represented as a series of discrete bars, each of which represents a mitigation measure (see Fig. 1). In this example, the width of each bar represents the reduction in GHG emissions,



CO_2e: carbon dioxide equivalent
GHG: greenhouse gas
kt: kilotonne
OFAD: on-farm anaerobic digestion

Fig. 1
Example of a simplified marginal abatement cost curve for the dairy sector in the United Kingdom

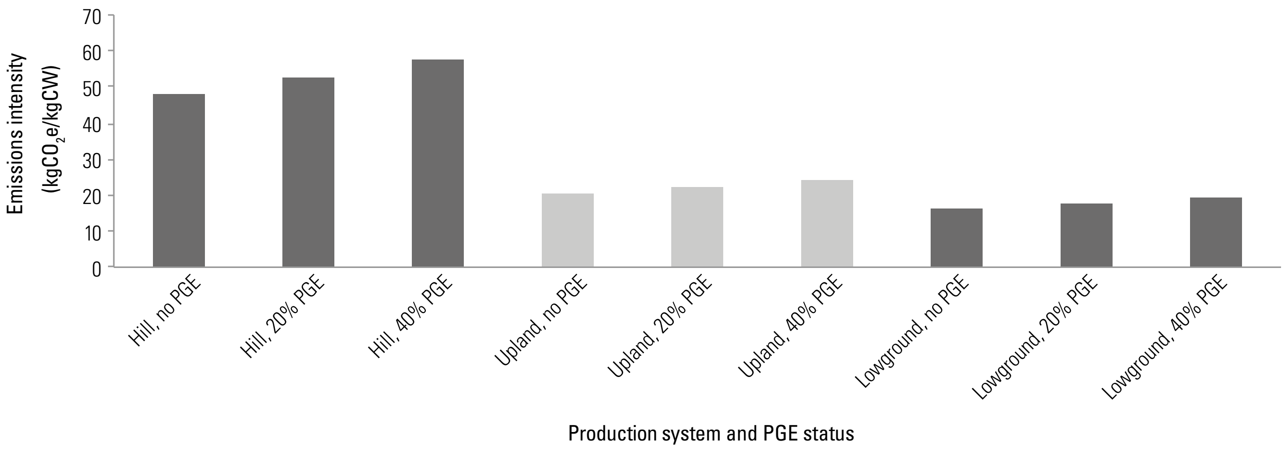
while the height of the bar shows the cost-effectiveness of the measure. The area under each bar is therefore equal to the total cost of the measure.

MACCs allow the estimation of the total reduction in emissions that can be made at a given cost, thereby enabling emission budgets to be set for the sector. Figure 1 shows that a reduction of 2,500 kilotonnes (kt) of carbon dioxide equivalent (CO_2e) could be achieved with measures costing up to £0 per tonne (t) of CO_2e (represented by the white bars) and a further 300 ktCO_2e reduction could be achieved with measures (the hatched bars) costing more than £0/tCO_2e, but less than the social cost of carbon (SCC) – the marginal global damage costs of each tonne of CO_2e emitted. MACCs also tell us something about how the reductions can be achieved by depicting the cost-effectiveness of mitigation measures. MACCs therefore have considerable explanatory power, and have been used in a number of countries (such as the UK, the United States, New Zealand, Ireland and France) to compare a range of agricultural mitigation measures. However, until recently, livestock health has been conspicuous by its absence from these studies. This is in part due to the complexity of integrating health into agricultural MACCs, which require information on baselines, impact of measures, and likely uptake rates and costs. Whatever the reasons for the omission, the absence of health from MACCs represents a missed mitigation opportunity.

Livestock health and greenhouse gas mitigation

Less healthy animals will, depending on the particular disease challenge, tend to have poorer performance, for example they will grow more slowly, secrete less milk, produce fewer offspring, be less efficient converters of feed, and in general be less productive. Some of these disease impacts will be avoided by control and prevention measures, with market prices guiding the decisions, yet an equilibrium will be reached that means disease presence will continue to cause losses in productivity and impact on the environment (10, 11). It therefore seems intuitive that improving livestock health will lead to reductions in the EI of the meat, milk and eggs they produce. However, there are only a few studies that address the relationship between health and GHG emissions (4, 12, 13, 14, 15, 16, 17). While all of these studies have indicated that some cost-effective mitigation could be achieved, it should be noted that these conclusions have a relatively weak empirical basis. Experimental studies are logistically challenging to perform and complicated by the fact that grazing livestock are naturally infected with multiple pathogens at the same time, so attributing production and/or GHG emissions effects to individual health conditions is difficult.

Livestock modelling can help to fill some of the gaps in our knowledge. A recent study (17) calculated the EI of meat from beef cattle herds with different levels of neosporosis and the EI of sheepmeat from flocks with different levels of parasitic gastroenteritis (PGE). The results for PGE sheep are shown in Figure 2. This study also undertook sensitivity analysis to identify the livestock parameters that had the greatest influence on the EI of Scottish cattle and sheep (see Table I). While such analysis needs to be interpreted carefully, it can help to identify the diseases and control options most likely to provide a reduction in EI.



no PGE: not affected by PGE
20% PGE: 20% have their performance affected by PGE
40% PGE: 40% have their performance affected by PGE
CW: carcass weight

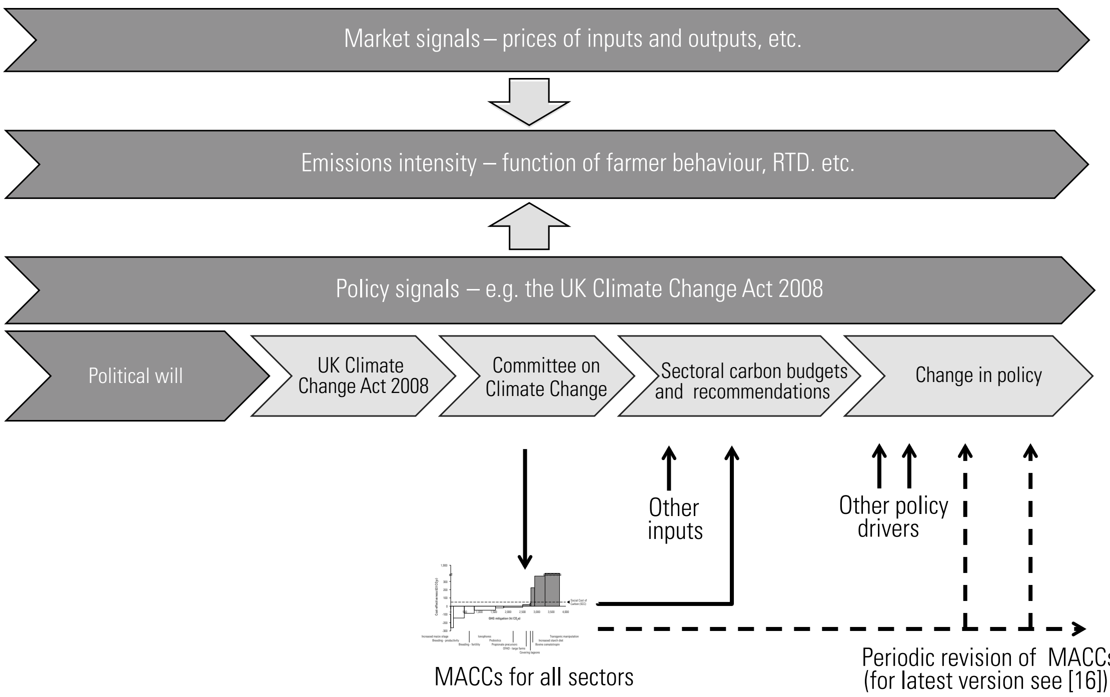
Fig. 2
Sheep emissions intensity by production system and parasitic gastroenteritis (PGE) status
Source: Skuce *et al.* (17)

Table I
Parameters that have the greatest influence on emissions intensity (indicated with an X) for Scottish cattle and sheep
Source: Skuce *et al.* (17)

Parameter	Dairy cattle	Suckler beef cattle	Sheep
Milk yield	X		
Maternal fertility	X	X	X
Abortion rates		X	X
Calf/lamb mortality		X	X
Calf/lamb growth rates		X	X
Feed conversion rates	X	X	X

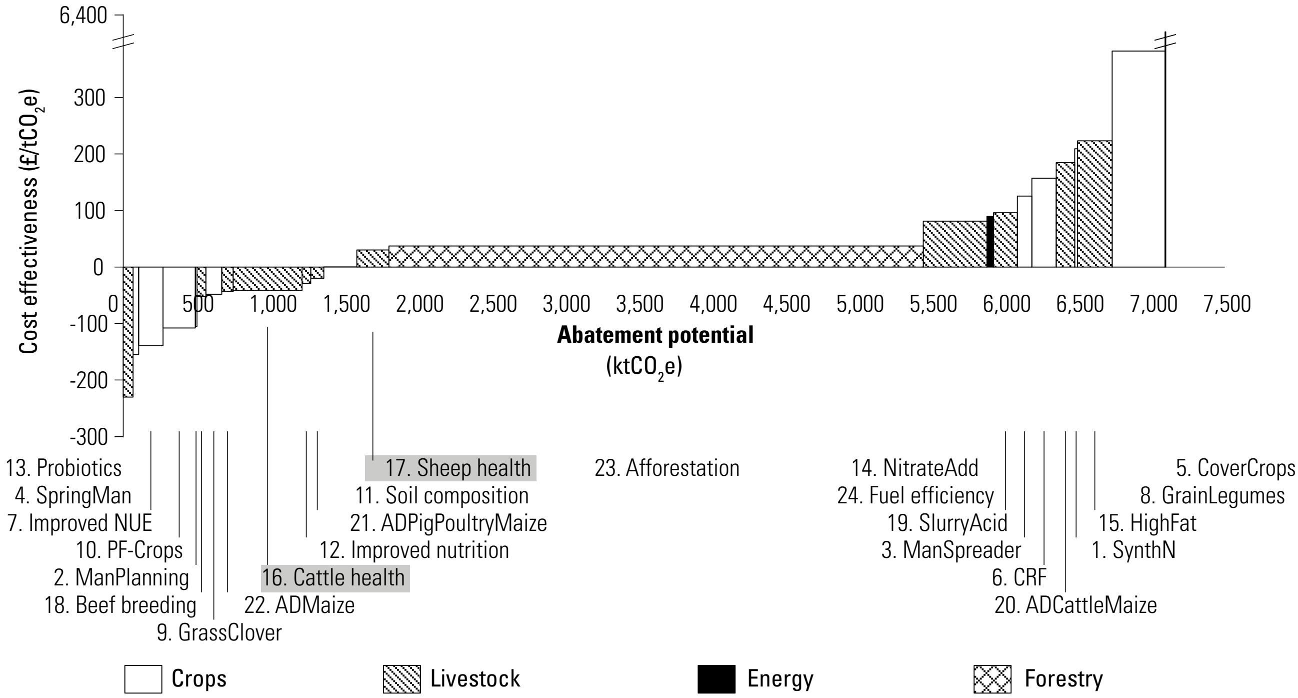
Integrating livestock health into the United Kingdom marginal abatement cost curves

In pursuit of ambitious GHG mitigation targets, the UK government has been proactive in defining sectoral budgets using MACC analysis. Figure 3 illustrates how MACCs fit into UK climate policy. Emissions intensity is determined by the nature of the farmer's production decisions, which in turn are influenced by market and policy signals that can constrain some behaviours and/or promote specific environmental practices. A key policy is the UK Climate Change Act. This Act led to the establishment (in 2008) of the Committee on Climate Change (CCC), which sets sectoral carbon budgets and provides recommendations on how these might be met. The CCC uses MACCs to inform their budget setting and recommendations, and the most recent agricultural MACCs were produced in 2015 (16) for the periods 2023–2027 and 2028–2032. A notable feature of these MACCs is that they include livestock health alongside other mitigation measures for the first time (Fig. 4). The analysis focused on two livestock health measures: improving cattle health and improving sheep health. For a number of reasons, these were considered to have a greater potential for reducing the emissions reported in the UK's GHG inventory (inventories are submitted to the United Nations Framework Convention on Climate Change every year) than improvements in monogastric health. First, ruminants account for a greater amount of the UK's GHG emissions and have greater exposure to pathogens. Second, the controlled environments and short life-cycle of monogastrics arguably provide fewer opportunities for health improvements. Third, improvements in monogastric health are likely to lead to reductions in feed conversion



RTD: research and technological development

Fig. 3
Schematic diagram of the climate policy framework in the United Kingdom



AD: anaerobic digestion
CFP: central feasible potential, discount rate: 3.5%
NUE: nitrogen use efficiency
1. Improving synthetic N use; 2. Improving organic N planning; 3. Low emission manure spreading; 4. Shifting autumn manure application to spring; 5. Catch and cover crops; 6. Controlled release fertilisers; 7. Plant varieties with improved N-use efficiency; 8. Legumes in rotations; 9. Legume-grass mixtures; 10. Precision farming for crops; 11. Reduce soil compaction; 12. Improving ruminant nutrition; 13. Probiotics as feed additive; 14. Nitrate as feed additive; 15. Dietary lipids for ruminants; 16. Improving cattle health; 17. Improving sheep health; 18. Selection for balanced breeding goals; 19. Slurry acidification; 20. AD: cattle slurry with maize silage; 21. AD: pig/poultry manure with maize silage; 22. AD: maize silage only; 23. Afforestation of agricultural land; 24. Improved fuel efficiency

Fig. 4
Marginal abatement cost curve for agriculture in the United Kingdom in 2035, considering cattle health and sheep health alongside 22 other greenhouse gas mitigation measures
Source: Eory *et al.* (16)

ratios and feed-related GHG emissions, much of which would not be captured by the UK emissions inventory (as some of the feed is produced outside the UK).

The calculation of the abatement potential (i.e. reduction in emissions) from improved cattle health was based on the work of Elliot *et al.* (4), which quantified the abatement potential for 30 individual control options for ten of the main diseases affecting UK cattle. The study found that significant abatement could be achieved at a cost less than £100/tCO_2e, but the analysis did not account for interactions between the health measures. The study notes that: 'It is important to recognise that the model does not deal explicitly with interactions between mitigation measures (MM), and given the extensive links between diseases, these are likely to be significant. As such, abatement values for each of the MMs cannot be aggregated to estimate sector abatement potential.' To assess the total abatement from improving cattle health, Elliot *et al.* used an alternative scenario-based approach to quantify the effects of a 20% and 50% movement from a reference situation to a healthy cattle population (4). Based on this analysis, and with reference to the UK MACCs, it was estimated that under a central scenario an abatement potential of 469 $ktCO_2$e per year could be achieved by 2035 by improving cattle health, and was likely to have a cost <£0/tCO_2e.

To estimate the potential GHG abatement potential from improving sheep health in the UK, a similar approach was adopted to the scenario approach used for cattle. The main steps were:

1) identify the main parameters changing in response to changing health status

2) estimate the change in the parameters arising from a move from average health status to high health status (i.e. flocks following a comprehensive health plan, with no major health issues) for three types of sheep system (hill, upland and lowground)

3) calculate the output of meat and GHG for reference and high-health flocks

4) calculate the change in gross margin arising from the health plan by subtracting the increase in gross margin (from increased output) from the cost of implementing the health plan

5) estimate the cost-effectiveness by calculating the change in gross margin arising from the implementation of a comprehensive health plan and dividing it by the change in GHG.

The analysis indicated that, under the central feasible potential (CFP) scenario, improving sheep health could provide an abatement potential of 218 ktCO_2e per year by 2035 at a cost greater than £0/tCO_2e, but less than the SCC (16), although these estimates are preliminary.

Challenges in integrating livestock health into marginal abatement cost curves

Prevalence

To quantify the abatement potential of a disease control option, an understanding of the (within and between) herd prevalence of the disease is required. However, Skuce *et al.*, in reference to Scotland, noted that: 'For most endemic diseases, there is a complete lack of active surveillance, with limited passive surveillance and inconsistent reporting' (17). Such data gaps can be filled using prevalence data from other locations, but this is not ideal as physical conditions and farm systems may be quite different.

Dealing with heterogeneity

Data on livestock performance, disease prevalence, and farm economics, are often only available at a national scale. But some parameters can vary both spatially and temporally. This matters, since the abatement potential and cost-effectiveness of a disease control option depend on the starting performance of the flock or herd. Those with below average health status are likely to provide scope for larger and more cost-effective reductions in GHG. It is therefore important to specify the baseline physical and economic performance as precisely as possible.

Interactions between mitigation measures

When two or more measures are implemented simultaneously they may interact in positive or negative ways. In some cases, two MMs may be mutually exclusive, while in other cases one control option may be ineffective unless it is implemented after another. These interactions need to be taken into account within MACCs to avoid over- or under-estimation of the total abatement potential.

Ancillary effects

MACCs are generally limited to one impact (here the examples have focused on climate change). In contrast to cost-benefit analysis, MACCs have the advantage of reporting the effects in terms of physical rather than monetary units. But this is also a weakness, as it prevents the integration of other impacts into the analysis. Mitigation measures can have significant ancillary (i.e. non-GHG) effects, which can provide benefits (e.g. improved animal welfare) or costs (e.g. increased antimicrobial resistance) to society.

Concluding remarks

To be successful, GHG mitigation measures need to be technically feasible, socially acceptable and economically efficient. MACCs provide a systematic way of presenting information on the economic efficiency of MMs in ways that are accessible to policy-makers. While they have limitations, MACCs make a significant contribution to GHG policy development, and it is important that efforts are made to integrate livestock health into them. Health measures were integrated into the latest UK agricultural MACCs in 2015, but these should be seen as a starting point. While improving livestock health looks like a promising mitigation route, translating the theoretical abatement potential in the MACCs into actual policy will require further refinement of the calculation methods. It will also be necessary to refine input assumptions about key parameters such as baseline prevalence, control option impacts and likely uptake rates.

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L'intégration des paramètres de santé du bétail dans les courbes de coût marginal d'abattement

M. MacLeod & D. Moran

Résumé

L'amélioration de la santé des animaux d'élevage apporte des bénéfices non seulement aux personnes et entreprises privées mais aussi à la société en général. La réduction des émissions de gaz à effet de serre est l'un des bénéfices potentiels apportés à la société par les élevages. Il est ainsi possible de réduire l'intensité des émissions (c'est-à-dire la quantité de gaz à effet de serre générée par kilogramme de viande, de lait ou d'œufs), dans la mesure où l'amélioration de la santé animale s'accompagne d'une amélioration des paramètres qui influent sur l'intensité de ces émissions ; par exemple, chez les ruminants, le taux de fécondité, le taux d'avortements, le taux de mortalité néonatale et le taux de croissance chez les ovins et les caprins, la production de lait et le taux de conversion des aliments donnés aux animaux. Or, l'amélioration de la santé n'est pas toujours reconnue comme étant une mesure de réduction des gaz à effet de serre, en raison notamment de la difficulté de quantifier de manière fiable les effets des différentes stratégies zoosanitaires en termes financiers et d'émissions de gaz à effet de serre. Les auteurs proposent une méthode permettant de quantifier les effets des mesures de lutte contre les maladies animales sur les émissions de gaz à effet de serre et de les intégrer dans une courbe de coût marginal d'abattement. Afin d'illustrer certains enjeux en la matière, les auteurs présentent l'expérience conduite récemment (2015) au Royaume-Uni pour intégrer les mesures sanitaires dans les courbes de coût marginal d'abattement du secteur agricole.

Mots-clés

Analyse coûts-efficacité – Changements climatiques – Réduction des gaz à effet de serre – Santé des animaux d'élevage.

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Incluir parámetros de salud pecuaria en las curvas del costo marginal de reducción

M. MacLeod & D. Moran

Resumen

El hecho de mejorar el estado de salud del ganado reporta beneficios de índole tanto privada como social. Entre los posibles beneficios sociales figura una reducción de las emisiones de gases de efecto invernadero resultantes de la producción pecuaria. Esas emisiones también pueden ser menos intensas (volumen de gases generados por kilogramo de carne, leche o huevos), pues la intensidad de las emisiones es sensible a una serie de parámetros cuyo valor mejora al hacerlo el estado de salud, tales como (en el caso de los rumiantes): tasas de fertilidad materna y de abortos; tasas de mortalidad y crecimiento en terneros y corderos; y tasas de producción de leche y de conversión alimenticia. Sin embargo, todavía no ha arraigado la idea de que la mejora del estado de salud es una medida de lucha contra los gases de efecto invernadero, debido en parte a las dificultades existentes para cuantificar con fiabilidad los efectos de los métodos de lucha zoosanitaria sobre parámetros económicos o sobre las emisiones. Los autores explican cómo cuantificar los efectos del control de enfermedades sobre los gases de efecto invernadero y a partir de ahí incluirlos en una curva del costo marginal de reducción. Para ilustrar algunos de los problemas que pueden surgir se refieren a la experiencia británica destinada a incluir parámetros que miden el estado de salud en las más recientes (2015) curvas del costo marginal de reducción en el ámbito agropecuario.

Palabras clave
Análisis de la relación costo-eficacia – Cambio climático – Lucha contra los gases de efecto invernadero – Sanidad del ganado.

References

1. Organisation for Economic Co-operation and Development (OECD) (2013). – OECD Compendium of agri-environmental indicators. OECD, Paris. doi:10.1787/9789264186217-en.

2. Gerber P.J., Steinfeld H., Henderson B., Mottet A., Opio C., Dijkman J., Falcucci A. & Tempio G. (2013). – Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities. Food and Agriculture Organization of the United Nations, Rome.

3. Hristov A.N., Oh J., Lee C., Meinen R., Montes F., Ott T., Firkins J., Rotz A., Dell C., Adesogan A., Yang W., Tricarico J., Kebreab E., Waghorn G., Dijkstra J. & Oosting S. (2013). – Mitigation of greenhouse gas emissions from livestock production: a review of technical options for non-CO_2 emissions. Food and Agriculture Organization of the United Nations, Rome.

4. Elliot J., Williams A.G., Chatterton J.C., Jones G., Hateley G., Curwen A. & Xiping W. (2013). – Study to model the impact of controlling endemic cattle diseases and conditions on national cattle productivity, agricultural performance and greenhouse gas emissions. Final report to Defra on project FFG1016. Department for Environment, Food & Rural Affairs (Defra), London.

5. Schulte R., Crosson P., Donnellan T., Farrelly N., Finnan J., Lalor S., Lanigan G., Brien D.O., Shalloo L. & Thorne F. (2012). – A marginal abatement cost curve for Irish agriculture. Teagasc, Carlow.

6. MacLeod M., Eory V., Gruère G. & Lankoski J. (2015). – Cost-effectiveness of greenhouse gas mitigation measures for agriculture: a literature review. OECD Food, Agriculture and Fisheries Papers, No. 89. Organisation for Economic Co-operation and Development, Paris. doi:10.1787/5jrvvkq900vj-en.

7. Bajželj B., Richards K.S., Allwood J.M., Smith P., Dennis J.S., Curmi E. & Gilligan C.A. (2014). – Importance of food-demand management for climate mitigation. *Nat. Clim. Chang.*, **4**, 924–929. doi:10.1038/nclimate2353.

8. Schneider U.A., McCarl B.A. & Schmid E. (2007). – Agricultural sector analysis on greenhouse gas mitigation in US agriculture and forestry. *Agric. Syst.*, **94** (2), 128–140. doi:10.1016/j.agsy.2006.08.001.

9. Moran D., MacLeod M., Wall E., Eory V., McVittie A., Barnes A., Rees R., Topp C.F.E. & Moxey A. (2011). – Marginal abatement cost curves for UK agricultural greenhouse gas emissions. *J. Agric. Econ.*, **62** (1), 93–118. doi:10.1111/j.1477-9552.2010.00268.x.

10. Howe K. (2016). – The allocation of resources for animal health. *In* The economics of animal health (J. Rushton, ed.). *Rev. Sci. Tech. Off. Int. Epiz.*, **36** (1), 35–48. doi:10.20506/rst.36.1.2607.

11. Mclnerney J.P., Howe K.S. & Schepers J.A. (1992). – A framework for the economic analysis of disease in farm livestock. *Prev. Vet. Med.*, **13** (2), 137–154. doi:10.1016/0167-5877(92)90098-Z.

12. Hospido A. & Sonesson U. (2005). – The environmental impact of mastitis: a case study of dairy herds. *Sci. Total Environ.*, **343** (1–3), 71–82. doi:10.1016/j.scitotenv.2004.10.006.

13. Stott A.W., MacLeod M. & Moran D. (2010). – Reducing greenhouse gas emissions through better animal health. Scottish Agricultural College, Edinburgh.

14. Guelbenzu M. & Graham D. (2013). – Prevalence of BVD in Northern Ireland dairy and suckler herds. Agri-Food and Biosciences Institute, Belfast.

15. Skuce P., Houdijk J., Hutchings M., Waterhouse A. & MacLeod M. (2014). – The impact of animal health status on greenhouse gas emissions from livestock. Knowledge Scotland, Edinburgh. Available at: www.knowledgescotland.org/briefings.php?id=378 (accessed on 10 June 2016).

16. Eory V., MacLeod M., Topp C.F.E., Rees R.M., Webb J., McVittie A., Wall E., Borthwick F., Watson C., Waterhouse A., Wiltshire J., Bell H., Moran D. & Dewhurst R. (2015). – Review and update the UK agriculture MACC to assess the abatement potential for the 5th carbon budget period and to 2050. Committee on Climate Change, London.

17. Skuce P.J., Bartley D.J., Zadoks R.N. & MacLeod M. (2016). – Livestock health and greenhouse gas emissions. ClimateXChange, Edinburgh. Available at: www.climatexchange.org.uk/files/7414/6054/5380/Livestock_Health_and_GHG.pdf (accessed on 13 February 2017).