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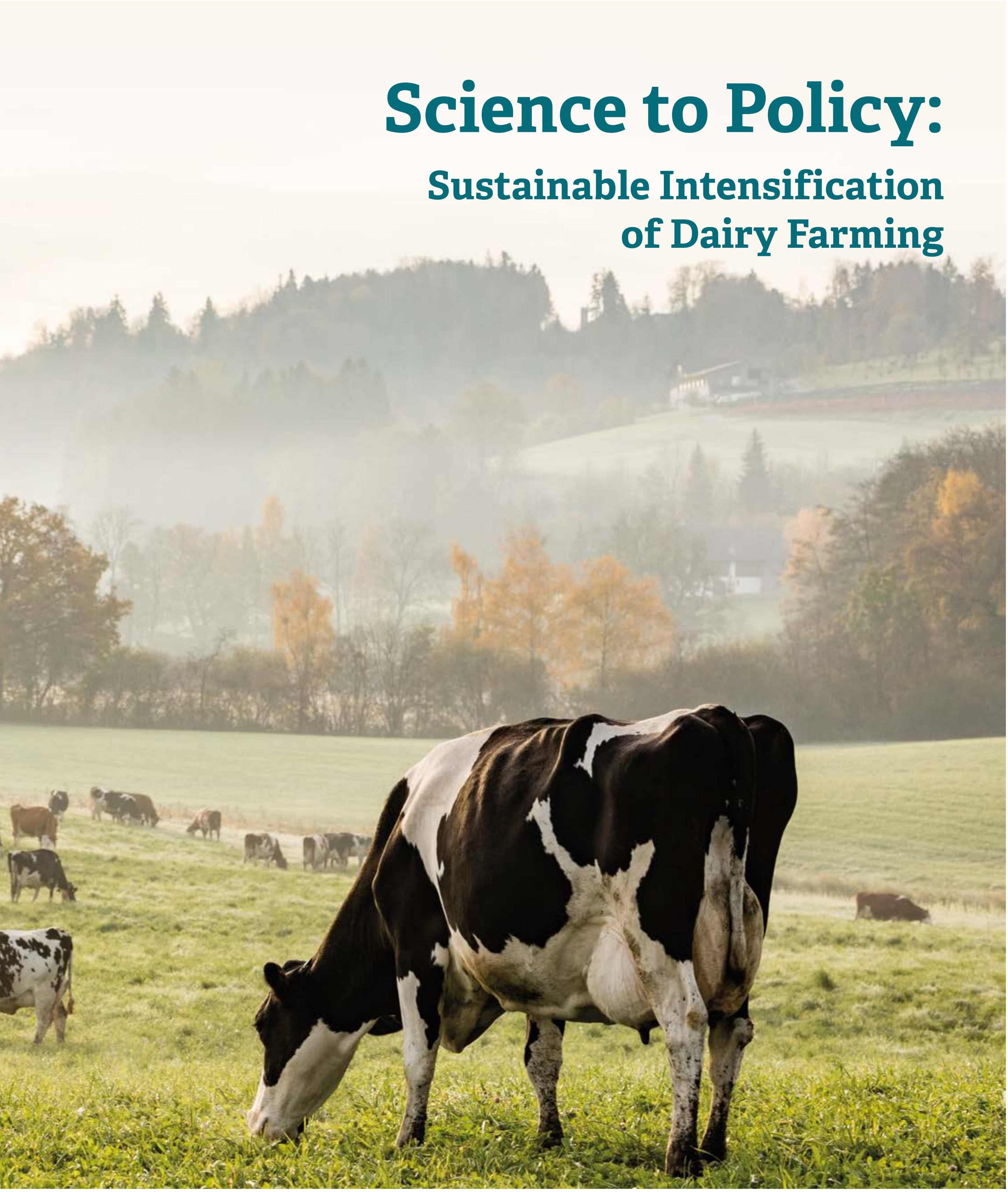
Sêr Cymru National Research Network
for Low Carbon, Energy and Environment

Science to Policy:

Sustainable Intensification of Dairy Farming



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Sustainable Intensification of Dairy Farming

Cleaner Cows was a Research Cluster that ran between 2013 and 2018 from the Sêr Cymru National Research Network Low Carbon, Energy & Environment (www.nrn-lcee.ac.uk).

The aim of Cleaner Cows was to investigate the role that consolidation and intensification in the dairy sector plays in the grander scheme of greenhouse gas emissions and sustainable intensification.

This is a summary of the policy implications of both scientific review and original research undertaken by Cleaner Cows that fall within the remit of current and evolving Welsh policy.

Key recommendations

- **Environmental footprints representing environmental intensity per unit product (e.g. kg of milk) should also account for local nutrient pollution associated with intensification.**

- **Consequences of land use change and associated environmental impacts should be evaluated in life cycle assessment of dairy intensification pathways.** One option would be a land footprint indicator encompassing the land required to produce reference quantities of milk plus beef.

- **In order to reduce land use change and greenhouse gas emissions resulting from dairy intensification, beef cattle grazing should be targeted on areas of grassland spared from dairy cattle. This should be done in direct conjunction with the afforestation of less productive livestock areas.**

- **The most holistic sustainable intensification strategy in regions with high grass yields (the wetter west of the UK), would involve improving grass feed use efficiency** instead of increasing the use of maize and concentrate feeds.

- **Covering manure stores and using trailing shoe or injectors to spread slurry would significantly reduce acidification, eutrophication and human health effects associated with ammonia emissions.**

- **Data Envelopment Analysis (DEA) can be used to benchmark farms** in terms of production and environmental burdens which provides guidance on pathways to more sustainable production.

Background

Agricultural intensification escalated in the UK after the Second World War with the development of new technologies and a policy focus on increased food production. Arable area and livestock numbers in the UK have then declined overall since the 1980s due to diverse drivers such as decoupling subsidy from production and foot and mouth disease[1]. Agricultural productivity in the UK (measured as outputs vs. inputs), however, has increased over this time period due to reduced labour and increased yields per animal and per hectare; indicative of the aspects of intensification that encompass mechanisation, increasing cattle densities, and improved animal nutrition.

Agriculture is a significant contributor to current greenhouse gas emissions in Wales (Figure 1), highlighting the importance to include carbon accounting of the agricultural sector as a key component of sustainable intensification.

The environmental impacts of the dairy sector in particular have complex relationships with intensification, via linkages between the dairy, beef and animal feed industries. Considering these linkages, it is important to investigate whether the environmental and greenhouse gas impacts of intensive dairy farms are lower than those of extensive farms. As both decarbonisation and public goods delivery (such as clean water and biodiversity) are a high national priority, and increasingly likely to be allocated direct subsidies within the agricultural sector, it is crucial to understand where the most strategic gains can be made, and what the trade-offs are.

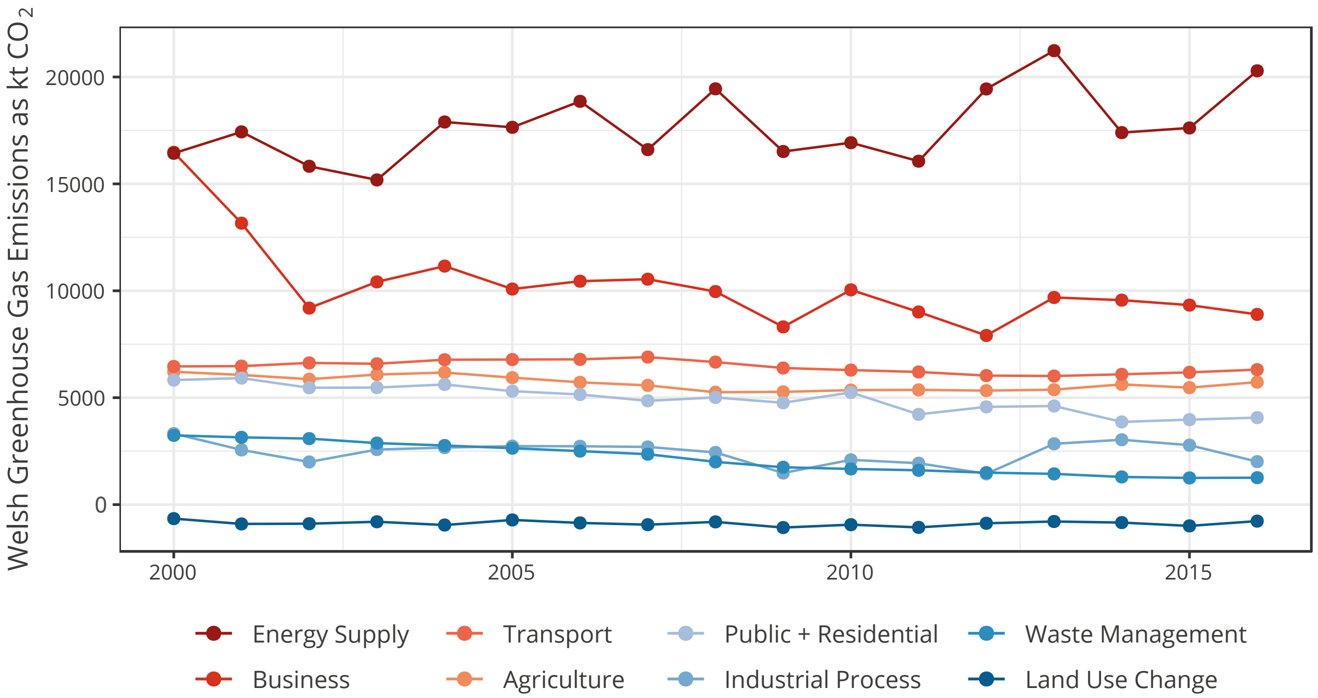

Figure 1
The agricultural sector accounted for 12% of Welsh greenhouse gas emissions in 2016.
Total emissions have not declined significantly over the 21st century.
Data from the National Atmospheric Emissions Inventory.
Figure: Emma Wiik (NRN-LCEE).

Trends in agriculture

Cleaner Cows reviewed UK farm data to evaluate how intensification in the dairy sector has taken shape in the 21st century. They found that between 2001 and 2014, the number of dairy farms in England and Wales fell by 49%. The number of dairy cows decreased by much less, reflecting the 54% increase in the average number of dairy cows per farm alongside an increase in average farm size. Simultaneously, there has been an increasing use of concentrate feed, which has led to higher milk yields per cow.

Two main farm typologies currently coexist in the UK, one characterised by high dependence on concentrate and maize feed, and a second pre-dominated by grass fodder. This divergence is reflected in livestock outdoor time, which is higher for the grass-dominated farms.

Wider consequences of local intensification

Environmental trade-offs are frequently encountered when changing land management practices. Intensification-driven greenhouse gas reductions via increased concentrate and maize feed use can worsen other environmental indicators such as eutrophication or acidification potential. For example, a global comparison of milk production suggests that intensification can shrink milk carbon footprints (per kg of milk) from 12kg to 2kg of carbon dioxide equivalent (CO_2e) alongside a fourfold increase in milk yield efficiency. Such intensification, however, is linked to lengthening cattle housing periods and associated with increases in nitrogen losses in the absence of investment in manure management. Furthermore, conversion of on-farm grass to maize feed production can lead to increased soil erosion[2] and flooding-related greenhouse gas emissions (see Figure 2).

Any local environmental gain from intensification may also lead to environmental deterioration elsewhere due to consequential changes in other land use sectors, or in other countries via global commodity markets[3].

To date, efficacy has primarily been accounted for at the product level (footprint studies) or at sector/national level by UN protocol-based inventories. Cleaner Cows research found that foot-printing exercises rarely account for these wider impacts, and therefore do not provide robust evidence of the efficacy of sustainable intensification pathways[4].

In contrast to previous studies, Cleaner Cows research demonstrates that the total land footprint of milk and beef production under a variety of conditions is higher following intensification, unless the associated reduction in dairy-beef production[1] can be replaced by suckler-beef produced at high intensity and spared grassland can be afforested[5]. The shift from grass to concentrate feed driving higher overall (indirect) environmental impact can be likened to the current biofuel-palm oil situation whereby direct emissions savings from biofuel substitution of diesel may be outweighed by indirect environmental costs associated with biodiversity loss, forest burning and large-scale land conversion.

Where and how concentrate and maize feed is produced and where and how beef cattle is produced, is very important.

[1] With fewer dairy cows, there are fewer male calves, thus less beef. In addition, total beef from culled dairy cows is also lower as the number of cows is smaller.

Figure 2

Increasing feed maize production within the UK has environmental consequences. Bare ground between plants is easily washed away during heavy rains, exacerbating erosion. Maize residue is often spread on fields to mitigate erosion, but the timing of residue spread often coincides with flooding, leading to not only erosion but also a pulse of greenhouse gases.

Environmental gains for grass-based farms

Soteriades *et al.*[6] showed that grass variety choice and the use of more efficient management technologies can deliver environmental gains with respect to global warming, eutrophication, acidification and resource depletion. For example, by switching to high-sugar grass varieties, the acidification impacts of milk production reduced by 7-11%, and eutrophication impacts by 4-6%; due to improved milk nitrogen use efficiency. These reductions could be enhanced to 40% and 22%, respectively, by improving manure storage facilities and spreading equipment. This is because open manure storage as well as splash plate manure spreading allow extensive contact between manure and the atmosphere, resulting in ammonia gas losses. Covered storage systems and targeted manure spreading reduce ammonia gas release.

Milk nitrogen use efficiency has been identified as one of the main factors determining the lifetime nitrogen emissions of a cow, supporting investment in feed-to-live weight gain conversion efficiency[7].

Identification of efficiency trade-offs

Data Envelopment Analysis (DEA) can assist intelligent decision-making when managing multiple outcomes[8]. Cleaner Cows demonstrated the applicability of DEA as a farm manager's tool by identifying inefficiencies via benchmarking. Analysing data from comparable UK farms, it is possible to find a realistic efficiency goal with regards to any metric of interest, including feed purchases, cattle replacement, and protein yield - based on the specific characteristics of any one farm (e.g. cattle numbers and farm area can be fixed in the analysis to reflect a farmer's plans to retain stocking density). DEA can also be combined with Life-Cycle Assessment (LCA) and future development aims to allow for the incorporation of environmental metrics such as carbon foot-printing, in order to arrive at holistic farm assessment.

Credit: Jon Moorby

Key terminology

Sustainable intensification:
Changes to a farming system that maintain or increase the production of agricultural products while enhancing or maintaining the delivery of a range of other environmental and societal benefits, measurable from a specified area of land and over a specified timeframe.

Concentrate feed:
Highly nutritious cattle feed in pellet form, consisting of a mixture of soybean, corn, various cereals and by-products from grain processed for human consumption.

Carbon footprint:
A term that encompasses the climate-warming impact of all greenhouse gases, not only CO_2, released during the production of a particular product or service, based on LCA methodology.

Life-Cycle Assessment (LCA):
Environmental accounting that includes measures of greenhouse gas emissions, acidification, eutrophication of waters, energy use and resource depletion from all stages of production. LCA provides a holistic measure of the ecological footprint of a product (e.g. one litre of milk), a farm system, or a whole sector.

Data Envelopment Analysis (DEA):
Data Envelopment Analysis evaluates the relative efficiencies of decision-making units in a system and allows for incorporation of multiple outputs and multiple inputs.

Contact

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The over-arching mission of the Network was to promote excellent research within Wales into the sustainable use of natural resources for the provision of energy, water, food, and other ecosystem services. The Network was the catalyst to bring a diverse set of talented researchers and partners into new collaborations, in order to conduct innovative research that was highly pertinent on an international research agenda.

Four themes tie together all research funded by the Network:

1. Sustainable Intensification
2. Low Carbon Energy Pathways
3. Developing the Bio-Economy
4. Impacts & Mitigation of Climate Change and Human Activities

The core of the Network research was centred around 8 Research Clusters (supporting 18 Research Fellows and 12 PhD students) and 10 Returning Fellowships. The latter were individuals returning from extended career breaks. It also supported STEM outreach opportunities, public lectures and a diverse range of workshops and events on topical science issues. **www.nrn-lcee.ac.uk**

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