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LCA modeling of GHG emissions from beef cattle systems

Key external stakeholders:
Bord Bia, beef farmers, agricultural industry, research organisations, consumers.

Practical implications for stakeholders:
This study shows that increasing stocking intensity via increased fertilizer N application rates and higher grass utilization rates lead to increased profitability on beef farms with only modest increases in greenhouse gas (GHG) emissions when expressed per kg of beef carcass produced and large increases when expressed per hectare (ha) of farmland utilized. With increasing global demand for beef meat, the alternative pathways for the beef cattle sector are to intensify production or to expand farmland. Given the high carbon losses associated with farmland expansion, intensification is likely to yield lower GHG emissions per unit of additional beef carcass produced.

Main results:
The lowest total GHG emissions per kg carcass and per hectare were found at the lowest stocking intensity for both bull/heifer and steer/heifer systems. As stocking intensity increased, GHG emissions per kg of carcass increased modestly with the highest stocking intensity being only 4% greater than the lowest stocking intensity for both bull/heifer and steer/heifer systems. When expressed per ha, GHG emissions increased considerably and were 52% higher at the highest stocking intensity relative to the lowest stocking intensity for both systems.

Opportunity / Benefit:
To meet increasing global demand for beef meat, intensification of pastoral-based beef production systems is likely to result in lower GHG emissions per unit of additional beef carcass produced than farmland expansion.

Collaborating Institutions:
Bord Bia

Contact Paul Crosson Email: paul.crosson@teagasc.ie

Teagasc project team: Paul Crosson (PI)
Anne-Marie Clarke
External collaborators: Padraig Brennan, Bord Bia

1. Project background:

Stocking rate is a key driver of profitability for beef cattle production systems, however, concerns exist that increasing the level of nitrogen fertiliser application together with higher organic nitrogen loading may result in increases in the greenhouse gas intensity of agricultural products. The relationship of beef output per ha and GHG emissions arising from variation in stocking intensities has been evaluated by a number of authors, however, much of this analysis was confounded by differences in animal or feeding system. Nevertheless, results appear to indicate that GHG emissions per kg of beef do not necessarily increase at higher stocking rates if nitrogen (N) application rates are not increased excessively. The objective of this study was to evaluate the effect of stocking intensity of spring calving suckler cow herds taking progeny through to beef on the GHG emissions profile and economic performance.

2. Questions addressed by the project:

This study set out to identify, for spring calving suckler beef cow production systems taking progeny through to beef, the impact of stocking intensity on:

- productivity (carcass output) and profitability (net margin).
- the quantity of greenhouse gas emissions generated per kg beef carcass and per hectare.

3. The experimental studies:

In evaluating the GHG emissions from suckler beef production systems a hybrid modelling approach was adopted. The scenarios were first run in a bioeconomic farm systems model, the Grange Beef Systems Model, and the output of this model were used to specify the system characteristics required for the life-cycle assessment model which evaluated the GHG emissions generated from the respective scenarios. Each stocking intensity scenario was examined separately. The functional unit (i.e. output metric) of the study was 1 kg of beef carcass produced on the farm. Included within the system boundary were direct GHG emissions generated on the farm and indirect GHG emissions. Indirect GHG emissions were those arising from the production of purchased inputs used on the farm and from indirect N_2O emissions from nitrate leaching and ammonia (NH_3) volatilization. Greenhouse gas emissions associated with activities after the farm gate (such as slaughtering, processing and distribution) were outside the boundary of the analysis. It was assumed that beef carcass takes the full GHG burden of the production system and therefore only one output (beef) and no co-products were defined for the farm system modelled. For this reason, no allocation (partitioning of inputs and outputs) was used in the current study. The model described in the current paper was developed using the software package SimaPro (PRe Consultants 2012).
The scenarios modelled were suckler beef cattle production systems finishing heifer progeny at 20 months of age and male progeny as bulls at 16 months of age or steers at 24 months of age. The mean calving date was 15 March after which the calves suckle their dam for 8 months while at pasture. Following weaning, it was assumed that males finished as bulls were housed and offered a concentrate and silage diet until slaughter at 16 months of age with a carcass weight of 372 kg. Where males were finished as steers and females finished as heifers for slaughter, they were housed following weaning and offered grass silage ad libitum and 1 kg of concentrates daily. At the end of the first winter housing period steers and heifers were turned out to pasture for a second grazing season, where they grazed predominantly perennial ryegrass swards on a rotational paddock system. Heifers were housed in September of the second grazing season, offered a diet comprising grass silage ad libitum and 3 kg concentrate daily and slaughtered at 20 months of age. Similarly, steers were housed in November at the end of the second grazing season, offered a diet of grass silage ad libitum and 4 kg of concentrate daily and slaughtered at 24 months of age. Respective carcass weights for steers and heifers were 397 kg and 317 kg.

4. Main results:

Total greenhouse gas emissions ranged from 20.1 kg CO_2e/kg beef carcass for the bull/heifer system at the lowest stocking intensity modelled to 23.1 kg CO_2e/kg beef carcass for the steer/heifer system at the highest stocking intensity. Greenhouse gas emissions per hectare increased substantially as stocking intensity increased; for a 47% increase in stocking intensity, bull/heifer system GHG emissions increased by 53% and steer/heifer systems GHG emissions increased by 52%. As stocking intensity increased, the contribution of

Contact Paul Crosson Email: paul.crosson@teagasc.ie

enteric fermentation and manure management to total GHG emissions reduced slightly. This was primarily associated with increases in inorganic N fertilizer application rates and thus, accordingly, the contribution to total GHG emissions from soils, indirect N2O and purchased input emissions increased at higher stocking intensities. In particular, GHG emissions from purchased inputs increased by 14% at the highest stocking rate when compared to the lowest stocking rate. There was a lower GHG emissions contribution from manure management for steer/heifer systems relative to bull/heifer systems. However, the contribution from GHG emission sources that related to soils and indirect N2O emissions were greater for steer/heifer systems when compared to bull/heifer systems.

5. Opportunity/Benefit:

The global demand for meat is predicted to increase by 21% by 2020 relative to 2010. In the case of beef meat, the increase is projected to be 17%. There are a number of alternatives for the global cattle industry to meet these demands but in broad terms the two main options are to 1) increase the intensity of production, thus producing more beef on the current beef cattle areas or, 2) divert additional land resources to beef cattle production. An important aspect of the results presented in the current study is the capacity of grass-based beef cattle production systems to increase intensity of production and beef output for a fixed area of land with only small increases in GHG emissions intensity (CO_2e/kg beef carcass). In addition to improvements in grassland management, further efficiency gains are possible if improvements in nutrient use efficiency were to be obtained. Thus, for beef cattle production systems it can be reasonably assumed that any increases in net global GHG emissions that arise due to intensification of production would be much lower than emissions from land use change.

6. Dissemination:

Scientific Publications:

Clarke, A.M., Brennan, P. and Crosson, P. (2013) Life-cycle assessment of the intensity of production on the greenhouse gas emissions and economics of grass based suckler beef production systems. Journal of Agricultural Science, 151, 714-726

Clarke, A.M. and Crosson, P. (2012) The effect of stocking rate on the economic and technical performance and greenhouse gas emissions profile of suckler beef production systems. Proceedings of the Agricultural Research Forum, Tullamore, Co. Offaly, Ireland, 12-13 March 2012, p. 14

Clarke, A.M. and Crosson, P. (2012) An assessment of greenhouse gas emissions and economics of grass based suckler beef production systems. Proceedings of the 8th International Conference on LCA in the Agri-Food Sector, Saint-Malo, France, 1-5 October 2012, p. 106

Popular publications:

Crosson, P. and Clarke, A.M. (2012) Strategies to reduce greenhouse gas emissions from Irish beef cattle systems. In: Proceeings of the Irish Grassland Association Beef Conference 2012, Horse and Jockey Hotel, Horse and Jockey, Co. Tipperary, 4 September 2012, pp. 7-10.

7. Compiled by: Paul Crosson

Contact Paul Crosson Email: paul.crosson@teagasc.ie