Teagasc National Farm Survey 2015 Sustainability Report

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Any errors or omissions remain the responsibility of the authors.

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Agricultural sustainability

We face significant challenges in feeding a growing human population while attempting to cope with and minimise environmental impacts resulting from climate change and resource limitations. To achieve this, agricultural production must be both intensive and sustainable. Global agricultural output must be maintained or increased, without impacting the capacity for future production, and minimising external impacts particularly where the environment is concerned.

Agricultural systems are complex, with multiple goals and wide-reaching effects which must be considered together. In order to measure and track the diverse components of farm performance, we consider Irish agricultural production in terms of **economic, environmental** and **social** sustainability, and also evaluate Irish farmers' adoption of **innovations** which may be important in driving the sector towards increased sustainability.

Measuring farm level sustainability

The measurement of sustainability is challenging, as it is a broad concept covering diverse areas, and may vary in time and space. As a result, rather than attempt to isolate a single sustainability score, key metrics are used as indicators for each of the components of sustainability, as defined above. These indicators can highlight particular areas of concern, and what might need to be done to improve them. The indicators are also statistically robust, and valid across time, so that a benchmark is provided from which to judge the progress of the sector.

Deriving a sustainability indicator set is difficult, as it requires detailed, accurate and consistent farm data across a wide range of attributes. The **Teagasc National Farm Survey (NFS)** provides such a dataset. The NFS is a representative sample of almost 1000 Irish farms. The NFS collects data annually, with farms weighted so that nationwide representation is given in terms of size and farm type for the principal farm systems in Ireland. Indicators are derived from the NFS at farm-level. This is important to ensure that aggregations can be made at an appropriate scale (for example, based on farm type), and are capable of highlighting potential links or trade-offs between different indicators depending on how individual farms are managed.

The NFS collects relevant farm data annually, allowing indicators to be compared across time, even as indicator methodologies are updated. This is demonstrated in a number of time-series for key indicators presented in this report. It is expected that based on scientific advances and emerging areas of interest, the indicator set will continue to evolve, remaining informative and relevant. Our aim is that as indicator methodologies develop, they will still be capable of being generated using NFS data, ensuring the on-going inter-temporal assessment of the sustainability performance of Irish agriculture.

Indicators

The indicators described here follow on from the original report based on data from 2012 (Hennessy *et al.*, 2013), with some updates based on methodological refinements. As described above, the indicators are grouped into four categories: **economic, environmental, social** and **innovation**.

Economic Indicators

Economic viability is essential to ensure that farm systems can sustain themselves, and that farming families are adequately compensated for their labour and capital. At a national level, agriculture is an important component of the Irish economy. The NFS is well-equipped to generate economic indicators, given that it is part of the EU Farm Accountancy Data Network (FADN), the primary purpose of which is to determine the impacts of the Common Agricultural Policy on farm incomes. The economic sustainability indicator set is therefore relatively unconstrained by issues relating to data availability, and is designed to cover a range of important economic measures.

Productivity of labour

In the NFS a distinction is made between family labour, which is generally unpaid, and hired labour which in accounting terms represents a production cost to the farm. The return on unpaid farm labour is measured as family farm income per unpaid family labour unit. A labour unit is defined as a person over 18 years old working at least 1800 hours a year (it is not possible to exceed one labour unit even where an individual works more than this). Labour unit equivalents of 0.75 and 0.5 are used for individuals aged from 16-18 and 14-16 respectively.

Productivity of land

The economic productivity of land is measured as gross output (€) per hectare of utilised agricultural area.

Profitability

The profitability of a farm is measured as market based gross margin (gross margin excluding grants and subsidies, where gross margin is defined as gross output less direct costs) per hectare.

Viability of investment

The economic viability of a farm business is measured as a binary variable, where a farm is defined as viable if family labour is remunerated at greater than or equal to the agricultural minimum wage, and is also sufficient to provide an additional five per cent return on non-land assets employed on the farm.

Market Orientation

The market orientation is measured as the proportion of total output (€) that is derived from the market (generally the sales value of the farm's outputs), as opposed to grants and subsidies, which are treated as a non market based output of the farm.

Economic indicators		
Indicator	***Measure***	***Unit***
Productivity of Labour	Family Farm Income per unpaid labour unit	€/labour unit
Productivity of Land	Gross Output per hectare	€/hectare
Profitability	Market based Gross Margin per hectare	€/hectare
Viability of Investment	Economic viability of farm business	1=viable, 0=not viable
Market Orientation	Output derived from market rather than subsidy	%

Environmental Indicators

Agriculture has a number of significant environmental impacts, based on specific activities undertaken in farming, and from boarder land management, as agriculture is the primary land use in Ireland. Our current set of environmental indicators focus on greenhouse gas (GHG) emissions and on nitrogen use efficiency.

Greenhouse gas emissions

In order to minimise the extent and the impacts of climate change, action must be taken to reduce greenhouse gas emissions. Agriculture is the largest contributor to Irish greenhouse gas emissions by sector, with 32% of the national total in 2013 (Duffy *et al.*, 2015), and so is under pressure to reduce its emissions in the context of Ireland's commitment to reduce its GHG emissions by 20% by 2020 under the current EU Effort Sharing Decision (ESD), and with more stringent targets now being agreed for 2030. Maintaining or even increasing food production will be very difficult while reducing aggregate emissions (Breen *et al.*, 2010; Lynch *et al.*, 2016), and relevant indicators are required to track the progress being made in emissions reductions in agriculture, and how this relates to the level of food production. GHG emission estimates used in these indicators are derived following the established IPCC (Intergovernmental Panel on Climate Change) methodologies: further details are provided below.

Total agricultural emissions are measured per farm, with emissions also disaggregated to show emissions originating from different farm enterprises (dairy, cattle, sheep and crops).

Agricultural greenhouse gas emissions per unit of output are used so that the total emissions of the farm can be decomposed into components relating to each of the farm's outputs (milk, cattle or sheep live-weight, and crop outputs). In addition, GHG emissions per Euro output are used to illustrate greenhouse gas emissions per € of output generated on farms with dissimilar agricultural output.

Emissions from on-farm energy use per unit of relevant output measures emissions from electricity and fuel use associated with agricultural production activities on the farm. As per the IPCC methodology these greenhouse gas emissions are considered separately from other agricultural greenhouse gas emissions.

Nitrogen use

Nitrogen (N) is an important agricultural nutrient, but where nitrogen is lost to the environment it is a significant risk factor for diffuse pollution. The nitrogen use indicators follow an in-out accounting methodology described below.

Nitrogen balance (per hectare farmed), is used as an indicator of the potential magnitude of nitrogen surplus which may result in nutrient losses to water bodies.

Nitrogen use efficiency is used to highlight the proportion of N retained in the farm system (N outputs / N inputs). This is a generic measure allowing comparison across disparate farm types. For dairy systems, it is also expressed as milk output produced per N surplus applied.

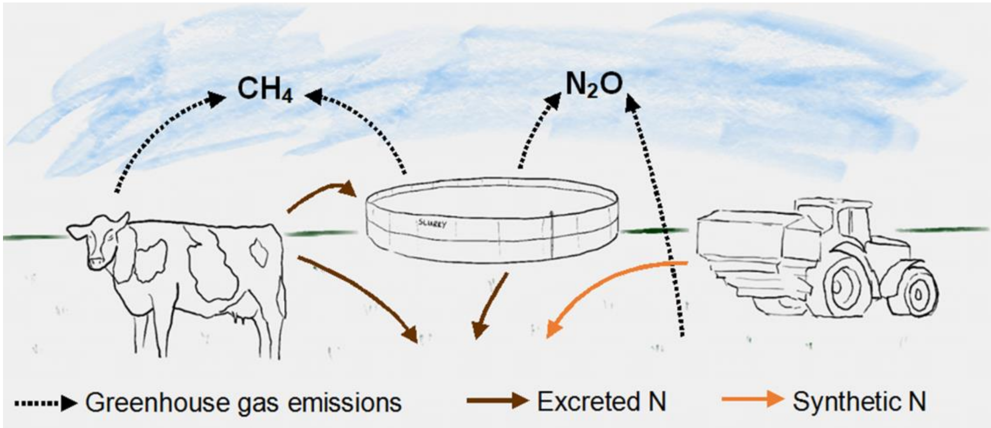
Environmental indicators

Indicator	*Measure*	*Unit*
GHG emissions per farm	GHG emissions	Tonnes CO_2 equivalent/farm
GHG emissions per kg of output	GHG emissions efficiency	kg CO_2 equivalent / kg output *AND* kg CO_2 e / € output
Emissions from fuel and electricity	Farm energy use efficiency	kg CO_2 equivalent / kg output
Nitrogen (N) balance	N pollution risk	kg N surplus/hectare
Nitrogen (N) use efficiency	N application efficiency	% N outputs / N inputs *OR* litres milk / kg N surplus

Calculating Greenhouse Gas Emissions

The greenhouse gas emissions are calculated following IPCC methodologies as employed in the 2015 National Inventory Report for Ireland (Duffy *et al.*, 2015). The three main agricultural emissions categories are methane (CH_4) emissions from enteric fermentation by ruminant livestock, methane and nitrous oxide (N_2O) emissions from the production and storage of livestock manures; and nitrous oxide emissions resulting from the application of manures and synthetic fertilisers to agricultural soils. A complicating factor inherent in a farm based approach (as opposed to a national emissions inventory approach) to emissions measurement is that animals can move freely between farms via inter-farm sales. Accordingly, an inventory approach is used whereby the methane emissions and manure production of each livestock category are adjusted to reflect the portion of the year it is present on the farm. For reporting purposes all non carbon dioxide (CO_2) emissions are converted to CO_2 equivalents using appropriate global warming potentials for methane and nitrous oxide which are respectively 25 and 298 times greater than CO2.

Figure 1. An illustration of some of the major agricultural greenhouse gas emissions



Emissions resulting from on-farm fuel and electricity use are considered independently, as they are a separate IPCC category. Energy emissions (CO_2 only) are estimated from expenditure on electricity and fuels, using standard Irish coefficients for prices and emissions factors.

It should be noted that the IPCC methodologies were not developed to represent a full life-cycle assessment (LCA) approach, which would include embedded emissions: for example the emissions generated in the production of feeds produced elsewhere but brought onto a farm.

Calculating Nitrogen Balance

Our nitrogen (N) use indicators follow a nutrient accounting approach based on Buckley *et al.* (2015). Nitrogen exports from the farm are subtracted from nitrogen imports to the farm to give a farm gate N balance. Nitrogen exports comprise of the N component of milk, crops, wool and livestock sold (including livestock for slaughter) from the farm. Nitrogen imports are composed of fertilisers applied, feeds purchased and livestock brought onto the farm. At present, the volumes of manure or slurry imported and/or exported by farms are not recorded, and so these farms are excluded from nitrogen balance indicators calculation. The nitrogen indicators do not provide estimates of nitrate losses to water, as such losses are complex and driven by site specific biophysical factors and weather conditions. Nitrogen balances are used as an indicator of eventual potential loss, and cover most of the key management decisions over which the farmer has control.

Social indicators

Agricultural systems will only be sustainable if employment in the industry can provide a suitable economic return, but also if farm operators and families have an acceptable quality of life from their farming and non-farming activities. If farming is not socially sustainable, individuals will leave the sector, or there will be a lack of farmers who are willing to take over farms when older farmers retire from farming. In addition, as agriculture is often the predominant economic activity in many rural areas, the social impacts of farming are also important in maintaining employment and social wellbeing in the broader community.

Household vulnerability

The household vulnerability indicator is a binary indicator, where a farm is defined as vulnerable if the farm business is not economically viable (using the economic viability indicator described earlier), and the farmer or spouse has no off-farm employment income source.

Formal agricultural education

This is a binary indicator that measures whether or not the farmer has received any formal agricultural training, at any level. Agricultural education can be an important factor in farm succession, as well as having a role in the nature of wider farm management decisions that can affect other dimensions of farm sustainability.

High Age Profile

Farms are defined as having a high age profile if the farmer is aged over 60, and there are no members of the farm household younger than 45. This indicator shows whether the farm is likely to be demographically viable.

Isolation

Isolation is measured as a binary score, depending on whether or not the farmer lives alone. It is an important consideration, given the continued trend for migration from rural to urban areas, and the ageing population of farmers in Ireland.

Work Life Balance

This indicator is the number of hours worked by the farmer on the farm. It should be noted that this does not include time spent in off-farm employment.

Social indicators

Indicator	***Measure***	***Unit***
Household vulnerability	Farm business is not viable and no off-farm employment	Binary variable, 1= vulnerable
Agricultural education	Formal agricultural training received	Binary variable, 1= agricultural training received
Isolation Risk	Farmer lives alone	Binary variable, 1=isolated
High Age Profile	Farmer is over 60 years old, and no members of household under 45	Binary variable, 1=high age
Work Life Balance	Work load of farm	Hours worked on the farm

Innovation indicators

More efficient production has the potential to increase profits while reducing negative external effects, and hence provide progress towards more sustainable agriculture. The innovations which can lead to increased sustainability may be novel technologies, newly developed or applied, or may be improved management techniques. As a result, the innovation indicators we have selected are a combination of specific technologies deployed by the farmer, and farmer membership in groups or schemes which may be positively associated with increased adoption of broader innovations.

All of the innovation indicators are scored as binary variables, either where a specific technology is used or whether a farm is a member of the given group or scheme. Innovation indicators can be especially useful to compare with financial performance, as they will highlight the benefits of specific technologies or behaviours.

Dairy innovation indicators

Milk recording (the practice of keeping detailed records of individual cow performance) was identified as a key aspect of management from which farms could build on and improve performance.

Discussion group membership was selected as indicating a degree of interaction with extension services.

Spring slurry spreading (spreading at least 50% of total slurry between January and April) was identified as an important practice to minimise environmental damage and maximise grass production.

Cattle and sheep innovation indicators

Sheep and drystock cattle systems used a common set of innovation indicators.

Membership of the Bord Bia Quality Assurance Scheme (for beef or sheep, as appropriate) was selected to indicate the effect of management standards under these schemes.

Reseeding some grassland within the last 3 years was identified as an indicator of management for pasture productivity.

Undertaking a soil test within the last 3 years was also selected as an aspect of pasture management.

Tillage innovation indicators

Forward selling was selected as an innovative management strategy for tillage.

ICT Usage (the use of smartphones, GPS or farm planning software) was selected as an important aid to decision making in tillage farm management

Undertaking a soil test within the last 3 years was used to explore the impact of tracking soil status on tillage farms.

Innovation indicators

Dairy	*Cattle*	*Sheep*	*Tillage*
Milk Recording	Quality Assurance	Quality Assurance	Forward Selling
Discussion Group	Reseeding	Reseeding	ICT Usage
Spring slurry spreading*	Soil Testing	Soil Testing	Soil Testing

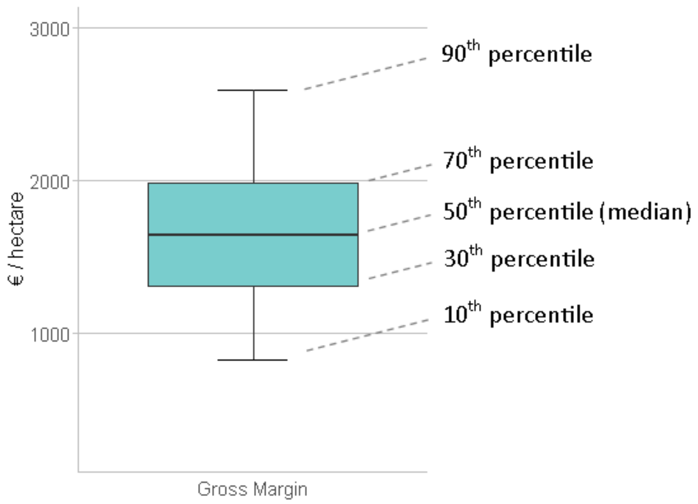
*****(50+% slurry spread in January - April)

2015 Sustainability Indicators

An overview of the main figures used to express sustainability indicator results is provided below.

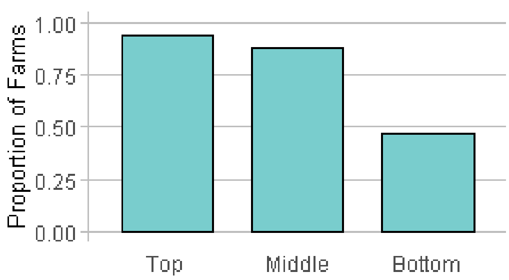
Boxplots are used to display continuous data in order to quickly visualise the range in results. The boxplots used here show the 10th, 30th, 50th, 70th and 90th percentiles of the population's distribution. An annotated example is shown below in figure 2, demonstrating the range in gross margin per hectare for dairy farms. The percentile measures are the values at which the stated percentages of farms fall below. For example, the 50th percentile (the median) on the figure below lies at approximately €1,600 per hectare, meaning that 50% of farms had a gross margin per hectare below this value (and conversely, 50% of farms were greater than this value). A shorter range between percentiles indicates farms within this range have similar results. In the dairy example below, the distance between the 90th and 70th percentiles is greater than the distance between the 50th and 70th percentiles, indicating that a large number of dairy farms were closer to this central range, with a wider spread among farms earning significantly more.

Figure 2. Example Boxplot: Dairy Gross Margins



For indicators with binary scores, bar charts show the proportion of farms that scored positively for the given indicator, as shown for dairy farm economic viability in figure 3 below. In order to give an impression of how a given indicator relates to economic performance, for most indicators, farms are segmented based on gross margin per hectare, into the top, middle and bottom performing thirds. This is also demonstrated below in figure 3, where it can be seen that 93% of the top third of dairy farms ranked by GM per hectare were economically viable, compared to 47% for the bottom third.

Figure 3. Example Bar Chart: Dairy Economic Viability

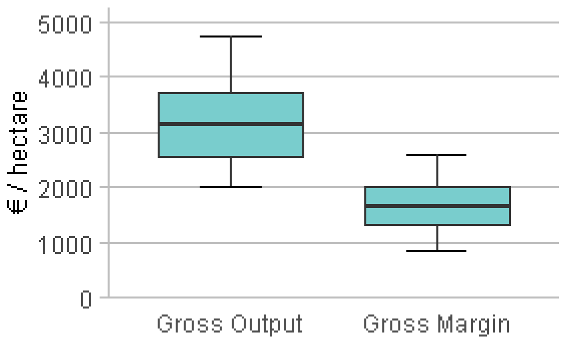


Dairy farms

Economic Sustainability Indicators

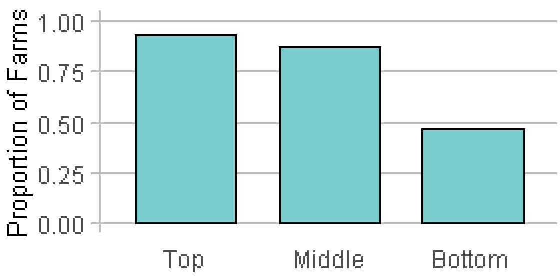
In 2015, the average dairy output per hectare was €3,278, and the average market gross margin per hectare €1,706.

Figure 4. Gross Output and Market Gross Margin: Dairy Farms



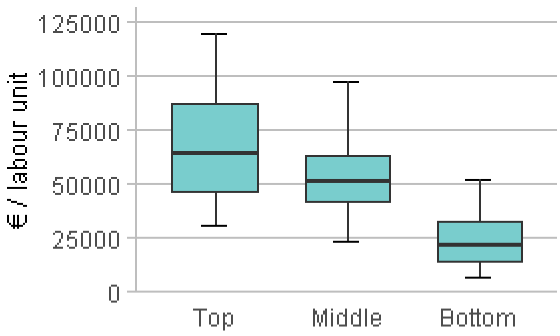
Overall, 76% of dairy farms were economically viable.

Figure 5. Economic Viability: Dairy Farms



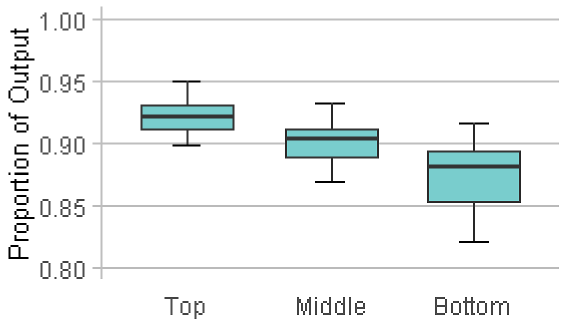
The average income per labour unit for dairy farms in 2015 was €47,860. There was a large range in the return on labour for dairy farms, especially for the higher performing farms.

Figure 6. Productivity of Labour: Dairy Farms



Most dairy farm output was derived from the market, with an average market share of gross output of 90% on dairy farms. A greater degree of market orientation was associated with greater farm profitability.

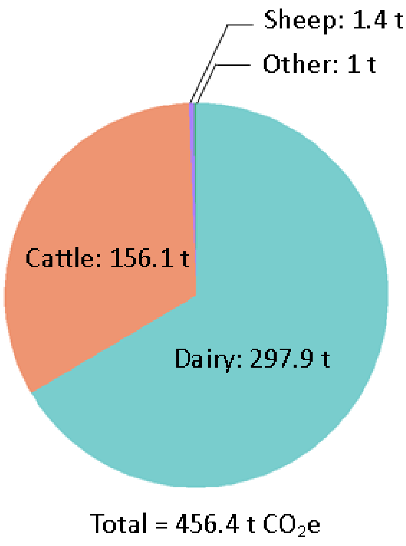
Figure 7. Market Orientation: Dairy Farms



Environmental Sustainability Indicators

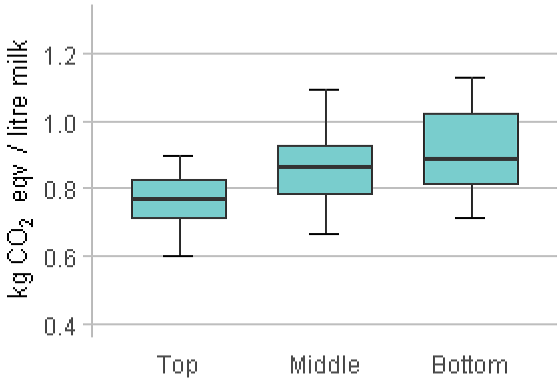
The average dairy farm emitted approximately 456 tonnes of CO_2 equivalents of agricultural greenhouse gases in 2015. It should be noted that this measurement is based on the IPCC definition of agricultural emissions, and is not a full life-cycle assessment that would include embedded emissions in agricultural outputs, such as purchased feed. The majority of dairy emissions, 65%, were from dairy output, with 34% from beef production, and the remaining 1% of emissions from sheep and crop production.

Figure 8. Agricultural GHG Emissions per Farm: Dairy Farms



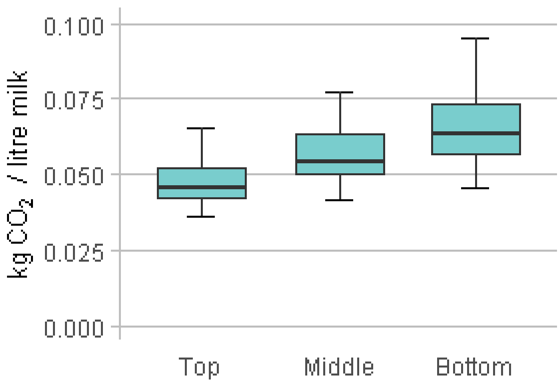
Emissions allocated to dairy output are expressed per litre of milk produced. The average farm emitted 0.86 kg CO_2 equivalent per of litre milk produced. Those farms with the best economic performance also have the lowest emissions per litre of milk produced.

Figure 9. Agricultural GHG Emissions per Litre of Milk: Dairy Farms



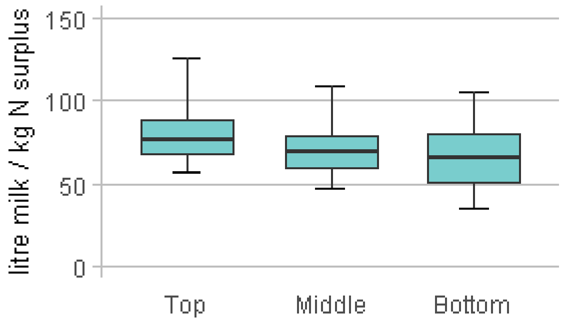
The average energy and fuel emissions were 0.06 kg CO_2 equivalent per litre of milk produced. The top economic performers were most efficient in terms of milk production per kg of energy related CO_2 emissions, in common with the agricultural emissions.

Figure 10. Energy GHG Emissions per Litre of Milk: Dairy Farms



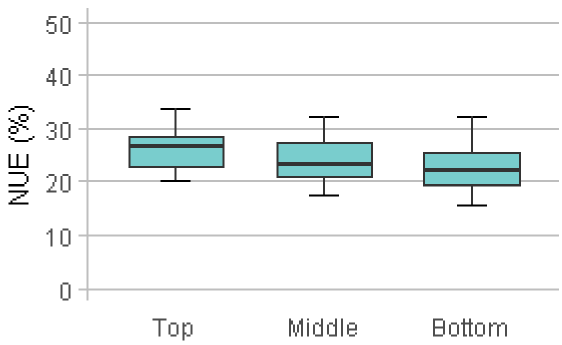
Nitrogen use efficiency (NUE) of milk production was also associated with economic performance, with the best economically performing farms producing more milk per kg surplus nitrogen applied. The average farm produced 80 litres of milk per kg of excess nitrogen.

Figure 11. N Use Efficiency of Milk Production: Dairy Farms



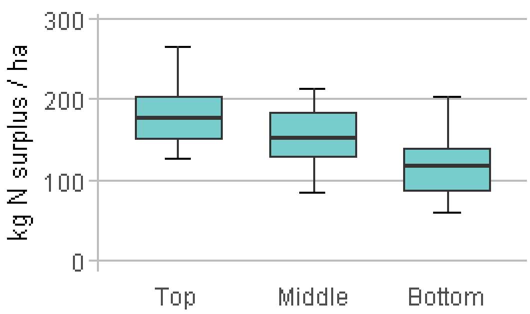
The same trend was observed for the generic N Use Efficiency measure of N outputs over N inputs. The average dairy farm had a nitrogen use efficiency of 25% (i.e. 75% of nitrogen applied within a year was retained within the farm system or lost to the wider environment).

Figure 12. N Accounting N Use Efficiency: Dairy Farms



On a per hectare basis, however, higher nitrogen surpluses were positively associated with economic performance due to the greater production intensity on economically better performing farms.

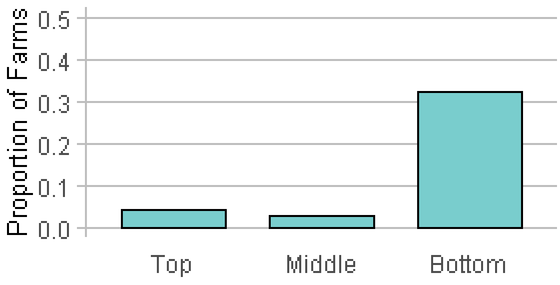
Figure 13. N Balance per ha: Dairy Farms



Social Sustainability Indicators

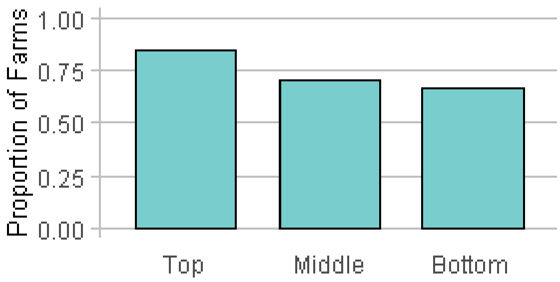
The majority of dairy farm households, 87%, were non-vulnerable. However, in line with the economic viability results, there were considerable numbers of households at risk among those farms with lower gross margins.

Figure 14. Household Vulnerability: Dairy



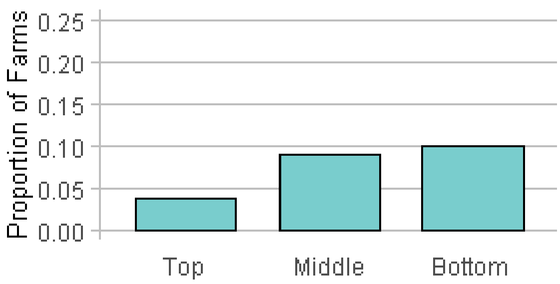
Overall, 74% of dairy farmers had received formal agricultural education of some description. Agricultural training was also associated with higher profitability.

Figure 15. Agricultural Education: Dairy



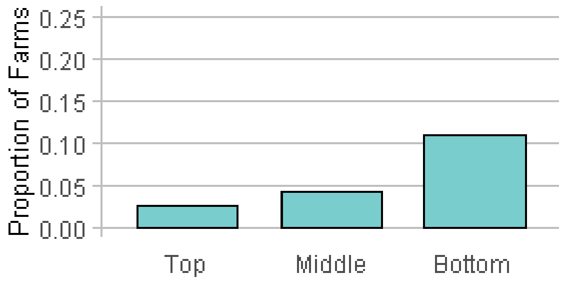
Only 8% of dairy farms were classified as being at risk of isolation. The risk was lowest for the most economically successful farms.

Figure 16. Isolation Risk: Dairy Farms



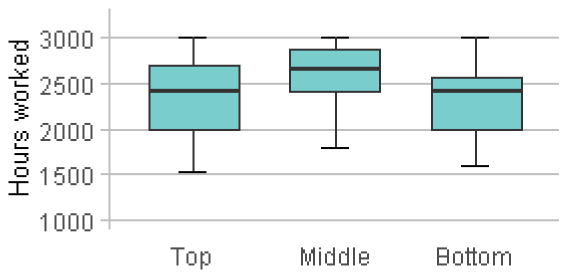
Across all dairy farms, 6% were identified as having a high age profile. This was more evident on farms with weaker economic performance.

Figure 17. High Age Profile: Dairy Farms



On average, dairy farmers worked 2,358 hours per year (approximately 45 hours per week). This was greatest for farms in the middle 1/3, ranked by economic performance, but this figure does not take into consideration off-farm employment, or the share of hours worked by other staff or family members.

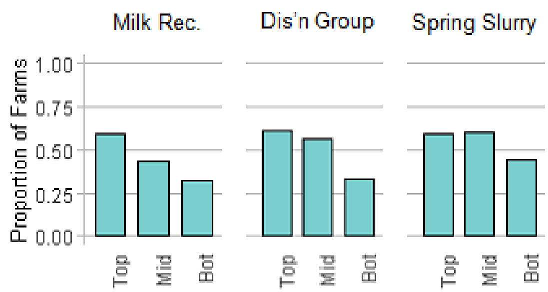
Figure 18. Hours Worked: Dairy Farms



Dairy Innovation Indicators

Three main innovation indicators were analysed for dairy farms: the use of milk recording, membership of a dairy discussion group, and whether at least 50% of slurry was spread in the period January-April. All three indicators were associated with better economic performance.

Figure 19. Innovation Indicators: Dairy



Cattle Farms

Cattle farms include both cattle rearing (mainly suckler based) and cattle finishing systems.

Economic Sustainability Indicators

The average output per hectare for cattle farms in 2015 was €1,257, and the average gross margin €499. Only 25% of cattle farms were defined as economically viable.

Figure 20. Gross Output and Gross Margin: Cattle Farms

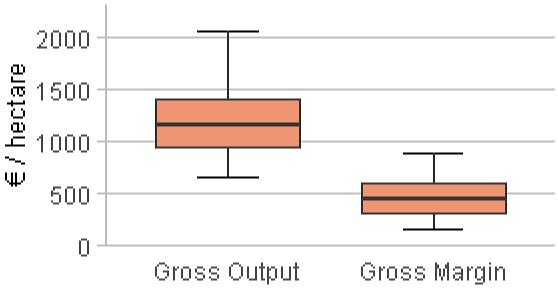
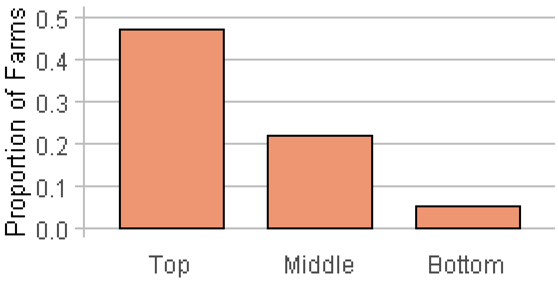
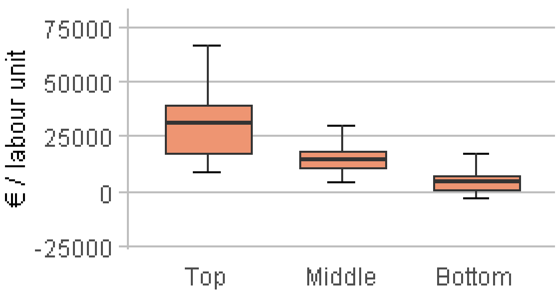


Figure 21. Economic Viability: Cattle Farms



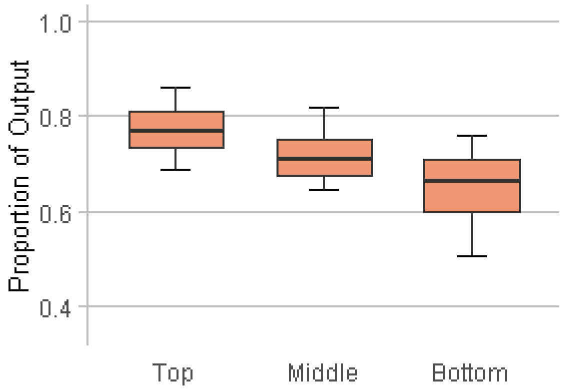
Across all cattle farms, the average income per labour unit was €20,938 in 2015. This was skewed by the top third performing farms including a large number of higher earners, with a mean income per labour unit of €42,188, compared with €15,145 and €5,370 for the middle and bottom third performing cattle farms respectively.

Figure 22. Productivity of Labour: Cattle



Market based output accounted for 72% output across all cattle farms, with the remaining 28% provided by subsidies and grants. Increased market orientation was associated with better economic performance.

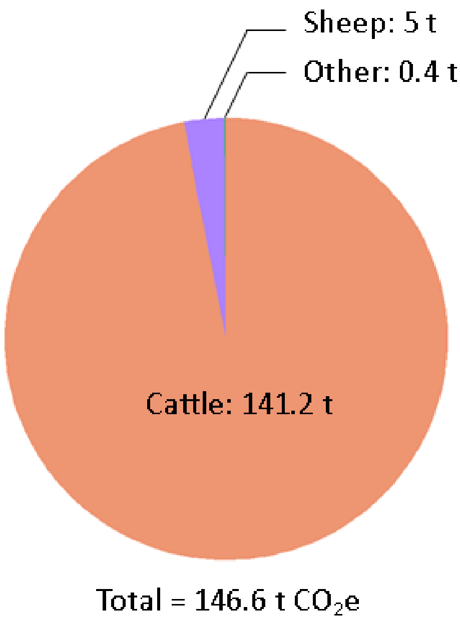
Figure 23. Market Orientation: Cattle Farms



Environmental Sustainability Indicators

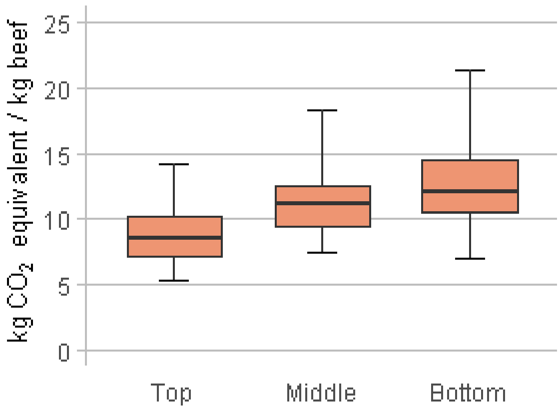
The average cattle farm emitted approximately 147 tonnes CO_2 equivalents of agricultural greenhouse gases. Beef production generated the overwhelming majority, 96%, of these emissions. Sheep were responsible for approximately 3.5% of emissions, and a very small proportion (less than 0.5%) from other sources.

Figure 24. Agricultural GHG Emissions per Farm: Cattle Farms



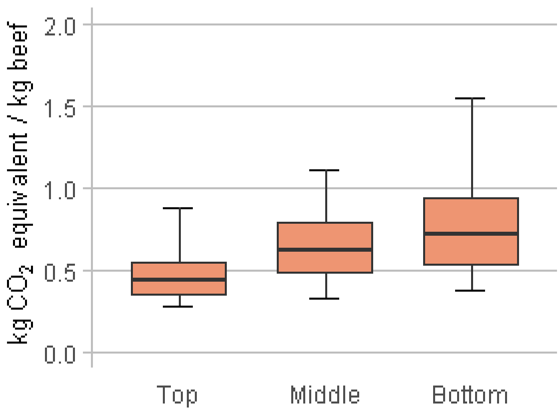
The emissions generated by cattle are assigned per kg output below (estimated using CSO price figures). There is a large range of emissions per unit of beef output. There was a positive correlation between emissions efficiency and economic performance. The top performing third of farms emitted, on average, 9.8 kg CO_2 equivalent per kg beef, compared with 16.7 kg for the bottom performing third of cattle farms.

Figure 25. Agricultural GHG Emissions per kg Beef: Cattle Farms



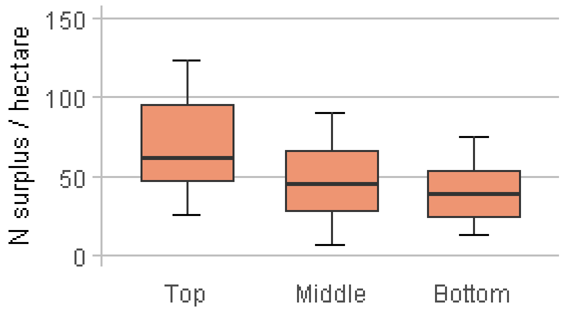
Electricity and fuel emissions per unit of beef output were also lower per unit of beef produced on economically better performing farms. The top third performing farms produced an average of 0.58 kg CO_2 energy-based emissions per kg beef produced, while for the bottom performing third this figure was 1.02kg.

Figure 26. Energy GHG Emissions per kg Beef: Cattle Farms



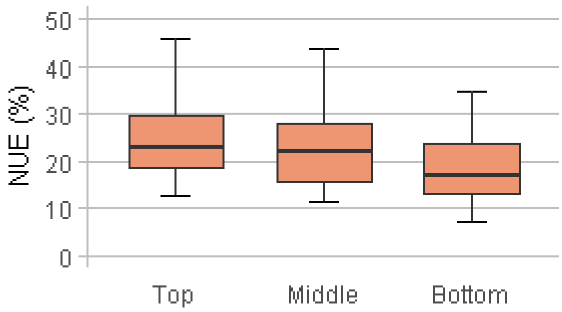
By contrast, nitrogen surplus per hectare was higher on the cattle farms which performed better in economic terms, in general because these are more intensive systems. The top performing third of farms had a nitrogen surplus of approximately 72 kg per hectare, ranging to 43 kg per hectare for the bottom third of farms.

Figure 27. N Balance per ha: Cattle Farms



Despite the higher application rates, nitrogen use was more efficient on farms with better economic performance, with the top third of farms showing an average NUE of 26%, and the bottom third 20%.

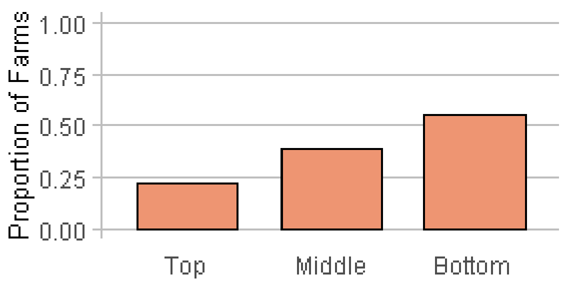
Figure 28. N Use Efficiency: Cattle Farms



Social Sustainability Indicators

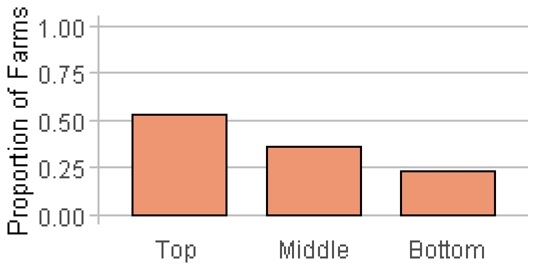
Approximately 39% of cattle farms were considered vulnerable overall.

Figure 29. Household Vulnerability: Cattle



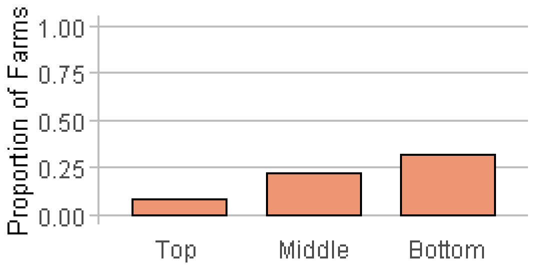
A total of 37% of cattle farmers had some form of agricultural education. This was associated with better economic performance.

Figure 30. Agricultural Education: Cattle



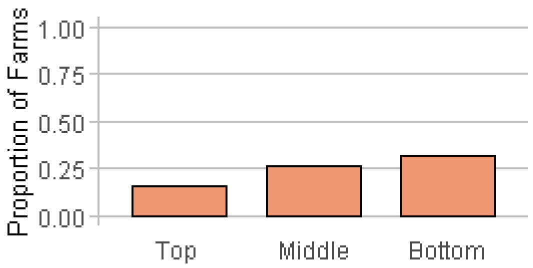
21% of cattle farms were classified as at risk of isolation; i.e. where the farmer lives alone. This was especially associated with farms with lower profitability.

Figure 31. Isolation Risk: Cattle Farms



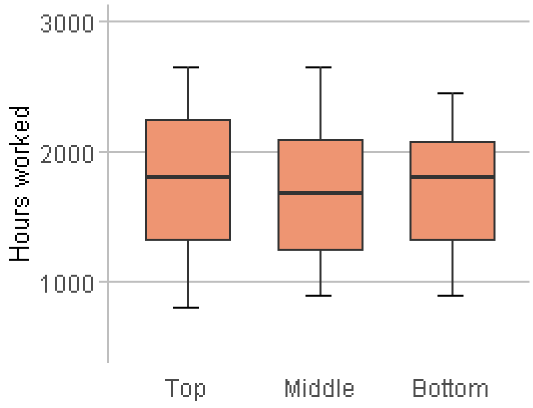
25% of cattle farms were classified as having a high age profile. In common with isolation, this was negatively correlated with economic performance.

Figure 32. High Age Profile: Cattle Farms



The average cattle farm operator worked for 1,630 hours across the year (31 per week). There was a large range of hours worked, and they did not differ greatly depending on economic performance. It should be noted that many cattle farmers have off-farm employment, so these figures are not necessarily representative of overall work-life balance.

Figure 33. Hours Worked: Cattle Farms



Cattle Farm Innovation Indicators

Three key innovation indicators were examined for cattle farms: membership of a quality assurance (QA) scheme, and whether soil testing or pasture reseeding had been undertaken within the last 3 years. All three innovation indicators were positively associated with better economic performance.

Figure 34. Innovation Indicators: Cattle

Sheep Farms

Economic Sustainability Indicators

For sheep farms, the average output per hectare was €1,245, and the average gross margin €471. Across all sheep farms, 26% were defined as economically viable.

Figure 35. Gross Output and Gross Margin: Sheep Farms

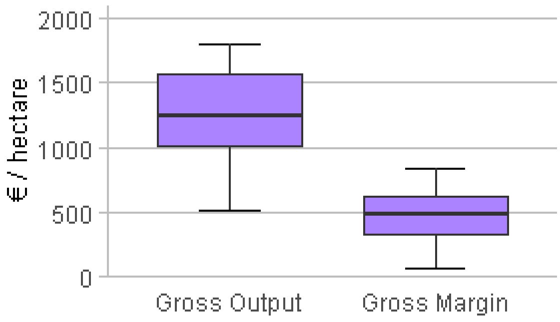
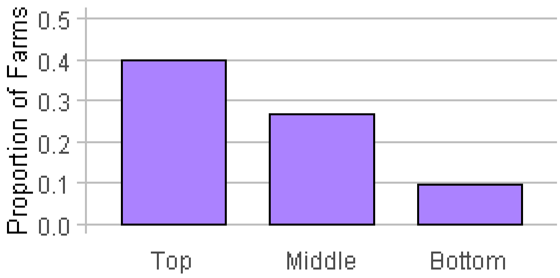
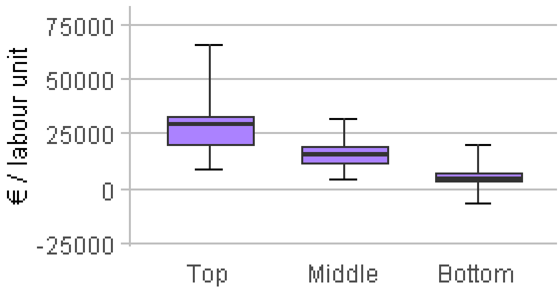


Figure 36. Economic Viability: Sheep Farms



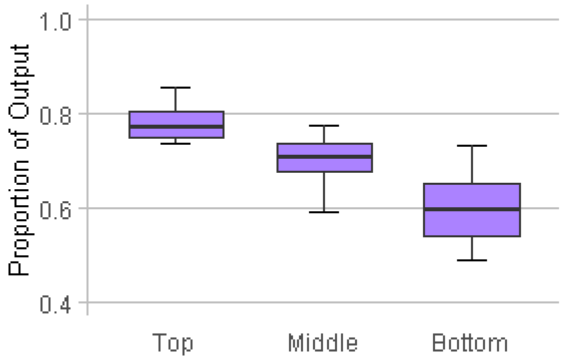
The average income per labour unit on sheep farms was €14,664. In common with cattle farms, there was a large spread in economic performance, with the top third performing farms earning a mean income per labour unit of €21,044, compared with only €5,789 bottom third, which also had a significant number of farms making net losses.

Figure 37. Productivity of Labour: Sheep



For the average sheep farm, approximately 68% of output was generated from the market, and 32% from subsidies and grants. This was positively correlated with economic performance, with the top third economic performing farms producing 75% of output from the market, and the bottom third 59%.

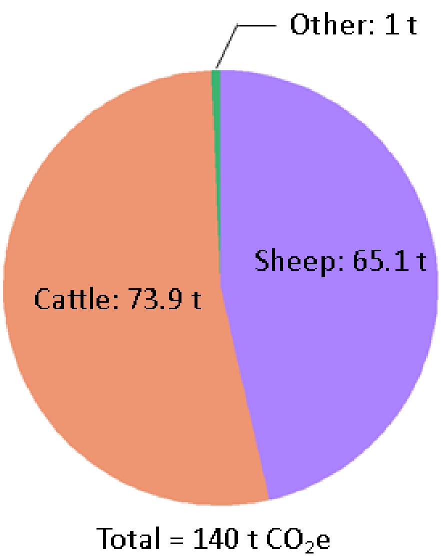
Figure 38. Market Orientation: Sheep Farms



Environmental Sustainability Indicators

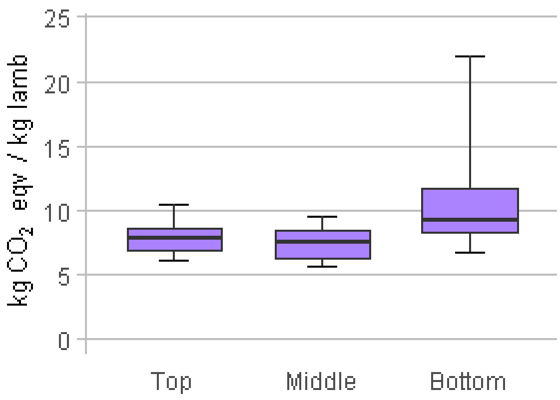
In 2015, the average sheep farm emitted approximately 140 tonnes CO_2 equivalents of agricultural greenhouse gases. Just under half (46%) of these emissions were generated by sheep enterprise, with over half (53%) generated by cattle enterprises present on specialist sheep farms, and the remaining 1% from other sources, mainly crop fertilisation.

Figure 39. Agricultural GHG Emissions per Farm: Sheep Farms



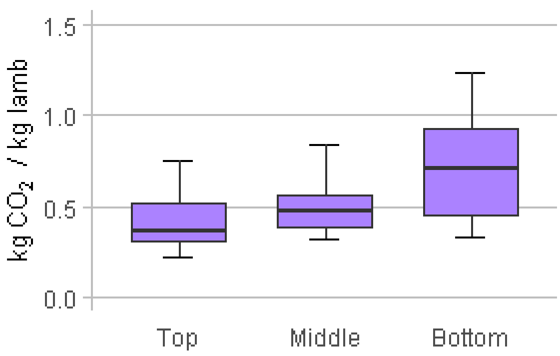
The emissions generated by sheep are shown per kg output lamb and sheep meat liveweight below (estimated using CSO price figures). The top and middle third of farms, ranked on economic performance, had similar emissions per output sheep live weight, at 8.29 and 8.06 kg CO_2 equivalent per kg lamb respectively. However, the bottom third of sheep farms when ranked by economics had greater emissions per kg lamb, 14.29 kg CO_2 equivalent, and a much larger range towards greater emissions.

Figure 40. Agricultural GHG Emissions per kg Lamb: Sheep Farms



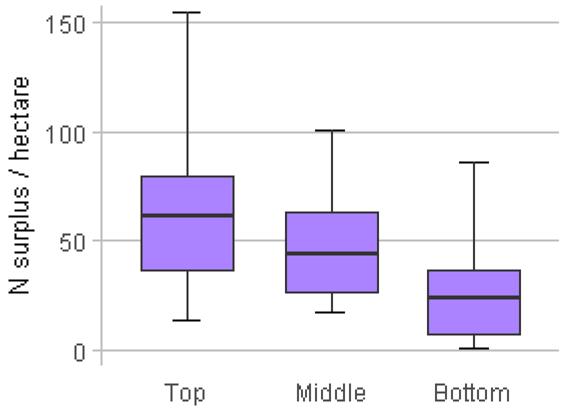
Better economic performance was also associated with lower electricity and fuel emissions per unit of output. The top and middle economically performing farms emitted 0.55 and 0.57 kg CO_2 from energy based emissions respectively, compared with 0.91 kg CO_2 for the bottom third of sheep farms.

Figure 41. Energy GHG Emissions per kg Lamb: Sheep Farms



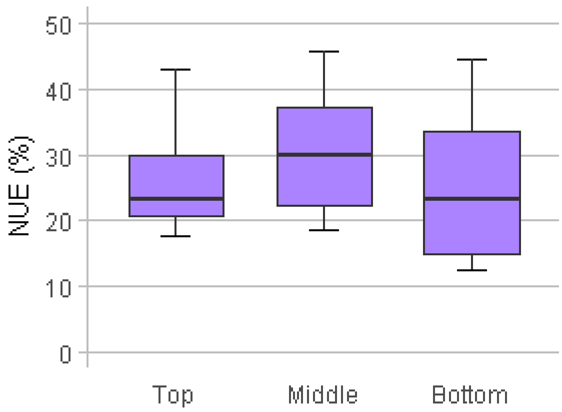
Similarly to cattle farms, nitrogen surplus per hectare was positively correlated with economic performance, due to greater production intensity on the more profitable farms. The top third farms, ranked by gross margin per hectare, had an average nitrogen surplus of 59 kg per hectare, compared with 29 kg for the bottom group.

Figure 42. N Balance per ha: Sheep Farms



There was no clear relationship between economic performance and nitrogen use efficiency on sheep farms. The average NUE across all sheep farms was 30%, which was similar for all economic performance groups (28, 32 and 31% for the top, middle and bottom performing thirds respectively), with a large range in each group. The NFS sheep farm sample includes a number of extensive hill farms, which typically have very low N inputs, and can result in high NUE values even where overall output and profitability are lower.

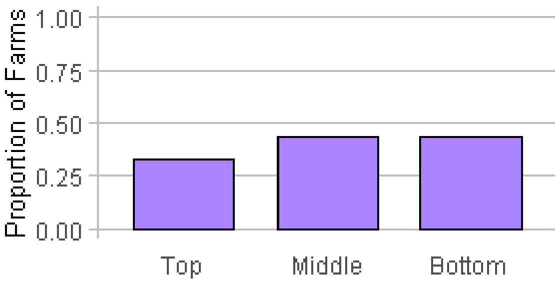
Figure 43. N Use Efficiency: Sheep Farms



Social Sustainability Indicators

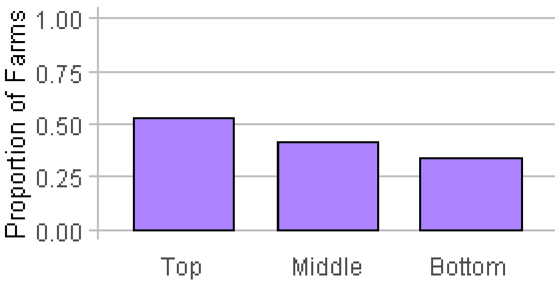
Forty percent of sheep farms were considered vulnerable, with similar rates across all levels of economic performance.

Figure 44. Household Vulnerability: Sheep



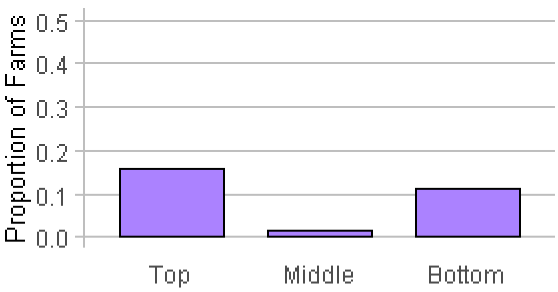
Overall, 44% of sheep farmers had received formal agricultural education. Agricultural training was correlated with better economic performance.

Figure 45. Agricultural Education: Sheep



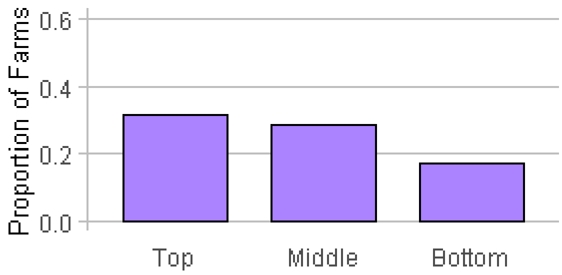
On average 10% of sheep farms were classified as isolated. There was no clear association between isolation risk and economic performance.

Figure 46. Isolation Risk: Sheep Farms



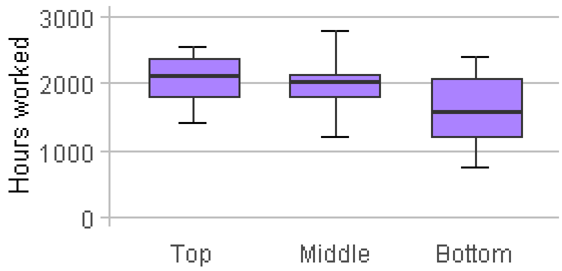
A high age profile was identified for 26% of sheep farms. Economically better performing farms were more likely to have a high age profile; the opposite trend to that observed for cattle farms.

Figure 47. High Age Profile: Sheep Farms



Sheep farmers worked on average for 1,698 hours per year (33 a week). In common with cattle farms, it should be noted that this may not capture their true work/life balance, as many farmers are engaged in off-farm work.

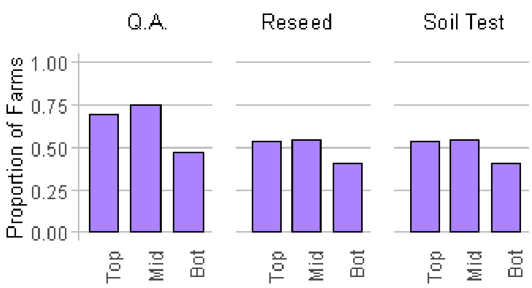
Figure 48. Hours Worked: Sheep Farms



Sheep Farm Innovation Indicators

The three innovation indicators studied for sheep farms were the same as those for cattle: membership of a quality assurance (QA) scheme, and whether soil testing or pasture reseeding had been undertaken within the last 3 years. The bottom third group ranked on economic performance were less likely to be in a QA scheme, or have performed a recent soil test.

Figure 49. Innovation Indicators: Sheep



Tillage Farms

Economic Sustainability Indicators

The average output per hectare for tillage farms was €1,771, and the average gross margin per hectare €738. Overall, 67% of tillage farms were classified economically viable.

Figure 50. Gross Output and Gross Margin: Tillage Farms

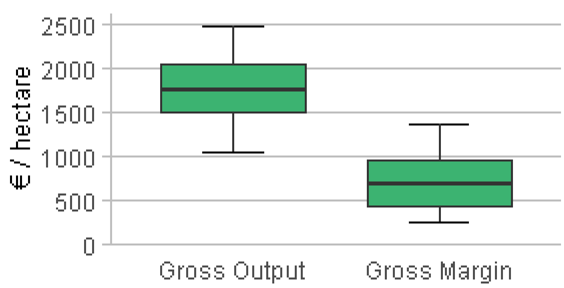
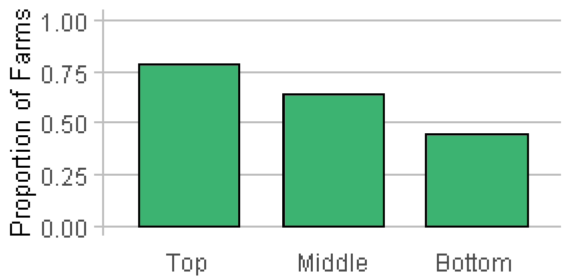
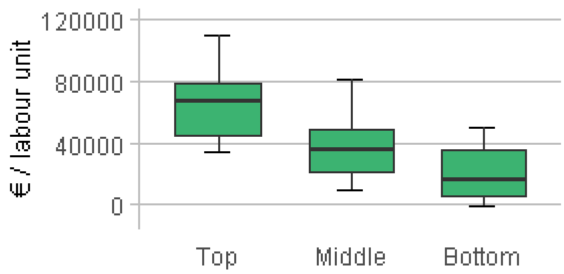


Figure 51. Economic Viability: Tillage



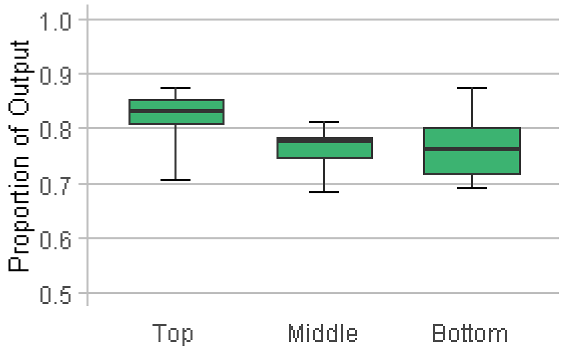
The average tillage income per labour unit was €39,189. There was a large range in incomes, with the top 1/3 ranked by gross margin per hectare earning an average of €59,745 per labour unit, and the bottom third earning €21,132 per labour unit. For some of the most profitable farms, income per labour unit is especially high due to a large proportion of the labour being undertaken by hired labour (via external contractors).

Figure 52. Productivity of Labour: Tillage



Tillage farms received most of their output value from the market, an average of 79%. This did not differ greatly depending on economic performance, with the top 1/3 farms receiving 82% of output from the market, and the bottom third 76%.

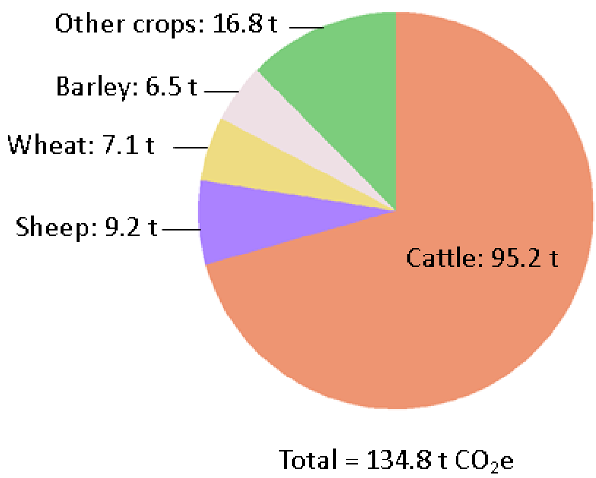
Figure 53. Market Orientation: Tillage



Environmental Sustainability Indicators

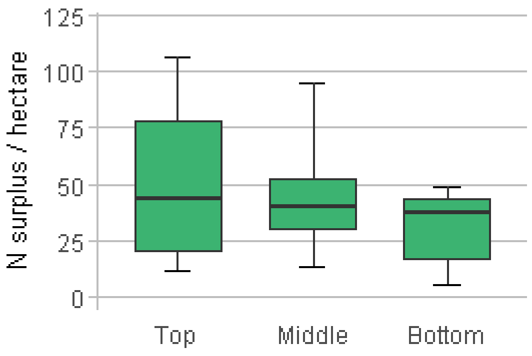
The average tillage farm emitted approximately 135 tonnes CO_2 equivalents of agricultural greenhouse gases, around 24% of which was from crop production (approximately 7% for wheat, 5% for barley, and 12% for all other crops). Despite being specialised on crop production, 70% of tillage farm emissions were from cattle present on these farms, and a further 6% from sheep.

Figure 54. Agricultural GHG Emissions per Farm: Tillage Farms



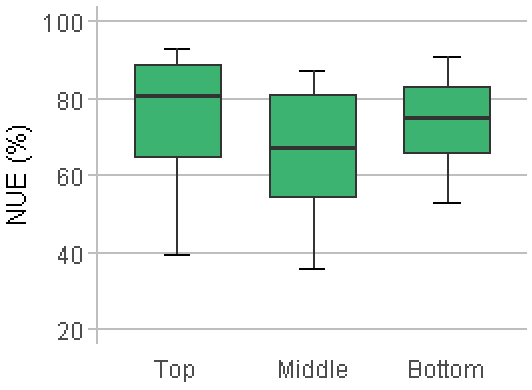
In terms of economic performance the top and middle third of tillage farms had fairly similar average N surpluses, of 50 and 47 kg N per hectare respectively, while relatively less intense production in the bottom third resulted in an average N surplus of 23 kg N per hectare. There was much more variation around the mean for the top and middle groups. It should be noted that not all tillage farms from the NFS are included here, as some farms import manure, quantities of which are not currently recorded.

Figure 55. N Balance per hectare: Tillage



Across all tillage farms, the average N Use Efficiency was 71%. There was no clear relationship between NUE and economic performance, as all groups showed a very large spread in NUE.

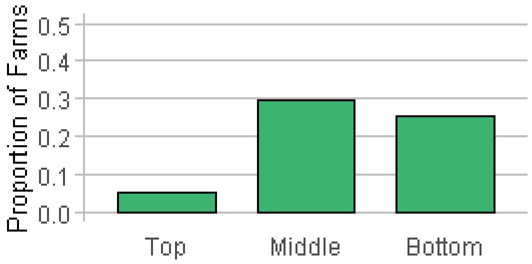
Figure 56. N Use Efficiency: Tillage



Social Sustainability Indicators

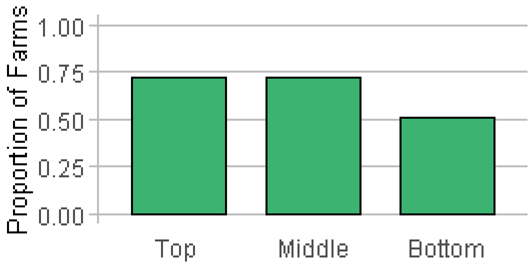
A total of 20% of tillage farms are considered economically vulnerable. This rate is especially low for the top farms (5% vulnerable), which were highly profitable.

Figure 57. Household Vulnerability: Tillage



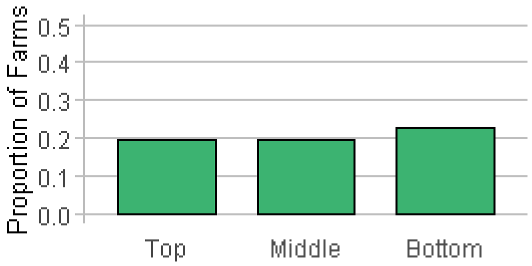
A total of, 65%, of tillage farmers had received agricultural education or training. This rate was lowest for the bottom performing third, at 51%.

Figure 58. Agricultural Education: Tillage



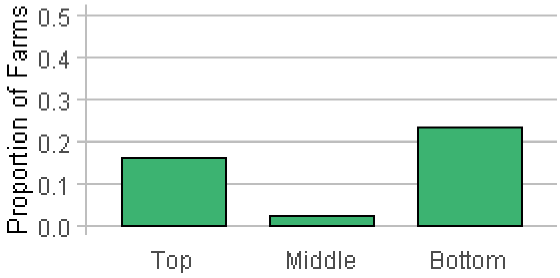
Overall, 21% of tillage farms were identified as at risk of social isolation. This was similar across all three groups ranked by economic performance.

Figure 59. Isolation Risk: Tillage Farms



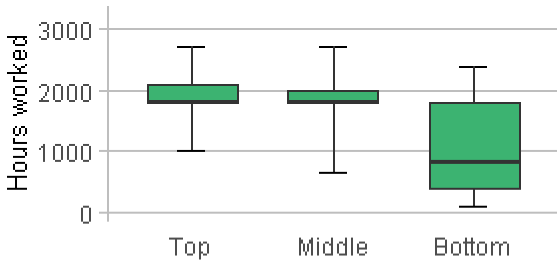
An average of 14% of tillage farms were identified as having a high age profile. This varied between the three economic performance groups, but there was no clear overall trend.

Figure 60. High Age Profile: Tillage Farms



The average tillage farmer worked 1,501 hours per year (29 per week). This was considerably lower for the bottom third of farms, ranked by gross margin per hectare, at 1,095 hours per year (21 hours a week).

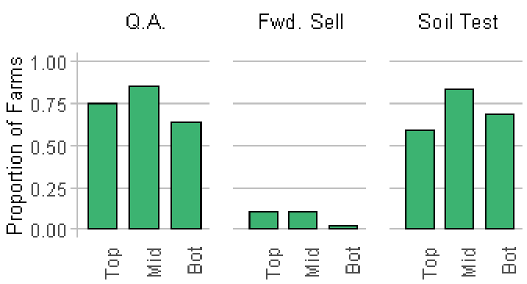
Figure 61. Hours Worked: Tillage Farms



Tillage Innovation Indicators

The three innovation indicators examined for tillage farms were: membership of a QA scheme, forward selling, and whether a soil test had been undertaken in the past 3 years. There was not a clear relationship between the three indicators and economic performance. Only a small proportion of all tillage farms (approx. 7%) used forward contracting.

Figure 62. Innovation Indicators: Tillage



Farm System Comparisons

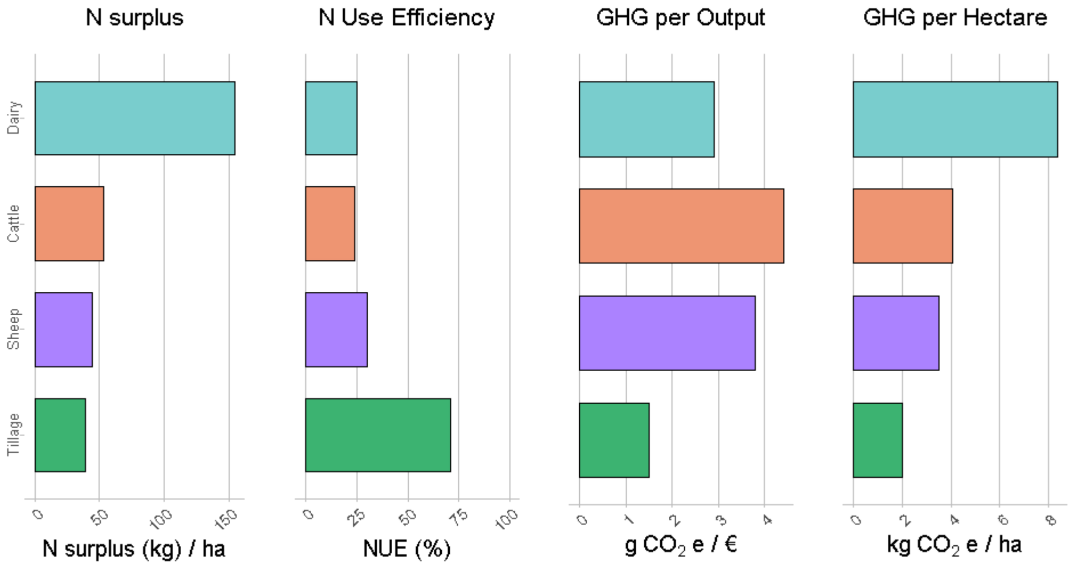
Economic Indicators: A comparison of economic sustainability between different farm types is shown below. In general, dairy farms show the strongest economic performance, with tillage farms slightly behind, while cattle and sheep farms perform similarly, quite substantially below dairy and tillage. The economic figures show that this pattern emerges firstly due to the greater level of output per hectare on tillage, and especially on dairy farms, which follows on to show similar trends in gross margins per hectare of each system. The spread between systems is slightly reduced when considering family farm income per labour unit, because of the relatively greater labour intensity of dairy systems, especially compared to tillage, although the overall trend in performance across all of the systems remains the same. The farm systems are most similar in terms of market orientation; however it should be noted that the proportion of income made up by subsidies may differ as reported in the 2015 NFS report, (Hennessy and Moran, 2016). In summary, cattle and sheep farms are most financially at risk, with only around 25% of both systems economically viable.

Figure 63. Economic Sustainability: Farm System Comparison (average per system)

Environmental Indicators: The environmental sustainability of farms is more difficult to compare directly across farm types, as the indicators are more directly linked with the type of farming undertaken, and different outputs produced. More detail can be revealed by comparing within farm types (see previous section), but some shared environmental indicators are available, shown below. Dairy farms have the largest N surplus per hectare due to the greater livestock production intensity per hectare in this system. Comparing the in-out accounting nitrogen use efficiency (NUE), it is observed that in terms of production output, dairy is similar to the other livestock systems, with tillage farms having greater nitrogen use efficiency than the livestock based systems. It should be noted, however, that this analysis excludes tillage farms with manure imports, and so may be under-represent the volume of nitrogen applied from animal manures on some tillage systems.

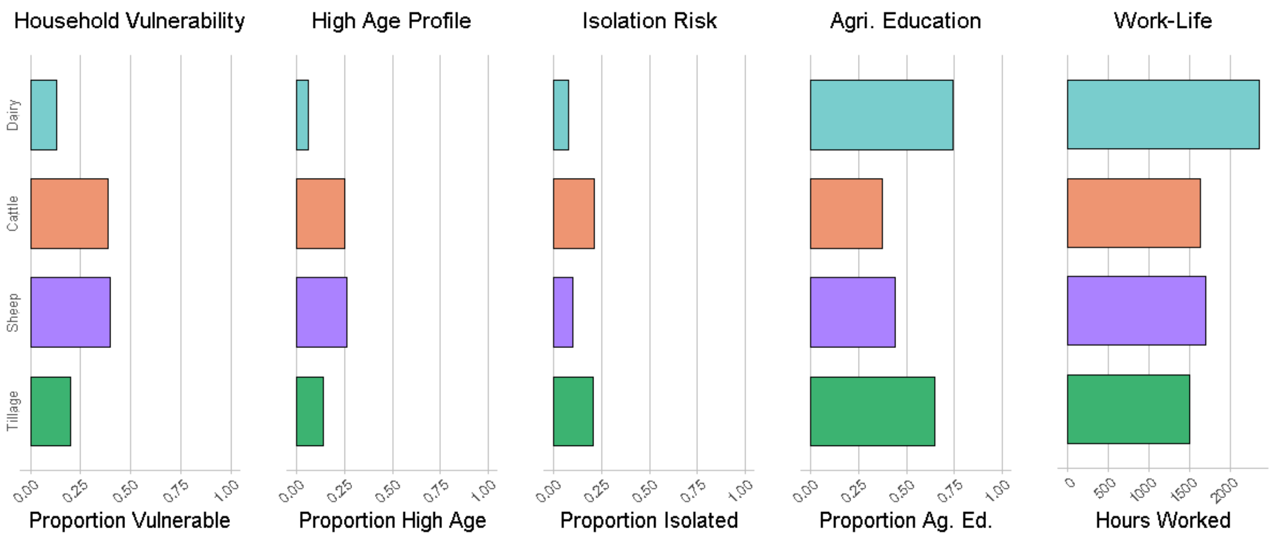
Livestock farms have greater greenhouse gas emissions than tillage, as expected due to the greater emissions associated with animal, and especially ruminant, systems. Scaled per euro of output, greenhouse gas emissions are relatively lower on dairy farms, as a result of the greater output associated with dairy. Per hectare, dairy farms show the largest emissions, significantly greater than any other system, due to the greater production intensity on these farms: the dairy emissions are a function of both greater stocking rates, more energy intensive diets for dairy cows, and more fertilisation than the other livestock systems.

Figure 64. Environmental Sustainability: Farm System Comparison (average per system)



Social Indicators: Comparing the social sustainability of different farm types shows a similar overall trend to economic performance, with dairy and tillage distinct from cattle and sheep systems, but with some notable differences. The relatively greater labour intensity of dairy production is shown in the longer hours worked for dairy, although it should be noted that other farm systems are more likely to incur hours in off farm employment, which would be in excess of the hours worked on farm recorded here. Following from the lower economic viability in cattle and sheep farms, these systems were also more likely to be vulnerable households. Cattle and sheep farms were more likely to have a high age profile, while cattle and tillage farms were more likely to be farmed by farmers living in isolation, but there was less variation for these than other social sustainability indicators. Dairy and tillage farmers were more likely to have received agricultural education or training than cattle or sheep systems.

Figure 65. Social Sustainability: Farm System Comparison (average per system)



Time Series Comparisons: 2012-2015

Following on from the 2012 sustainability report (Hennessy *et al.*, 2013), we can now begin to track changes in sustainability indicator scores over time. The figures below highlight changes in indicators, with averages across all farm types, and for specific systems. It is important to appreciate that some factors influencing the various indicator measures shown here are partially within the control of individual farmers (e.g. input use efficiency) and hence may be improved by changes in farmer behaviour, while others factors are outside of an individual farmer's control (e.g. farm prices, weather conditions). Since farming is influenced by weather conditions, which vary from year to year, and which therefore may affect the level of production or the level of input utilisation in a given year, this limits the inferences that can be drawn from a short time series.

Economic sustainability indicators

The value of output (€) and gross margins per hectare have remained fairly similar over time since 2012, for individual systems, and for farms overall, although some general trends can be noted. Tillage farms have declined slightly from 2012, due to the high level of cereal prices in that year. Dairy farms showed an increase in output and gross margin in 2013 and 2014 due to increased production, followed by a slight decline in 2015 as the milk price per litre fell.

Figure 66. Output per hectare: 2012-2015 (average per system)

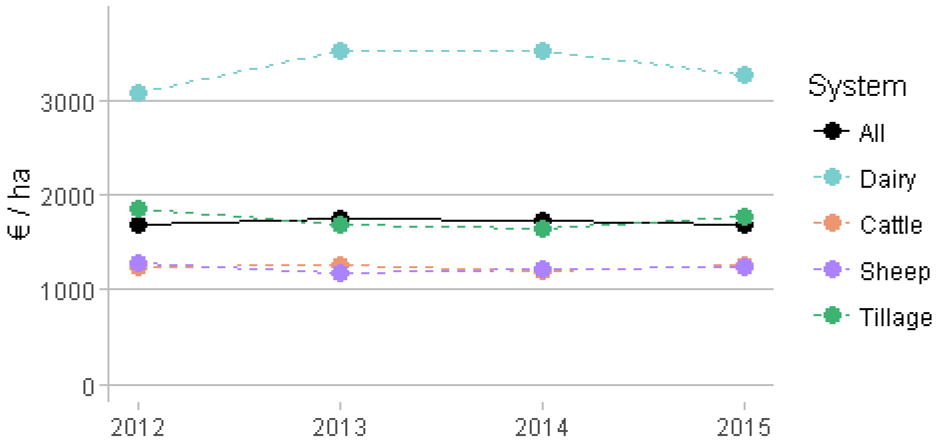
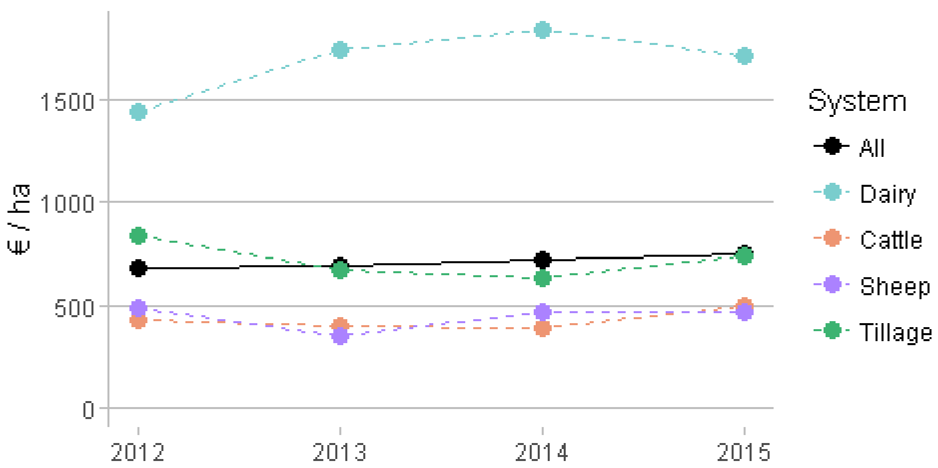
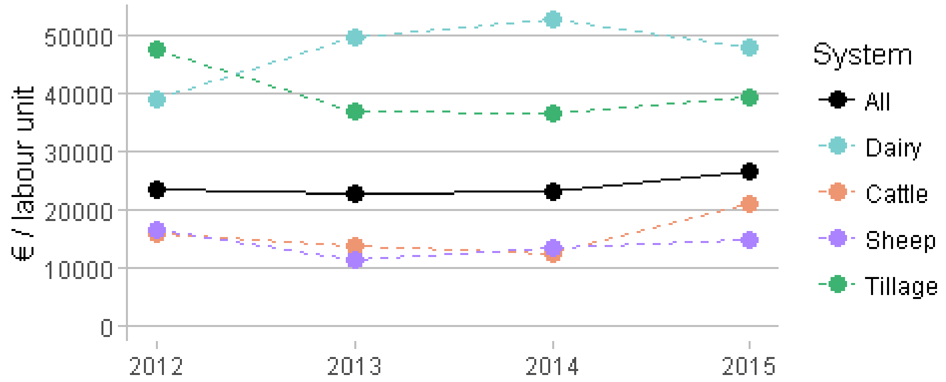


Figure 67. Gross Margin per hectare: 2012-2015 (average per system)



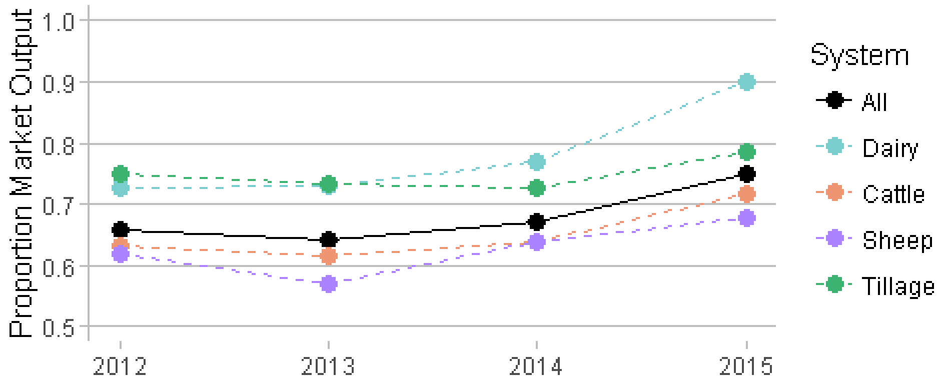
Farm incomes per labour unit reveal the same trends as financial output and gross margin per hectare, with some rescaling as a result of the different labour intensity of each production system. The time series shows a slight average increase across all systems in income per labour unit in 2015.

Figure 68. Productivity of Labour: 2012-2015 (average per system)



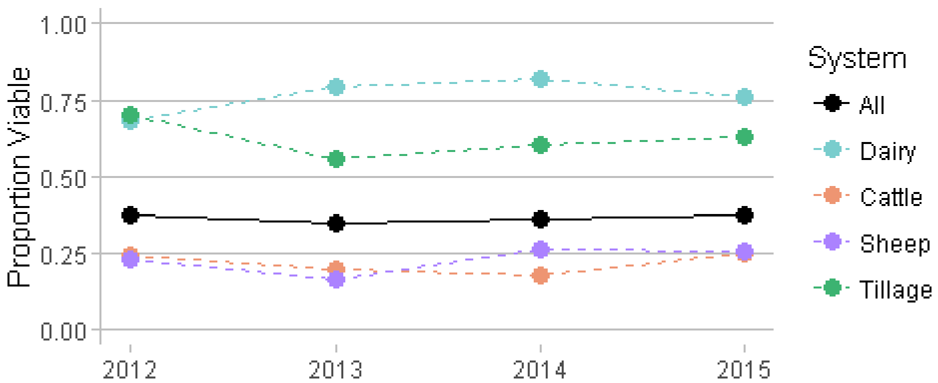
The share of output derived from the market increased in 2015, to an average of 75%, up from 66% in 2012. This is a result of both a decrease in direct payments, and an increase in market output, in 2015. An increase from 2014 to 2015 is especially noticeable in dairy and cattle systems, due to an increase in cattle prices over this period, as noted in the 2015 National Farm Survey Report.

Figure 69. Proportion of Output Derived from Market: 2012-2015 (average per system)



The same trends over time are also observed in terms of farm economic viability, and these highlight the gap between dairy and tillage systems when compared to cattle or sheep farms.

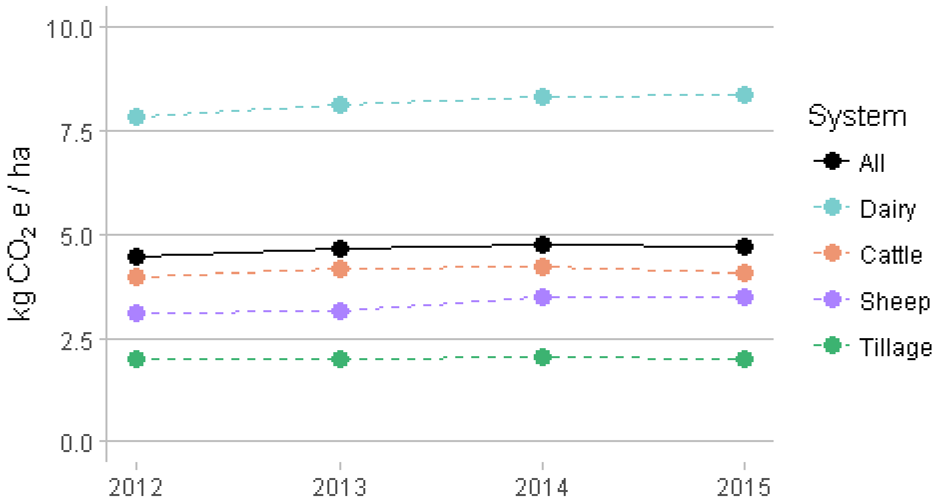
Figure 70. Economic Viability: 2012-2015 (average per system)



Environmental sustainability indicators

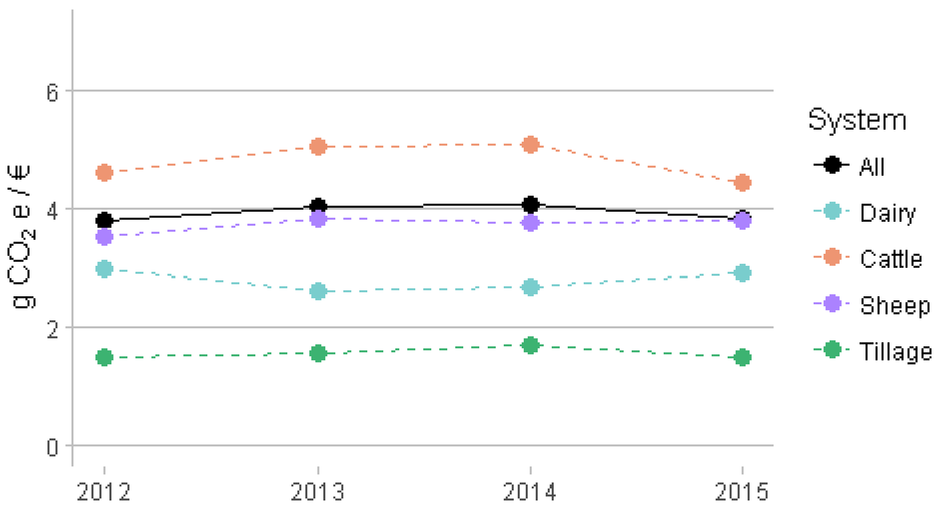
Agricultural greenhouse gas emissions per hectare have remained fairly stable since 2012. The main trend has been for a slight decrease in cattle stocking intensity, as some production has shifted from drystock to dairy production, and an increase in dairy GHG emissions per hectare, as a result of this shift and an increase in dairy production intensity more generally.

Figure 71. Agricultural Greenhouse Gas Emissions per hectare: 2012-2015 (average per system)



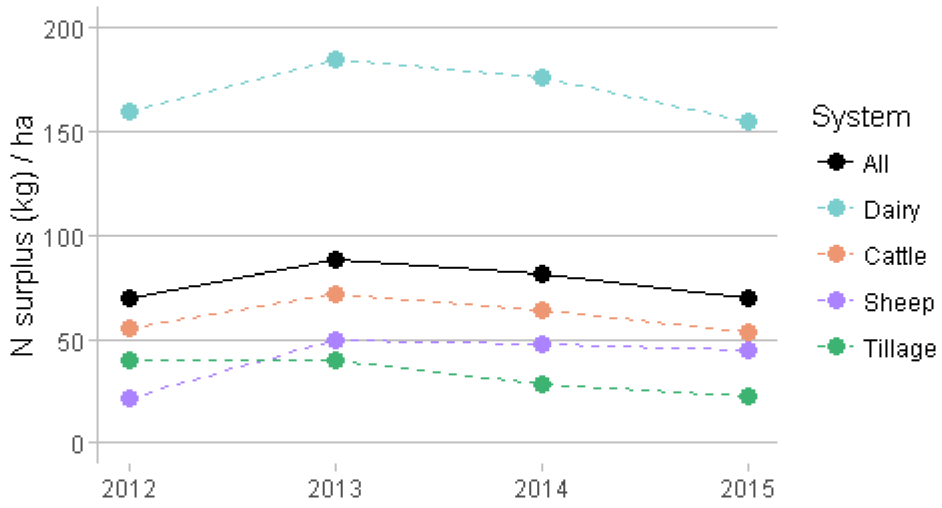
The agricultural greenhouse gas emissions per € output have remained largely flat for the time period covered, with slight fluctuations due to varying weather conditions and changing prices of agricultural goods. The increase in dairy emissions per hectare is not shown in emissions per € output, reflecting the fact that there has been substantial variability in milk prices over the years under examination. The change in emissions associated with milk production is examined in further detail below.

Figure 72. Agricultural GHG Emissions per € output: 2012-2015 (average per system)



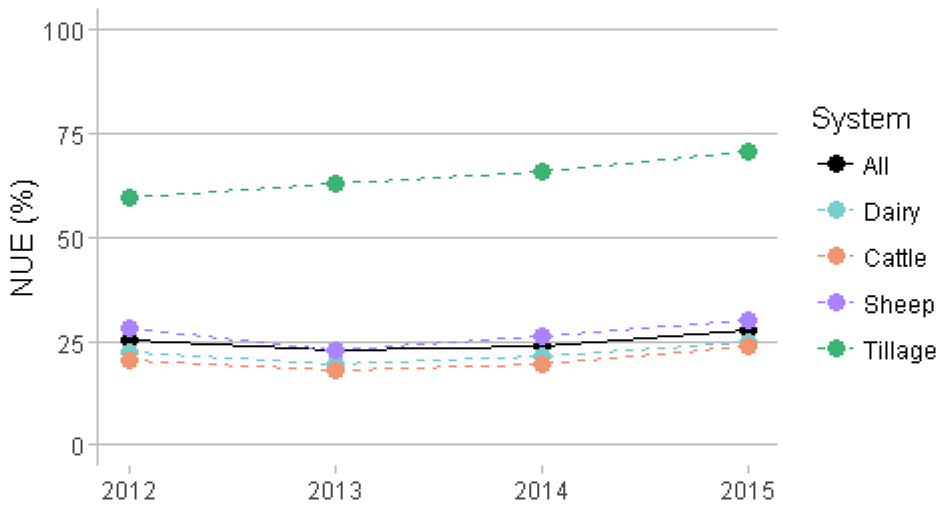
Nitrogen surpluses per hectare show a slight peak in 2013 for livestock farms, and a subsequent decline. Tillage farms have shown a gradual decline from 2012. The amount of nitrogen applied by farmers is driven by a number of factors. As shown above, greater nitrogen surpluses were often associated with better economic performance, on farms with more intensive production. However, a general trend for decreased nitrogen surpluses is a positive finding, indicating improved efficiency if it does not come at the expense of economic returns.

Figure 73. Nitrogen Balance per ha: 2012-2015 (average per system)



Nitrogen Use Efficiency, shown here as N outputs / N inputs in order to illustrate across all farm types, shows a generally increasing trend, highlighting that the decrease in nitrogen application shown above haa not come at the expense of productivity. Livestock farms had a lower NUE in 2013, as the fodder crisis resulted in extra nitrogen application in order to maximise grassland yields and rebuild silage reserves required to achieve a normal production level. Tillage NUE has increased year on year, and appears especially high in 2015 (at 71%), in large part due to exceptional, weather related, crop yields in recent years.

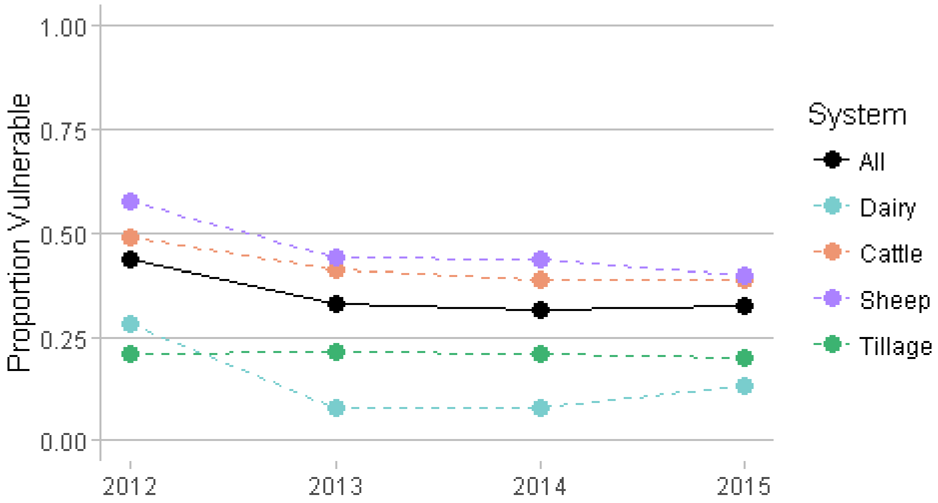
Figure 74. Nitrogen Use Efficiency: 2012-2015 (average per system)



Social Sustainability Indicators

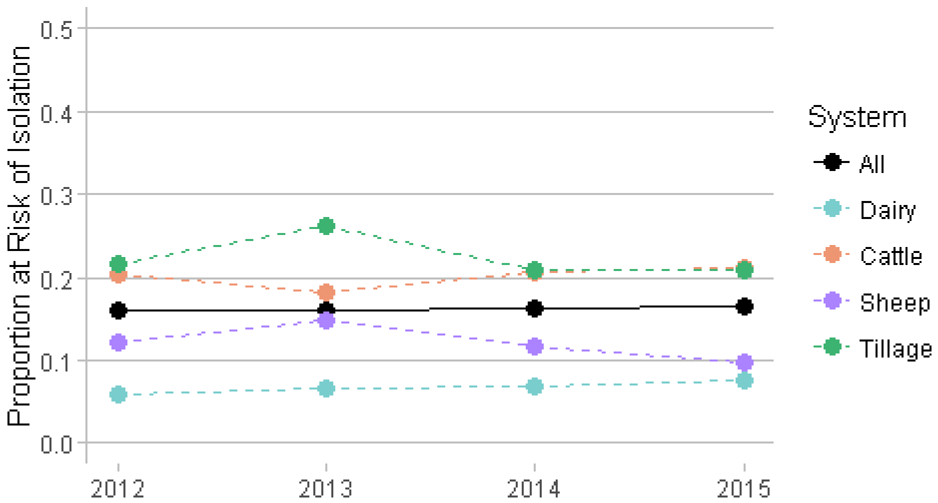
The rate of vulnerability of farming households has shown an overall decline since 2012. Cattle and sheep farms in particular have gone from a position where as many as 75% of farms were vulnerable, to just below 50%. Across all farm types, the rate of vulnerability has declined from 63% in 2012 to 41% in 2015, however this high rate remains a concern, given the consistent lack of economic security faced by these farm households.

Figure 75. Farm Household Vulnerability: 2012-2015 (average per system)



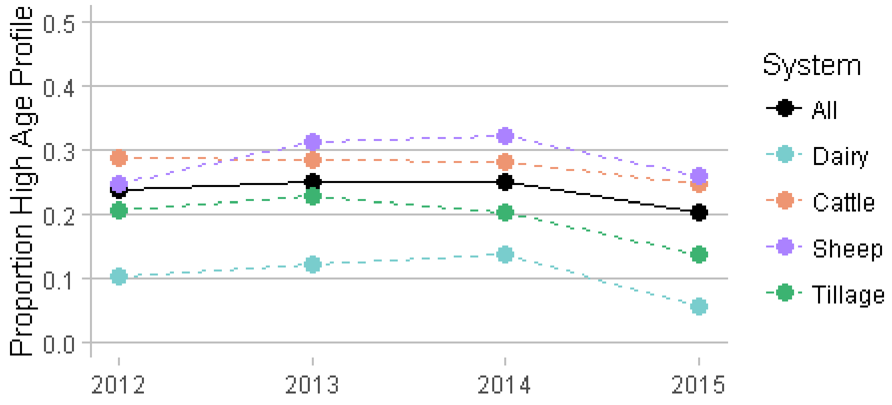
The proportion of farmers at risk of isolation has remained fairly stable over the time period 2012-2015, with fluctuations for specific farm types likely to reflect slight changes in demographic representation as farms moved into or out of the National Farm Survey sample frame.

Figure 76. Isolation Risk: 2012-2015 (average per system)



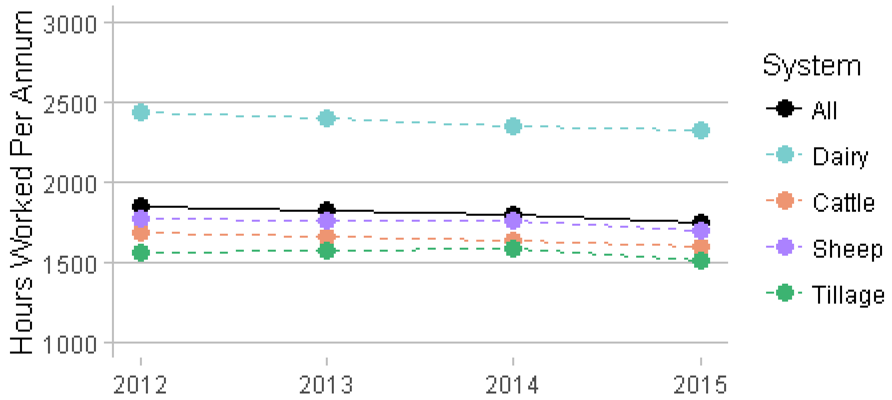
The proportion of farms with a high age profile has not changed dramatically, but does appear to have declined in 2015, representing a slight demographic change. This is especially so for dairy farms, down to a low of 6%.

Figure 77. High Age Profile: 2012-2015 (average per system)



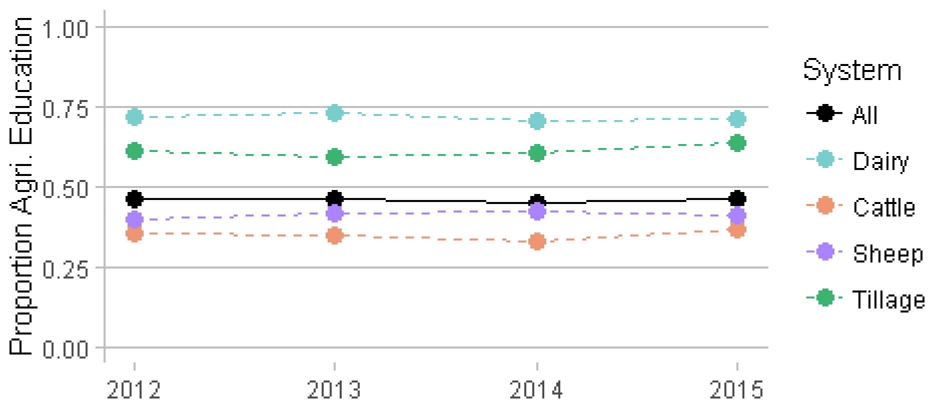
The hours worked per annum seems to show a slight year-on-year decline across all farm types. In 2015 an average of 1,755 hours were worked on farm, the lowest across the time period. However, it is not clear to what extent this decline in hours worked on farm may be matched by an increase in time engaged in off-farm employment, rather than a true reflection of improved work/life balance.

Figure 78. Hours Worked Per Annum: 2012-2015 (average per system)



The proportion of famers who have received some form of agricultural education has remained consistent for the period 2012-2015.

Figure 79. Formal Agricultural Education: 2012-2015 (average per system)

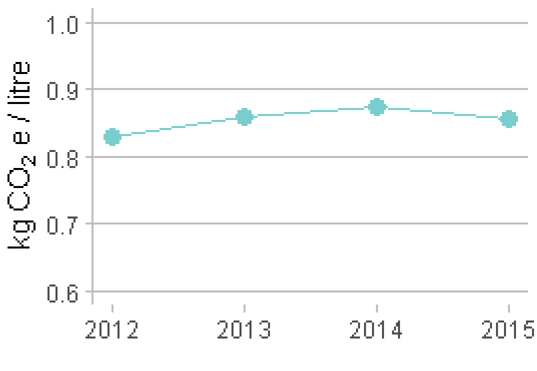


Environmental Sustainability Trends – Dairy Farms Post Milk Quota

Dairy farms are of particular interest, due to their prominent role in Irish agriculture, and on-going concerns relating to changes taking place arising from the abolition on milk quotas in 2015, and the significant volatility in milk prices that had been a feature of the dairy sector in recent years. Furthermore, dairy farms are among the most richly recorded in the NFS. The following section examines the environmental sustainability of milk production in more detail.

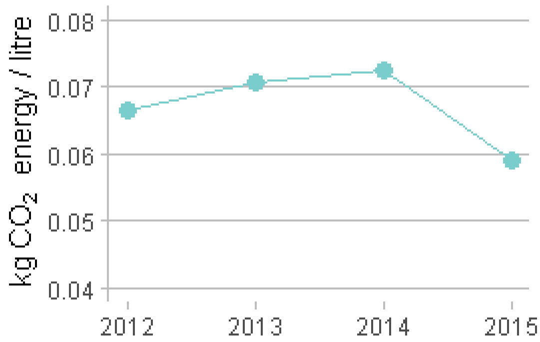
Agricultural greenhouse gas emissions associated with milk production are a result of enteric fermentation resulting in methane from dairy cows, methane and nitrous oxide from storage and management of their excreta, and nitrogen fertilisation of agricultural land for their feed. The emissions per litre of milk remain fairly constant over time, as there are physical limits to production whereby cows on high energy diets which produce more milk, also emit more methane. Improvements in emissions efficiency are still possible based on efficient herd and pasture management, and further reductions may be possible as new dietary research is undertaken and agricultural technologies emerge and are adopted by farmers. Continued development and use of this indicator will allow these changes to be incorporated and tracked.

Figure 80. Agricultural GHG Emissions per Litre Milk Produced: 2012-2015



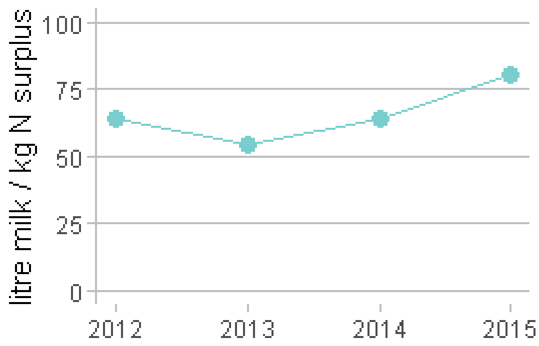
Management practices can already have more of an impact on greenhouse gas emissions associated with electricity and fuel emissions. Electricity and fuel emissions may be constrained by the weather for a given year: for example if extra heating is required for a cold winter, or wet conditions requiring extra movement of the herd. However, efficiency management can also minimise the emissions resulting from fuel, and there has been a decline in fuel emissions of 0.059 kg CO_2 per litre milk in 2015.

Figure 81. Electricity and Fuel Emissions Associated with Milk Production: 2012-2015



Excess nitrogen application not only increases greenhouse gas emissions, but can also pose a risk to the aquatic environment through increased risk of nutrient transfers from agricultural land to watercourses. However, nitrogen is also a key agricultural nutrient, and necessary for production. We therefore need to ensure that it is used efficiently, with the maximum return on nitrogen use. This is demonstrated below for the litres of milk produced for each kg of surplus nitrogen applied. An increase in efficiency of milk production is shown between 2012 and 2015, from 64 to 80 litres of milk for each kg of surplus nitrogen.

Figure 82. Milk Produced per kg N Surplus: 2012-2015



On-going and Future work

The National Farm Survey Sustainability Indicators are a powerful tool to assess farm performance across a range of important areas, allowing detailed comparisons between similar farms of different economic performance and entirely different systems. This report builds on the previous 2012 sustainability report (Hennessy *et al.*, 2013), and also shows the progress of the indicators since then. The indicator set will continue to be useful into the future, showing changes and improvements in Irish agriculture. The indicators themselves are also under continued refinement.

Greenhouse Gas Emissions

The national greenhouse gas inventory undergoes methodological changes each year, as both the underlying science behind climate change is increasingly well understood, and what needs to be considered for individual countries. A number of significant changes were made in the greenhouse gas emissions calculations for this report, bringing the methodologies in line with the 2015 Irish National Inventory Report (Duffy *et al.,* 2015). These changes keep estimates up-to-date, and are also essential to keep comparisons reliable, both across time and internationally, as the latest methodologies are also used to update prior emissions estimates. Work is already underway to prepare the farm sustainability indicators for upcoming changes to the Irish emissions inventory.

Ammonia Emissions

Agriculture is the main source of ammonia emissions, and European Union member states have national reduction targets to achieve. Calculations undertaken as part of the greenhouse gas emissions inventory already incorporate some of the processes resulting in ammonia generation, and future work will explore the possibility of adding add ammonia emissions as an environmental indicator.

Biodiversity

Farms may not only be producing food, but also providing appropriate environments for wildlife. This can provide benefits on the farm itself through the provision of ecosystem services, as well as contributing to the wider environment, being appreciated by local communities and tourists, and having its own intrinsic value. However, one of the concerns surrounding intensive agricultural production is that wildlife may be negatively impacted, resulting in irrevocable biodiversity loss. Biodiversity is therefore an important component of farm performance, but can usually only reliably be assessed by detailed on-farm surveys, which would be beyond the current scope of the NFS. Recent work being undertaken by Teagasc is exploring cost-effective methods to include farmland habitats in sustainability assessments, which could be aligned with other sustainability metrics for NFS farms. The inclusion of some measure of biodiversity is becoming increasingly desirable in quantitative measurements of sustainability, as food companies respond to wider sustainability assessments that require the inclusion of farmland habitats.

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