Extended Abstract

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Paper/Poster Title	A preliminary economic and environmental analysis of virtual fencing for intensive lowland grazing.

Abstract prepared for presentation at the 98th Annual Conference of The Agricultural Economics Society will be held at The University of Edinburgh, UK, 18th - 20th March 2024.

Abstract	*200 words max*

Virtual fencing is an unseen boundary created using Global Navigation Satellite Systems (GNSS). It can be managed remotely to control grazing livestock without physical fences. The animals experience the virtual boundaries as audio or vibration cues and possibly as electric shocks administered through battery-powered collars. This study provides a multi-objective optimisation of the economic and environmental performance of intensive lowland grazing farms managed via two stocking strategies and three fencing types. The two stocking strategies include set stocking and rotational stocking. The three fencing types are woven wire, electric, and virtual fencing. The aim of the analysis is to identify trade-offs among farm income and carbon footprint for a range of decision-maker types. Results show that the cost of the virtual fencing system studied almost completely offsets the economic benefits achieved with rotational stocking in intensive lowland grazing systems. Environmental benefits in rotational stocking systems managed via electric or virtual fencing are comparable for intensive lowland grazing farms. A hypothesis for future research is that virtual fencing is a promising solution for managing extensive conservation grazing systems located in sensitive landscapes or remote areas where installing physical fences is uneconomical or not allowed.

Keywords	Virtual fencing, profitability, carbon footprint, multi-objective optimization
JEL Code	Q550 see: www.aeaweb.org/jel/guide/jel.php?class=Q)

Introduction	*100 – 250 words*

Virtual fencing is an invisible boundary created using Global Navigation Satellite Systems (GNSS). It is managed remotely and in real time by app-based technology to control grazing livestock without physical fences. The animals experience the virtual boundaries as audio or vibration cues and possibly as electric shocks administered through battery-powered collars. Virtual fencing makes precision grazing possible without cost and work of physical fencing.

Globally, there are more than 40,000 virtual fencing collars used for managing cattle and small ruminants on more than 3,000 farms. In the UK, there were more than 140 virtual fencing users as of 2022, with this figure expected to quickly grow in forthcoming years. However, economic and environmental implications of virtual fencing are still largely unclear. Pilot projects led by public-private partnerships in the UK, Ireland and the US and grazing livestock management research are aiming to better identify the sustainability potential of virtual fencing.

Methodology	100 – 250 words

This study is a multi-objective optimisation of virtual fencing in beef cattle grazing systems using the Hands Free Hectare Multi-Objective Linear Programming (HFH-MOLP) model developed at Harper Adams University. For this analysis, the objective function is the weighted sum of maximising return on operator labour, management and risk taking (ROLMRT) and minimising the whole-farm carbon footprint expressed in kilograms of CO_2 equivalent. The weights span from 1 on ROLMRT and zero on carbon footprint for the profit-oriented farmer to 0.6 on ROLMRT and 0.4 on carbon footprint for the more ecologically motivated decision-maker. The carbon footprint is estimated with the Cool Farm Tool developed by the Cool Farm Alliance.

This analysis compares the economic and environmental performance of intensive lowland grazing farms managed via two stocking strategies and three fencing types. The two stocking strategies include set stocking and rotational stocking. The three fencing types are woven wire, electric, and virtual fencing. The modelled farm is a 295-ha mixed farm in the UK West Midlands. 50% of the land is allocated to winter wheat, 25% to winter field bean (break crop), and the remaining 25% is equally allocated to maize silage and cattle grazing. The grazing system is an intensive summer beef finishing enterprise. Cattle are purchased at 8 months old, grazed for 300 days and sold at 18 months old. The initial cattle weight is 280 kg, and the final cattle weight is 595 kg. The supplementary feed includes 3,000 kg of maize silage and 330 kg of concentrate feed per head annually.

Results	100 – 250 words

The HFH-MOLP results show that in spite of higher labour requirements (about 672 hr/yr), rotational grazing with electric fencing provides the highest expected ROLMRT among these scenarios (Table 1). Virtual fencing slightly reduced labour needs (32 hr/yr less than with electric fencing), but requires a substantially higher capital investment than movable electric fences. The investment in movable electric fences is estimated at about £6,406 with a 20-year useful life, while the virtual fencing system is priced at £53,405 with an estimated 6-year useful life. Consequently, the ROLMRT for rotational grazing with the virtual fencing is only slightly above that of the set stocking scenario when depreciation and opportunity cost of capital are taken into account.

Carbon footprints for both rotational grazing scenarios are higher than in the set stocking system because overall more grass is grazed and more beef is produced (Table 1). Rotational grazing with electric fences is preferred for both the profit-oriented farmer and the more ecologically oriented decision-maker. The decision weight on carbon footprint affected the next best choice. When more weight is shifted to carbon footprint minimisation, the second best choice switches to set stocking because the small monetary gain from rotational grazing with virtual fencing does not outweigh the increased carbon footprint obtained in this scenario.

Table 1. Herd pasture consumption, total beef produced, return to operator labour, management and risk taking (ROLMRT) and carbon footprint across scenarios

Scenarios	Herd pasture consumption (MgDM * year^{-1})	Total beef produced (Mg)	ROLMRT (£)	Carbon Footprint (kgCO_2eq * TotalFarm Output^{-1})
Set stocking	1,774	70.6	28,141	56.8
Rotational stocking (Electric fencing)	2,301	98.8	45,786	65.8
Rotational stocking (Virtual fencing)	2,301	98.8	29,826	65.8

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Discussion and Conclusion

100 – 250 words

Results show that the cost of the virtual fencing system studied almost completely negates the economic benefits achieved with rotational stocking in intensive grazing systems. Environmental impacts, defined as average carbon footprint by scenario, in rotational stocking systems managed via electric or virtual fencing are comparable for intensive lowland grazing farms. On the other hand, virtual fencing may be a promising solution for managing extensive conservation grazing systems located in sensitive landscapes or remote areas where installing physical fences may be uneconomical or not allowed. The hypothesis is that, in conservation grazing systems, virtual fencing may enable increased profitability from beef production while promoting environmental conservation. This hypothesis will be evaluated in further research. Further analysis should also consider interactions between grazing management system and changes in pasture botanical composition and biodiversity, as well as the finer interactions between selective grazing and animal performance.