Exploring the emissions intensity of Scottish sheep and cattle livestock farms

Barnes, AP

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Andrew Barnes, Department of Rural Economy, Environment and Society, SRUC, West Mains Road, Edinburgh, UK

Summary

At an absolute level the Scottish Government has a requirement to meet Net Zero Carbon by 2045. Whilst most production activities produce greenhouse gases, emissions intensity is a way to explore how emissions relate to these activities. Lower emissions intensity in farming helps to support progress towards Net Zero carbon agriculture. However, farms in Scotland operate across a diverse set of biophysical, climatic and economic constraints.

The purpose of this brief is to measure emissions intensity and compare these with estimates of farm-level technical efficiency, which reflects decision making at the farm level. We utilise a pilot study linking farms in the Scottish Farm Business Survey to SAC's Agrecalc carbon calculator for the crop year 2019/2020. We focus on beef and sheep-meat sectors which is the most common enterprise across Scotland.

Overall we find a high level of variance in emissions intensity in our beef and sheep farms, with a number of very high and very low emitters operating in cattle and sheep farms. Whilst we focus on gross emissions - those which relate to direct agricultural activity - but also measure net emissions and find the specialist sheep farms tend to have higher proportions of emissions sequestered, predominantly due to farm woodland. The relationship between farm-level technical efficiency and emissions intensity differs between farm types. With a higher amount of variance in emissions intensity attributable to specialist sheep farms compared to cattle or mixed farms. For these farms herd-level factors, such as breed and age structure will also be an important component of emissions intensity.

Understanding where farms are with respect to emissions intensity helps to appreciate their capacity to adopt more efficient and sustainable practices and new production technologies. Moreover it provides an exercise in understanding how we can approach measurement of emissions intensity to support progress in reporting and monitoring within Scottish farming.

1.0 Introduction

Emissions intensity is calculated as the carbon dioxide equivalent (Co2e) per kg of product produced. It therefore provides a metric which compares the relative performance - in terms of output - of farms of a similar type. The factors which do drive emissions intensity are related to efficiencies in management. Whilst the range of management practices are not collected in the Farm Business Survey they can be inferred by the efficiency of resource use (See Barnes, 2022). Accordingly, the aim of the brief is to

- outline the variance in emissions and emissions intensity between farm types in the Scottish Farm Business survey,
- explore the relationship between emissions intensity and the technical efficiency of these farms

2.0 Method

The Scottish Farm Business Survey (SFBS) collects data for around 400-500 individual farm businesses across Scotland. The FBS has collected data since the 1930s but has only been digitised from 1989 onwards. Data are collected over each succeeding crop year using detailed farm accounts data for each farm business and collated through an individual assessor. The data go through numerous quality checks before release and are used as the basis for understanding some of the main changes in economic circumstances of Scottish farms.

The Agricultural Resources Calculator (Agrecalc) is a farm-level tool developed by SRUC for measuring resource efficiency to improve profitability and environmental impact. As with other farm-level tools, it requires reasonably detailed information of farming activities and deploys a range of assumptions and (e.g.) emission factors to estimate the effects of management changes.[1] It has been developed in Scotland, and is well suited to Scottish farming systems. For example, it is able to estimate the effects of changes on fertiliser application rates, livestock diets and daily growth rates – all of which were identified by Farmer Led Groups as areas for best practice adoption.

To estimate emissions intensity we simply take the gross emissions of the farm, which is composed of direct and indirect carbon emissions, methane and nitrous oxide and divide by the total kilogram of product produced. This is not ideal as even specialised farms can produce a mixture of commodities, e.g. meat and milk. More mixed farms will produce hay. However, it provides a close approximation of the amount of product produced and links to the gross emissions from that activity. To reduce the effect of this we focus on two main farming types, namely dry stock producers, which covers specialist cattle and sheep, and dairy producers, which mostly covers milk production.

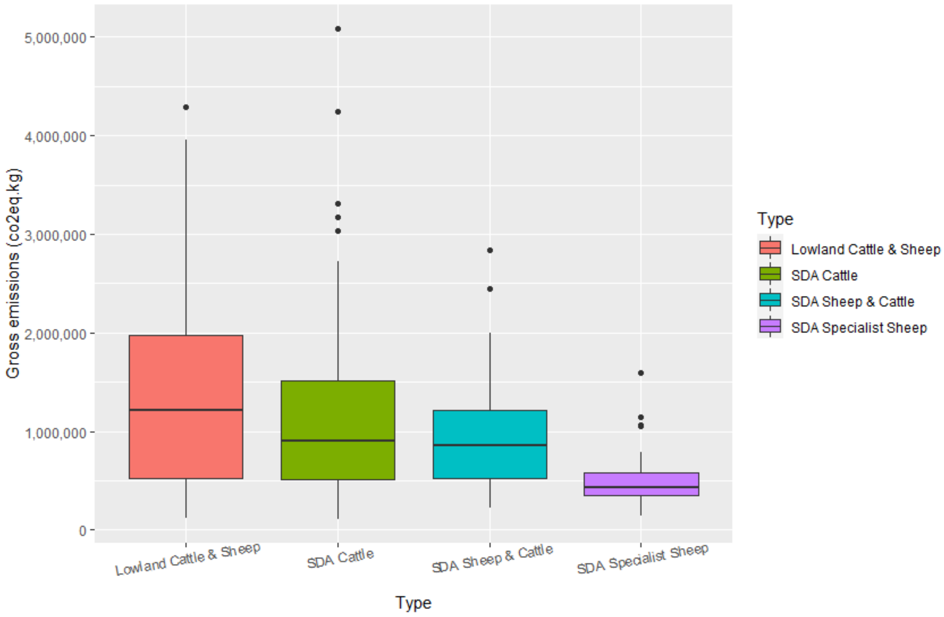
[1] see https://www.sruc.ac.uk/business-services/what-is-your-goal/sustainability/Agrecalc/ and https://www.climatexchange.org.uk/research/projects/comparative-analysis-of-farm-based-carbon-audits/

3.0 Results

3.1. Overall emissions by farm type

The figure below shows the ranges of overall emissions - in Co2 equivalents of the four farming types. It is important to know that for most farm types these are only small samples, however the SFBS does provide some representation of farming in Scotland, albeit from an economic perspective. Nevertheless what is clear is the range - at farm level - of emissions within farming types. Lowland cattle, as would be expected from more intensive systems, has the highest median emissions, followed by specialised cattle. The lowest median and lowest smallest range are specialist sheep producers, which reflect extensive systems.

Figure 1. Range of emissions by livestock farm type^



^ The dots represent outliers - these are individual farms with emissions above the top 5%

The table below shows the summary statistics, in terms of overall emissions, as well as the proportion of the type of emissions by farm type. Furthermore the level of sequestration and net emissions, ostensibly emerging from woodland on farm is shown. Clearly, this table shows the large ranges within farm type but also, at the mid-point level, only the extensive specialist sheep have any contribution to sequestration compared to other systems.

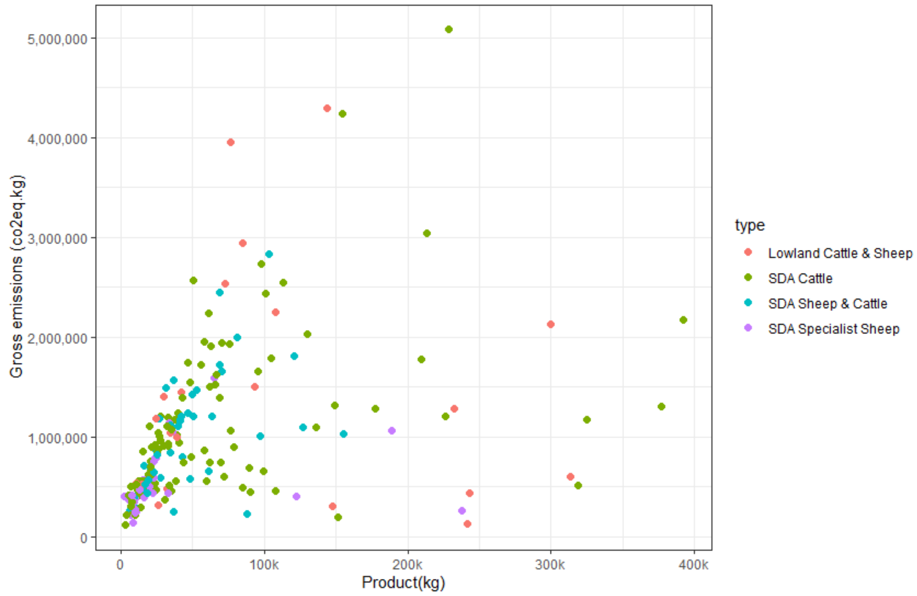
Table 1. Summary gross and net emissions by farm type, median and ranges

	Lowland Cattle & Sheep (n=22)		SDA Cattle (n=106)		SDA Sheep & Cattle (n=49)		SDA Specialist Sheep (n=30)	
	median	*range*	median	*range*	median	*range*	median	*range*
GHG CO2e (kg)	1,216,703	4,166,452	900,270	4,967,643	859,689	2,607,726	432,626	1,445,094
Direct CO2 (%)	5%	9%	5%	9%	4%	8%	5%	11%
Indirect CO2 (%)	20%	25%	17%	36%	17%	27%	12%	23%
Methane (%)	47%	27%	54%	33%	56%	32%	61%	31%
Nitrous Oxide (%)	24%	24%	25%	25%	22%	19%	21%	8%
Net Emissions CO2e (Kg)	1,209,788	4,177,343	900,270	4,799,132	844,444	5,278,246	329,349	2,757,529
Seqestered CO2e (Kg)	-	100,188	-	518,364	10,563	2,699,849	25,047	1,779,099
Sequested (%)	0.0%		0.0%		1.3%		7.6%	

3.2. Emissions Intensity by farm

Whilst emissions per farm provides a useful descriptor of Scottish farming it does not accommodate for differences at the farm level. Emissions intensity can be measured a number of ways (See MacLeod et al., 2016). A common metric is to look at emissions per product (kgCO2e per kg of output). This allows us to adjust the measures for how much emissions are the result of production on the farm, and especially useful when comparing similar products. One weakness is that most farms produce mixtures of products, however these farm types produce mostly red meat from cattle or sheep. Hence we cannot fully accommodate for other products but it provides a reasonable approximation of production at farm level. Figure 2 shows a simple scatter plot where emissions are mapped against total farm output for all farms in the sample. What is clear is that there is a slight positive effect but then the results are dispersed for much higher levels of output. This indicates that effect of production against GHG emissions if affected by farm-level factors and, is, arguably driven by individual farm efficiencies.

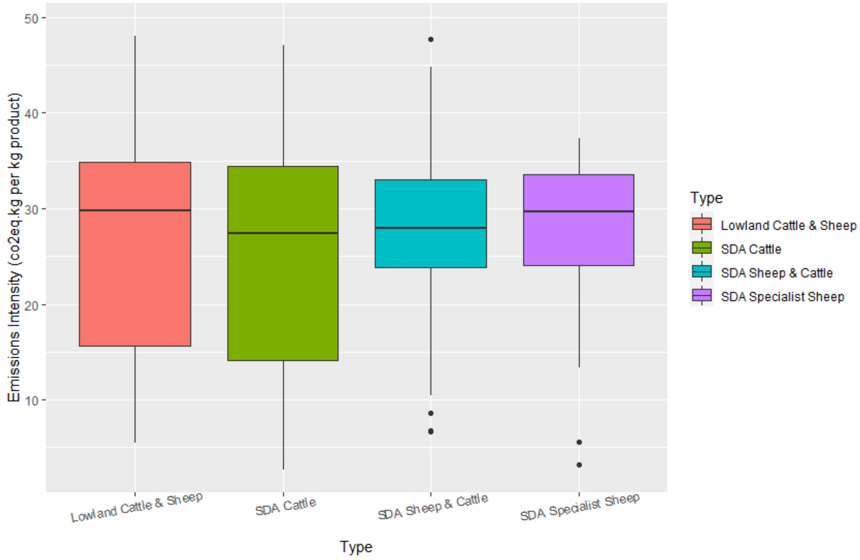
Figure 2. GHG CO2e emissions compared to per kg of product produced^



^ only product of less than 400,000 kg are shown

Some of these management efficiencies are perhaps shown in Figure 3, which summarises the emissions intensity by farm type and the higher levels of production efficiency expected in more specialised systems. This equalises the impact across farm types, at around 30 kg CO2e per kg of output, though there are large ranges which infer some differences, from structural factors, e.g. size of the farm, and managerial efficiencies.

Figure 3. Emissions intensity (CO2e per Kg of product) by farm type



This is further shown in Table 3 which indicates the median, the ranges as well the minimum and maximum values found within the sample. Notably, for those more outlier farms at the minimum and maximum there tend to be different mixes of enterprises and stocking densities which may be driving the low values identified here.

Table 3. Emissions intensity (CO2e per Kg product) by farm type,

	min	median	max	range
Lowland Cattle & Sheep (n=22)	0.51	23.19	51.98	51.47
SDA Cattle (n=106)	1.29	27.45	77.00	75.71
SDA Sheep & Cattle (n=49)	2.57	27.92	47.70	45.12
SDA Specialist Sheep (n=30)	1.09	31.18	204.62	203.53

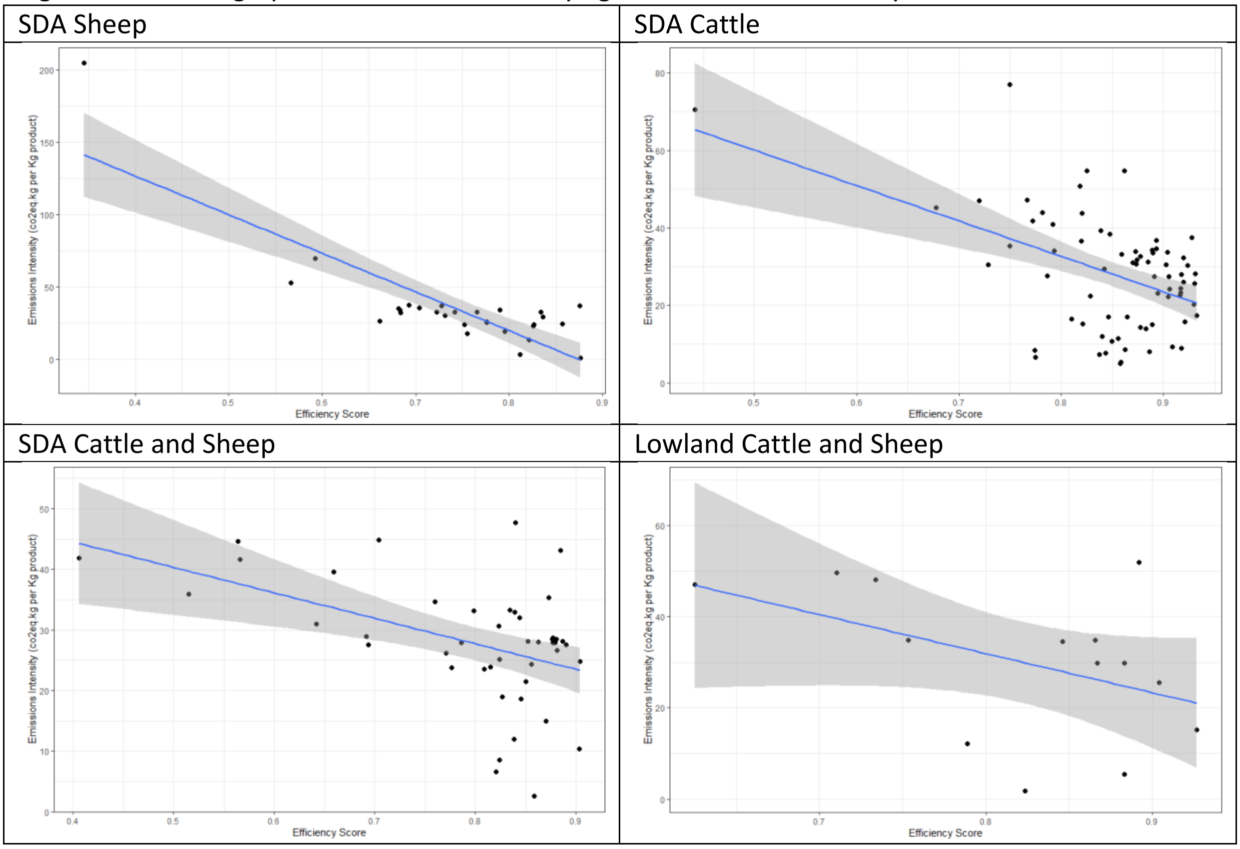
It is notable that MacLeod (2016) [2] argued that efficiency is not revealed through the most common metrics of emissions intensity. Given the data used it is useful to link these environmental indicators with a metric of efficiency. With the same SFBS data set we estimated technical efficiency for farms operating in the same crop year (See Barnes, 2022). The next section examines how emissions intensity may relate to these overall farm level technical efficiencies.

3.3. Emissions intensity and technical efficiency

Using the Farm Business Survey we estimated technical efficiencies for each farm type, using output and the main inputs from each farm to generate a score. These scores indicate the overall technical efficiency relative to other peers in the same farm type, where a score of 1 shows the farm is the most technically efficient within that farm type and anything below 1 shows the gap between that farm's efficiency and current best practice.

[2] https://www.climatexchange.org.uk/media/2026/benchmarking_the_emissions_intensity_of_scottish_livestock-derived_agricultural_commodities_-_final_-_mar_16.pdf

Figure 4. Scatter graphs of emissions intensity against technical efficiency



Overall these figures tend to show an overall downward trend, that is as farms become more efficient then emissions intensity reduces. However, for most farm types, aside from specialist sheep, there are large confidence intervals. This reflects the dispersions seen within the scatter graph, in addition to the outliers but also the low number of observations available. To explore this relationship further table 4 shows results of a simple linear regression analysis explaining emissions intensity against technical efficiency scores.

Table 4. Summary results from a linear regression analysis of emissions intensity and technical efficiency

	R-sq	Sig.
Lowland Cattle & Sheep (n=22)	0.141	
SDA Specialist Sheep (n=30)	0.681	***
SDA Cattle (n=106)	0.207	***
SDA Sheep & Cattle (n=49)	0.198	**

This shows both the R-squared and whether the effect is significant or not. For all farm types, aside from the lowland cattle and sheep type, there was a significant negative effect - namely as efficiency increases then we would expect emissions intensity to decrease. Moreover the R-squared shows the strength of the relationship. For specialist sheep farms around 70% of the variation between emissions intensity is explained by efficiency differences, whereas for cattle and sheep farms only around 20% of the variation is explained by efficiency. This means other factors. e.g. age and breed, will also contribute to emissions intensities.

4.0 Summary

- Cattle and Sheep farms in the farm business survey were compared in terms of environmental their emissions and their farm-level technical efficiency.
- A large amount of variance was found between farms within the same farm type indicating the adoption of a range of practices with similar farms.
- Emissions intensity provides an approach to accommodate for some of the differences within farms as it links emissions to production levels.
- We find a negative relationship between emissions intensity and farm-level technical efficiency. This means that farms with higher technical efficiencies will be expected to have lower emissions intensities.
- This relationship is strongest in specialist sheep farms, explaining 68% of the variance, whereas it the effect is less clear in cattle and mixed farms indicating that whilst influential, other - herd level factors - are contributing to emissions intensity.
- Focusing on farm level technical efficiency - the efficiency of utilisation of resources - reflects the decision making on the farm. It consequently offers a pathway to reduce emissions intensity but has to be considered against other factors which are not easily observed or collected within the Farm Business Survey, such as movement and herd structure data.

5.0 References

MacLeod,M., Eory, V., and Amponsah, N. (2016). Benchmarking the emissions intensity of Scottish livestock–derived agricultural commodities. Report for Climate Exchange, Edinburgh.

Barnes, A.P. (2022). Scottish Farm Efficiency: trends and drivers from 1989 to 2020. SRUC Policy Brief(forthcoming)

For further details please contact: Andrew Barnes SRUC

☎: +44(0)131 535 4042 🖮: andrew.barnes@sruc.ac.uk

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