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Sustainable Intensification

Estimated differences in economic and environmental performance of dairy herds across the UK

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Summary

Production data were obtained from about half a million milk recorded dairy cows and the Farm Business Surveys for England, Scotland, Wales and Northern Ireland. This study modelled the average herd in each region between the years 2010 to 2015 and assessed the impact of a single unit change on the economic value and greenhouse gas emissions intensity (expressed as carbon dioxide equivalents per kg milk solids) for selected production, health and fertility traits associated with dairy cows. The results of this study show that there are differences in the average production of dairy herds across regions of the UK; however, only slight differences in calculated economic values and emissions intensity values associated with biological traits were found. Recognising the regional and potential genotype x environment differences associated with milk production, and providing a methodology to assess these differences at the farm level, would help improve the resilience and efficiency of milk production in the future.

Key words: Dairy systems, biological traits, profit, greenhouse gas emissions

Introduction

The UK is a significant global producer of milk, with about 1.8 million cows producing 14 million litres of milk each year (valued at £4bn), making the UK the tenth largest global milk producing country (FAO, 2017). Improvements in production efficiencies and profitability of milk produced from dairy cows is of great interest to farmers, with the added benefit of efficiency savings also helping to reduce the environmental impact of milk products, which is socially important (Bell *et al*., 2011). The livestock industry has made large advances in efficiencies over the past 60 years as a result of changes in breeding, nutrition and management. However, inefficiencies in the total output of production can be caused by factors such as poor animal health and wellbeing and animal nutritional requirements not being met, which may also be linked to the genetic background of the individual animal (i.e. genotype × environment interaction). In dairy cows, although the greenhouse gas (GHG) emissions per unit milk appears to have reduced due to a dilution in animal maintenance requirements with increased average milk yields per cow (Bauman *et al*., 1985), there is little evidence to suggest that improvements in fitness traits has been made with regard to health (e.g. mastitis, lameness) and fertility during this time (FAWC, 2009); therefore there is further potential to reduce the emissions intensity of production. Maintaining healthy animals will enhance production, particularly later in life from increased lifetime performance (Bell *et al*., 2015*a*).

The current study used the model by Bell *et al.* (2015) to assess the impact on economic value (£ cow^{-1}) and GHG emissions intensity (carbon dioxide equivalent (CO_2-eq) emissions per unit milk solids) of a unit increase in selected biological traits for the average herd in England, Scotland, Wales and Northern Ireland.

Materials and Methods

Model and data

Average production records between the years 2010 to 2015 were obtained for dairy cows in England (n=346,538), Scotland (n=51,904), Wales (n=65,725) and Northern Ireland (n=46,713) from the Centre for Dairy Information (CDI, 2016) for milk recorded herds (Table 1). This study used an existing economic model (for more detail see Bell *et al.*, 2013, 2015*a*) to dynamically describe the nutrient partitioning of a cow using a Gompertz growth curve over its lifetime. Cow values were multiplied up to a 100 cow herd, to allow investigation of changes in profit and CO_2-eq emissions per unit product in response to changes in biological traits. Responses to changes are quantified by calculating differences between the current state (baseline situation) and an increase in a biological trait (altered situation). A total of 11 age groups including heifer replacements and 10 lactations for milking cows were modelled. A Markov chain was used to obtain a steady state herd in each age group to allow the effect of survival within a population to be investigated. Briefly, the model calculates the total energy requirements for a herd replacement and a lactating cow for maintenance, growth of body fat and protein, pregnancy, activity and lactation. The associated feed intake required is then formulated based on the average animal, which was assumed to be for a lactating cow diet (heifer diet in parentheses): 33 (40)% pasture, 33 (40)% grass silage and 34 (20)% concentrate per kilogram DM intake per lactation, with an average nutrient composition of 196 (192) g kg^{-1} DM crude protein, 80 (79) g kg^{-1} DM ash, 392 (423) g kg^{-1} DM NDF, 35 (37) g kg^{-1} DM ether extract, 80 (70) g kg^{-1} DM sugar, 12.1 (11.9) MJ kg^{-1} DM metabolisable energy and 19.4 (19.2) MJ kg^{-1} DM gross energy as found appropriate to represent UK systems by Bell *et al.* (2015*b*). The proportion of cows in each lactation that had mastitis was calculated using a cumulative normal distribution with a mean log transformed SCC of 400,000 somatic cells/ml (de Haas *et al.*, 2004). A cow with mastitis had an associated cost for treatment and loss of milk. For mastitis, on average 0.25 incidences were assumed to be clinical cases and the remainder were assumed to be subclinical cases. A case of clinical mastitis had an average cost of £181 per incidence and subclinical average cost of £62.

Change in profit and efficiencies of production

The economic value and emissions intensity as CO_2-eq emissions per kg MS (environmental impact) were calculated by a single unit increase in each biological trait. The model included a partial budget calculation to determine the change in gross profit or economic value (e.g. income – variable costs = gross profit or loss) per cow for each age group in the herd for a change in each trait. The average variable costs and income during the study period were obtained from the Farm Business Surveys for England (http://www.farmbusinesssurvey.co.uk/), Scotland (http://www.gov.scot/Topics/Statistics/Browse/Agriculture-Fisheries/Publications/FASdata), Wales (https://www.aber.ac.uk/en/ibers/research/fbs/stats/) and Northern Ireland (https://www.daera-ni.gov.uk/publications/farm-incomes-northern-ireland-2004-2014) and appropriate financial values were used (Appendix A). The average milk price obtained from Farm Business Surveys was 28.5 p L^{-1} for England, 28.7 p L^{-1} for Scotland, 28.0 p L^{-1} for Wales and 28.0 p L^{-1} for Northern Ireland. A single phenotypic change was assessed for the following traits: milk volume, fat yield, protein yield, survival, somatic cell count (SCC), mastitis and calving interval. The traits represented a range of production, health and fertility traits.

Table 1. *Average production values for herds in England, Scotland, Wales and Northern Ireland per lactation*

Trait	Units	England	Scotland	Wales	NI
Milk volume[1]	Litres	9025	9189	8664	8744
Milk fat yield[1]	Kg	359	363	344	349
Milk protein yield[1]	Kg	287	290	275	278
Survival[1]	%	71	69	71	70
Somatic cell count[1]	'000 cells mL^{-1}	183	198	199	237
Mastitis[1]	%	21	23	24	29
Calving interval[1]	Days	413	418	416	411
Enteric CH_4[2,3]	Kg	249	257	249	250
Manure CH_4[2]	Kg	48	49	47	47
Total N_2O[2]	Kg	11	11	11	11

[1] Data from CDI (2016).

[2] Includes contribution from herd replacements.

[3] Enteric CH_4 emissions were estimated by: CH_4 (g kg^{-1} DM intake) = 0.046 × DOMD - 0.113 × ether extract (both g kg^{-1} DM) – 2.47 × (feeding level - 1), where DOMD is digestible organic matter in the dry matter and feeding level is metabolisable energy intake as multiples of maintenance energy requirements.

The loss of greenhouse gas emissions in the form of enteric and manure methane (CH_4) and direct (N_2O) from stored manure and application of dung, urine and manure, and indirect nitrous oxide from storage and application of manure to land (from leaching and atmospheric deposition of nitrogen from NOx and NH_3) were calculated and used as a measure of production efficiency. Kilograms of CO_2-eq emissions for a 100-yr time horizon were calculated using conversion factors from CH_4 to CO_2-eq of 25 and from N_2O to CO_2-eq of 298 (IPCC, 2007) and UK estimates (UKGGI, 2010) for manure systems. The N excreted by the animal was partitioned into dung (N intake – digested N intake) and urine (N intake – (N retained + N in dung)).

Results and Discussion

In Scotland, the average herd contained a higher proportion of first to third lactation cows and fewer cows achieving greater than three lactations than in other regions (Fig. 1). Also, Northern Ireland had a noticeably high proportion of cows in their first lactation. The proportion of cows in their second lactation or more in the average herds in England, Wales and Northern Ireland were similar.

Economic and emission intensity values

Across the UK, of the seven biological traits assessed a desirable increase in economic value and reduction in CO_2-eq emissions was associated with an increase in milk fat and protein yield, survival, and decrease in milk volume, SCC, mastitis incidence and calving interval (Table 2). Overall there were only slight differences in economic values and emissions intensity values between regions studied. The economic values for milk production traits were similar for England and Scotland, and about 4% – 5% lower for Wales and Northern Ireland. England had considerably higher economic values (between 10 – 30%) and emission intensity values (between 11 – 37%) for SCC and mastitis incidence than other regions.

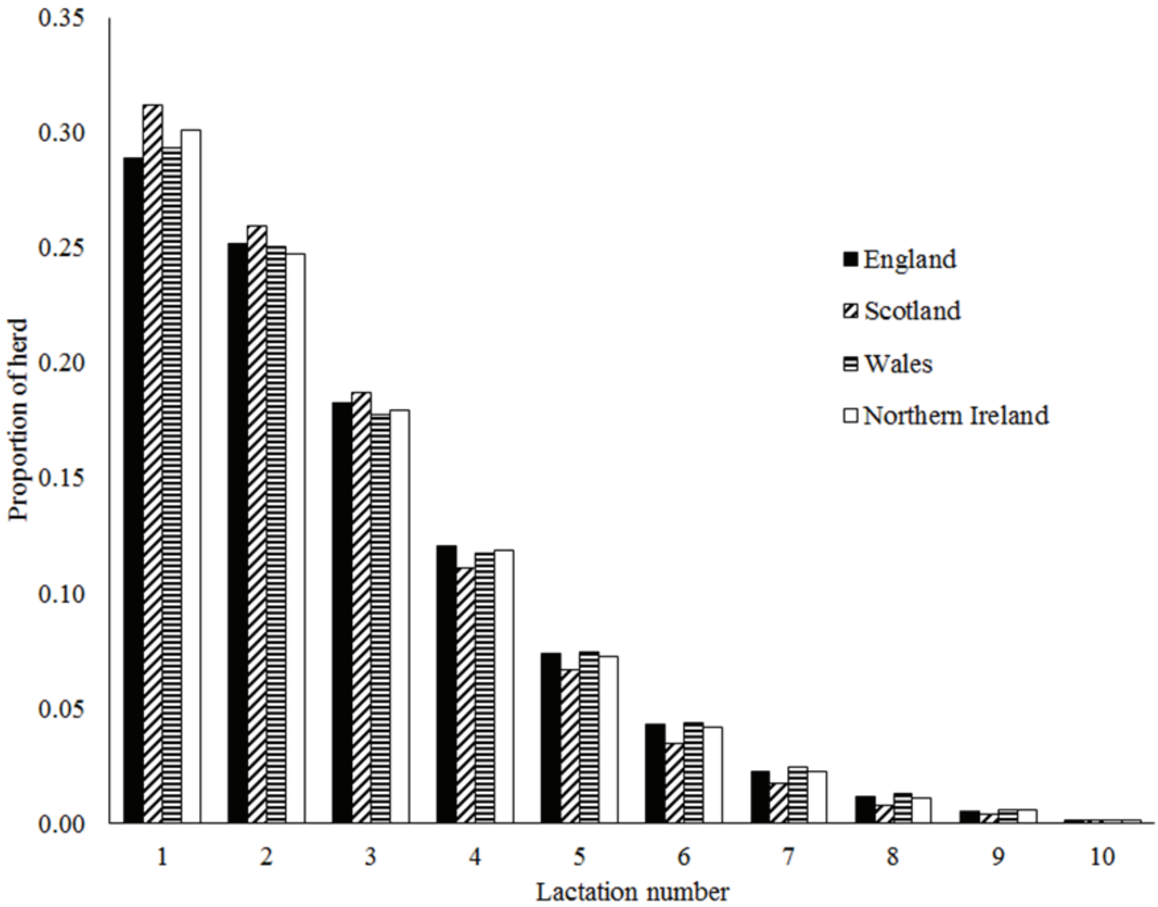

Fig. 1. Steady-state herd showing proportion of cows in each lactation for UK regions studied.

Table 2. *Average change in profit (EV) and emission intensity (CO_2-eq) due to a single unit increase in biological traits for the average herd in England, Scotland, Wales and Northern Ireland*

		EV (£ cow^{-1})				CO2-eq. (g kg^{-1} MS)			
Trait	Units	England	Scotland	Wales	NI	England	Scotland	Wales	NI
Milk volume	litres	-0.04	-0.04	-0.04	-0.04	0.2	0.2	0.2	0.2
Milk fat yield	kg	2.85	2.83	2.72	2.70	-16.4	-16.6	-17.7	-17.5
Milk protein yield	kg	3.33	3.31	3.20	3.18	-23.5	-23.6	-25.3	-24.9
Survival	%	13.53	14.00	13.80	14.10	-91.1	-92.7	-97.9	-98.3
Somatic cell count	'000 cells mL^{-1}	-0.28	-0.25	-0.24	-0.20	0.2	0.2	0.2	0.1
Mastitis	%	-1.83	-1.65	-1.58	-1.37	1.3	1.1	1.2	0.9
Calving interval	days	-2.78	-2.86	-2.80	-2.82	23.1	23.4	23.7	23.9

Conclusions

The challenge for society, scientists and farmers is to maintain the profitability of food production, such as milk, by better matching available and appropriate resources to requirements, in order to optimise profit and production, and to minimise pollution (from waste). This study used a bio-economic model that can be customised at the farm level to assess production efficiencies (economic and nutrient use) to changes in biological traits, nutrition or management. In the case of dairy cows, this approach would allow farmers to quantify traits which are often difficult to quantify such as methane output of animals, feed efficiency and nutrient losses.

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Appendix A

Table A. *Assumed production and financial parameters associated with an average herd in England, Scotland, Wales and Northern Ireland*

Parameter	Units	Value
Age at first calving	days	730
Gestation	days	283
Growth rate	kg protein day^{-1}	0.0033
Milk fat	%	4.0
Milk protein	%	3.2
Income (£)		
Calf value	kg	2.50
Culled cow	kg	0.70
Costs (£)		
Value of heifer	kg	2.00
Enterprise	litre	0.02
Labour	hour	10
Semen	straw	15
Pasture	MJ ME	0.003
Grass silage	MJ ME	0.009
Concentrate	MJ ME	0.020