

Emerging Climate-Smart Technologies as Greenhouse Gas Mitigation Strategies in Scottish Beef Systems

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Overview

Emerging climate-smart technologies will need to play a key role in reducing greenhouse gas (GHG) emissions from beef production, however, their impact at farm level is not fully quantified. Modelling using real Scottish beef farm data demonstrated that three emerging climate-smart technologies: feed additives (including bolus), microbiome-driven breeding and GreenShed (a methane capturing cattle shed that utilises waste products to power the shed and grow indoor crops) reduced both whole farm and product emissions across all farms.

Main Findings

Fifteen Scottish beef farms were selected. **Six spring calving lowland herds** and **six beef finishing systems** were selected for feed additives and microbiome-driven breeding and a further three beef finishing systems were selected for GreenShed to reflect the size of finishing system required to fill a 100-cattle shed all year round. Baseline emission estimates were calculated using **AgreCalc** and impacts of different technologies were modelled.

- **Feed additives** – Up to **36%** reduction in whole-farm emissions (if administered to grazing animals). However, **impacts are more limited on farms where cattle are grazing for part of the year without a bolus** (up to 24% for housed cattle >12 months only). Substantial mitigation is only achieved when feed additives are supplied to all housed cattle >12 months, whereas housed suckler cows alone results in reductions of up to 8%.
- **Microbiome-driven breeding** – Average whole farm emission reductions of up to **21% by year 10**, with potential for further gains beyond the modelled period. As genetic improvement is gradual, it **takes longer** to achieve a significant reduction in whole-farm emissions. However, microbiome-driven breeding offers **cumulative** and **permanent emission reductions**, unlike feed additives which cease to have any effect once the additive stops being fed.
- **GreenShed** - Similar emission reductions across all scales and scenarios, with a reduction in whole farm emissions of around **14%**. However, GreenShed is only applicable to **larger indoor finishing systems**.



As production remained constant for all scenarios, the reductions in emission intensity (kg CO₂e/kg dwt) mirrored those observed for the total beef emissions.

Overall, emerging technologies show strong GHG mitigation potential, however, they vary in their relative timescales and suitability in different systems, highlighting the need for tailored policy frameworks and incentives.



Introduction

To achieve their net zero by 2045 target, the Scottish Government have called for a 31% reduction in agricultural emissions by 2032 compared to 2018 levels. Achieving this will require the adoption of new technologies on farms to reduce GHG emissions. While many emerging livestock technologies present as promising GHG mitigation strategies, their impacts have not yet been fully evaluated at a farm level. The aim of this study was to model the potential GHG impacts of various emerging technologies including different methane inhibiting feed additives, microbiome driven breeding and GreenShed on real beef farms.

Assumptions

Feed additives

Three feed additives were modelled using average abatement potentials from multiple studies with a range of supplementation rates (Miller et al., 2022): 3NOP - 34.9%, Ca(NO₃)₂ - 10.9% and *Asparagopsis* – 64.6%. Each additive was tested under three application scenarios:

- i. Housed suckler cows only
- ii. All housed cattle over 12 months
- iii. All cattle over 12 months, including grazing animals (assuming a bolus was available)

Microbiome-driven breeding

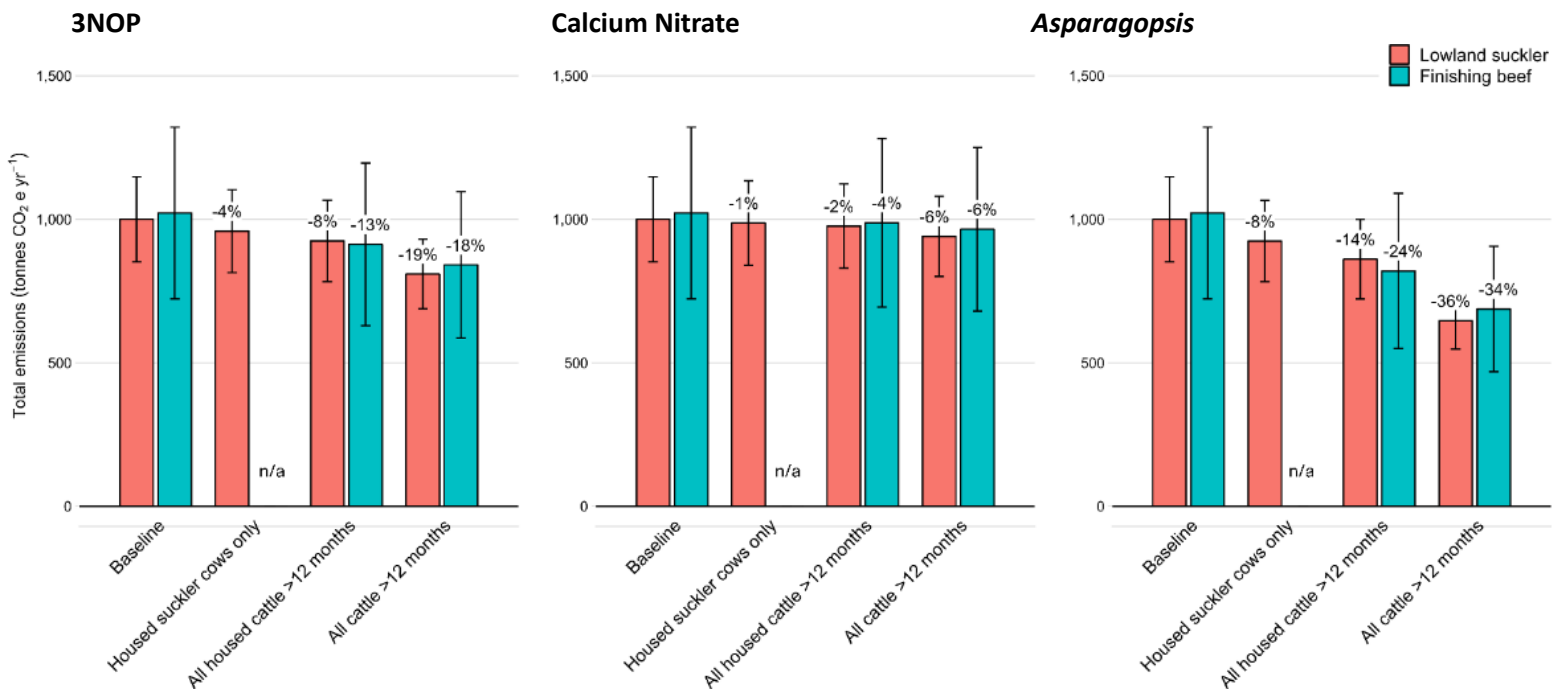
Microbiome-driven breeding was modelled over a 10-year period assuming selection of animals based on the 30 most informative microbial genes linked to methane production and metabolism. This was assumed to result in a 17% reduction in enteric methane emissions per generation (Martínez-Álvaro et al., 2022a) and cows were artificially inseminated using semen from low-emitting bulls, with a three year generation interval.

GreenShed

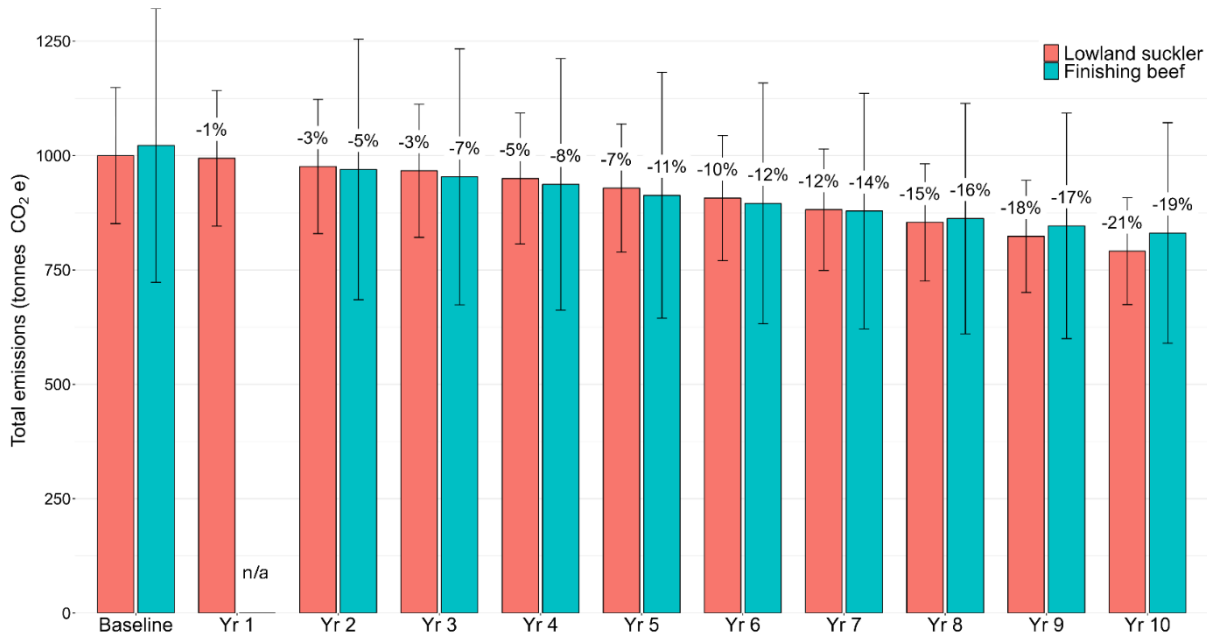
Three scenarios were modelled for GreenShed (based on a 100-head cattle shed) on different sized finishing systems: i) a farm with one shed, ii) a farm with two sheds and iii) a supply chain with 15 sheds across multiple farms. GreenShed modelling assumptions were informed by a full life cycle assessment and included methane captured from the housing (-127 tCO₂e), energy generation from combined heat and power (CHP; -156 tCO₂e), and electricity and fertiliser use (+147 tCO₂e).

Results

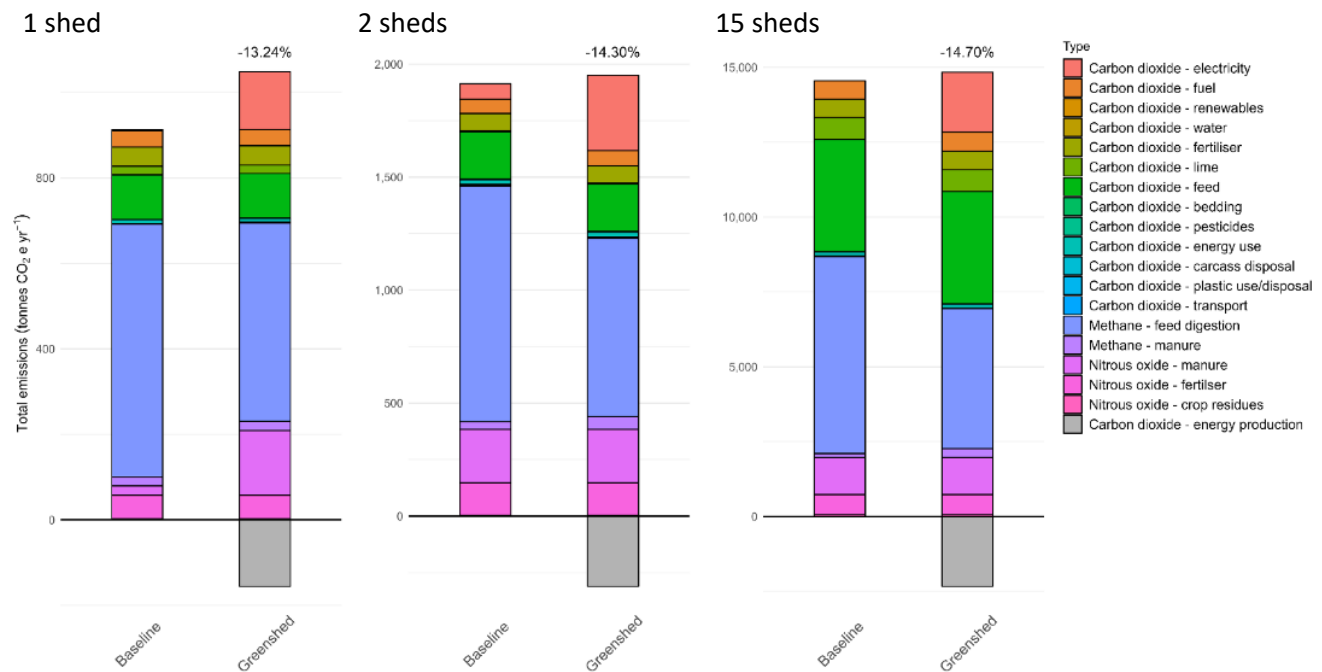
Feed additives



Microbiome-driven breeding



GreenShed



Policy Implications

- Emerging technologies show strong GHG mitigation potential, however, they vary in their relative timescales and suitability in different systems, highlighting the need for tailored policy frameworks and incentives.
- Demonstrating these benefits and supporting uptake could accelerate the Scottish beef sector's transition to net zero.
- Further innovation is needed to enable delivery of feed additives in grazing systems, where their potential is currently limited.

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