

AGRICULTURAL GREENHOUSE GAS EMISSIONS REDUCED BY AGRI-ENVIRONMENT SCHEMES ON IMPROVED GRASSLAND GRAZED BY INTENSIVE BEEF CATTLE

WARNER, D.J.¹, GREEN, A.¹, TZILIVAKIS, J.¹, LEWIS, K.A.¹

¹Agriculture and Environment Research Unit, University of Hertfordshire, Hatfield, Herts, AL10 9AB, UK

ABSTRACT The alteration of land use and management practices under agri-environment schemes may impact agricultural greenhouse gas emissions. Scheme agreements require modifications to, for example, the location of livestock during the winter or stipulate the targeted creation of grass buffer strips to reduce erosion. The following paper reports on the change in net greenhouse gas emissions for agri-environment schemes applicable to intensive beef production, relative to existing land management. A Life-cycle Assessment approach has quantified the net greenhouse gas emissions, either positive or negative, that result from a change in management as stipulated by the agri-environment scheme agreement. Seasonal livestock removal (winter housing) reduced emissions, mainly nitrous oxide from wet and potentially compacted soil, and prevented soil carbon loss, typically by a net $-0.1 \text{ t CO}_2\text{eq ha}^{-1} \text{ year}^{-1}$. The method of manure storage during the housing period is potentially key in defining the overall impact. Strategies to mitigate emissions during storage, for example the covering of lagoons, are essential to maximise the value of seasonal livestock removal in reducing greenhouse gas emissions. The creation of grass buffer strips had the greatest potential to reduce emissions overall, particularly when placed adjacent to watercourses to prevent erosion or run-off ($-11.6 \text{ t CO}_2\text{eq ha}^{-1} \text{ year}^{-1}$). They require, however, the removal of land from its current management. Careful targeting of these options is critical, to maximise agricultural greenhouse emissions reduction from Environmental Stewardship and to minimise the risk of agricultural production displacement.

Keywords: GHG, N₂O, CH₄, Cattle, Agri-environment scheme

INTRODUCTION Agri-environment schemes, such as Environmental Stewardship (ES), were introduced in England in response to reform of the Common Agricultural Policy (CAP). Scheme objectives are: to improve water quality and reduce soil erosion, enhance farmland wildlife, maintain and enhance landscape character, and to protect the historic environment (Natural England, 2010ab). The landowner receives payment to compensate for income foregone (such as a reduction in, or loss of crop yield, or increased management costs) associated with any required change in land use and land management, to a maximum 100%. The specified management changes may also impact on agricultural greenhouse gas (GHG) emissions and climate change mitigation, on which the following paper reports for ES options relevant to intensive beef production.

1. MATERIAL AND METHODS

1.1. Boundary, baseline setting and management modifications for ES options A baseline management scenario provides a reference point against which changes in land

use or land management practices, through the implementation of ES agreements, can be compared. The temporary grassland grazed by intensive beef cattle (TGBC) baseline and ES option management scenarios (Natural England, 2010ab) are summarized in Table 1. Options that stipulate existing minimum nitrogen (N) fertilizer inputs (EE6, EE10, HJ6) are implemented where the majority of N is supplied by inorganic fertilizer (TGBC). Other options (EK1, HE11) assume a proportion of N is supplied by clover (TGBC + clover). Livestock removal during the winter (HJ7) assumes cattle are grazed all year (TGBC clover + 100% grazing).

Table 1. Baseline temporary grassland grazed by beef cattle (TGBC) scenarios and Environmental Stewardship option management per ha per year.

Scenario	Lime (t)	Re- seed	N (kg)	P ₂ O ₅ (kg)	Chain harrow	Mow / herbicide ^a	Head	Housed ^b
Baseline								
TGBC	0.75	0.2	210	20	1	0 / 1	2.8	Yes
TGBC + clover	0.75	0.2	100	20	1	0 / 1	2.8	Yes
TGBC + clover + 100% grazing	0.75	0.2	100	20	1	0 / 1	2.8	0
ES option								
EE6 / EE10 / EK1 - Buffer strips & Field corners	0	0	0	0	0	2 / 1	0	0
HJ6 - Erosion or run-off prevention	0.75	0.2	100	20	1	0 / 1	1.2	Yes
HJ7 - Seasonal stock removal	0.75	0.2	100	20	1	0 / 1	2.8	Yes
HE11 - Enhanced buffer strips	0	0	0	0	0	1 / 0	0	0

^aHerbicide (fluroxypyr 200 g l⁻¹) applied by weedwiper; ^bFeed as concentrates (495 kg per head) and silage (1571 kg DM per head)

The total N excreted by cattle per ha per year are compliant with Nitrate Vulnerable Zone rules of 170 kg N ha⁻¹ annual farm limit and 250 kg N ha⁻¹ annual field limit (Defra, 2009). The required feed (to satisfy total metabolisable energy need) and composition (proportion of concentrates, grass silage and grazing) have been derived from Defra (2010) and Williams *et al.* (2009). Manures are stored as farmyard manure in unconfined piles or stacks, at a mean temperature of less than 10°C (assumed stored during the winter for application during the spring).

1.2. Inventory of greenhouse gas emissions.

1.2.1. Nitrous oxide Nitrous oxide is emitted post application from inorganic nitrogen fertilizer and manures, manures during storage and from livestock deposition (IPCC, 2006; Williams *et al.*, 2009). Four processes are involved: microbial nitrification and denitrification, leaching of nitrate (NO₃⁻) and volatilization of ammonia (NH₃). The IPCC (2006) methodology to calculate N₂O from the application of inorganic or organic N to grassland in northern Europe has been followed. Housing livestock during the winter, replaces direct N deposition onto grass with N collected and stored as manure.

The quantity of N₂O emitted per kg of N excreted, depends on the storage method and length of time stored (IPCC, 2006; Williams *et al.*, 2009). Nitrous oxide emissions have been calculated per kg of N excreted for the stocking rates stated in Table 1, annual N excretion values per head of beef cattle (Defra, 2009), method (grazing or manure piles), split proportionally for an assumed 151 days housing.

1.2.2. Methane Feed digestion by beef cattle emits CH₄ (IPCC, 2006). The calculated enteric CH₄ emission is accounted for by the proportion of forage relative to concentrates in the diet (Williams *et al.* 2009). Methane produced from manures during housing, considers the volatile solids within the feed consumed (Thomas, 2004), storage method and storage temperature (IPCC, 2006).

1.2.3. Carbon dioxide Fossil fuel consumption during the operation of agricultural machinery or during the manufacture of agro-chemicals emits CO₂. The calculations incorporate direct Scope 1 emissions (spraying, spreading and tillage) and indirect Scope 3 emissions (manufacture of pesticides, fertilizers and farm machinery (Brentrop and Pallière, 2008; Tzilivakis *et al.*, 2005; Williams *et al.*, 2009).

2. RESULTS AND DISCUSSION Input free grass strips (EE6) reduce GHG emissions by an estimated 11.5 tCO₂eq ha⁻¹ year⁻¹ relative to the TGBC baseline (Figure 1).

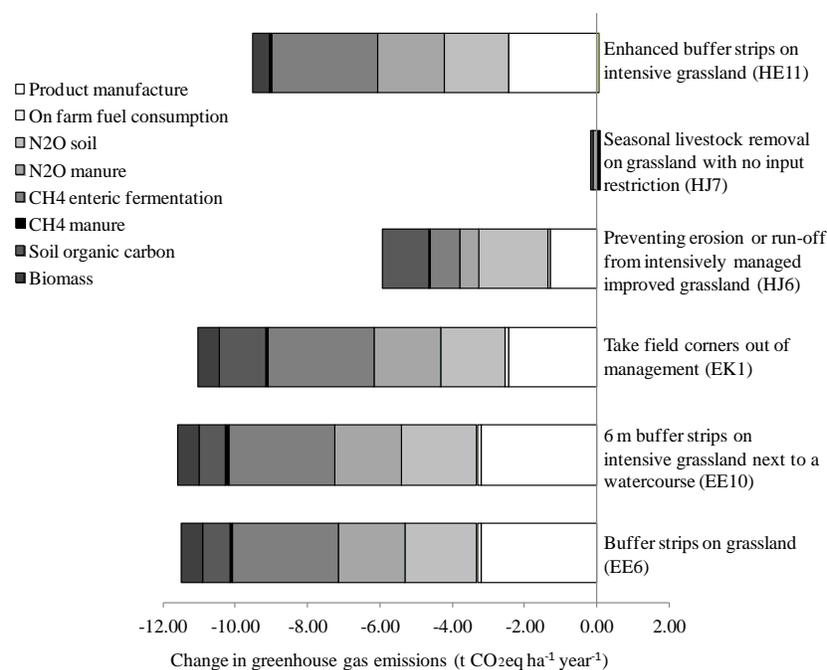


Figure 1. Baseline scenario greenhouse emissions (t CO₂eq ha⁻¹) and impact of ES options on emissions EDP and as mitigation.

Where buffer strips prevent erosion or surface run-off entering a watercourse (EE10), the utilisation by grass of the NO₃⁻ within the run-off captured by the buffer strip, further reduces indirect N₂O emission (-11.6 tCO₂eq ha⁻¹ year⁻¹). Option HJ6 does not remove livestock completely. Erosion or run-off is prevented by a reduction in stocking rate and N fertilizer. The appropriate spatial targeting of these options confers an additional GHG reduction capacity supplementary to the reductions associated solely from the removal of livestock and reduction of agro-chemical inputs.

Livestock may congregate in particular areas of a field (e.g. near gateways or feeders) and cause poaching and topsoil compaction, and hinder grass growth. Poaching and compaction create anaerobic soil conditions (Moorby *et al.*, 2007) that favour denitrification (Machefert *et al.*, 2002) exacerbated in combination with the concentration of deposition N. Seasonal livestock removal on grassland with no input restriction (option HJ7) has potential to reduce topsoil structural damage and N deposition onto wet soils where the risk of NO₃⁻ leaching and surface run-off, or soil compaction and denitrification, are greater. There is potential for ‘pollution swapping’, increased CH₄ emission from manure storage compared to direct deposition onto grassland (IPCC, 2006) and as such, the method of manure storage is critical in maximising the benefit of ES options that remove livestock from grazing land during the winter.

3. CONCLUSION The removal of productive grassland from production risks the displacement of that production elsewhere, and no net emissions reduction may result. The spatial targeting of ES options, to prevent erosion or run-off into water courses or removal of livestock from land during the winter where compaction and increased denitrification is a risk, provides additional GHG reduction benefits beyond the removal of land from production alone.

Acknowledgements. This work was funded by the Department for Environment, Food and Rural Affairs, England.

REFERENCES

- Brentrup, F., Pallière, C., 2008. Greenhouse gas emissions and energy efficiency in European nitrogen fertiliser production and use. *Int. Fert. Soc. Proc.*, 639.
- Department for Environment, Food and Rural Affairs, 2009. Nitrate Vulnerable Zone (NVZ) Guidelines leaflet 3 PB12736c. Crown copyright, UK.
- Department for Environment, Food and Rural Affairs, 2010. Fertiliser Manual (RB209) 8th Edition. PB13381. Crown copyright, UK.
- Intergovernmental Panel on Climate Change (IPCC), 2006. IPCC Guidelines for National Greenhouse Gas Inventories. Eggleston, H.S., Buendia, L., Miwa, K., Ngara, T., Tanabe, K. (Eds). IGES Publications, Japan.
- Machefert, S.E., Dise, N.B., Goulding, K.W.T., Whitehead, P.G., 2002. Nitrous oxide emission from a range of land uses across Europe. *Hydrol. Earth System Sci.*, 6, 325-337.
- Moorby, J.M., Chadwick, D.R., Scholefield, D., Chambers, B.J., Williams, J.R., 2007. A review of best practice for reducing greenhouse gases. Defra project report AC0206, UK.
- Natural England, 2010a. Entry Level Stewardship (ELS) Handbook 3rd edition NE226. Copyright Natural England, UK.
- Natural England, 2010b. Higher Level Stewardship (HLS) Handbook 3rd edition NE227. Copyright Natural England, UK.
- Tzilivakis, J., Warner, D.J., May, M., Lewis, K.A., Jaggard, K., 2005. An Assessment of the Energy Input for Sugar Beet (*Beta vulgaris*) Production in the UK. *Agricultural Systems*, 85, 101-119.
- Williams, A.G., Audsley, E., Sandars, D.L., 2009. Environmental Burdens of Agricultural and Horticultural Commodity Production - LCA (ISO205) version 3. Cranfield University, UK.