Teagasc National Farm Survey 2018 Sustainability Report

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Any errors or omissions remain the responsibility of the authors.

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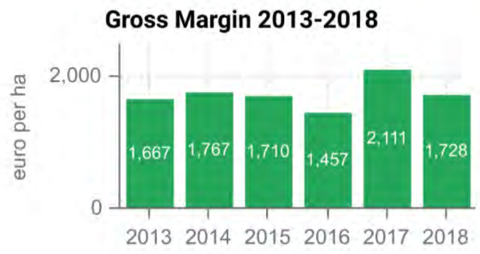
Abbreviations

CH_4	Methane
CO_2	Carbon dioxide
CSO	Central Statistics Office
ESD	EU Effort Sharing Decision
FPCM	Fat and protein corrected milk
GHG	Greenhouse gases
GM	Gross Margin
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Analysis
N	Nitrogen
NH_3	Ammonia
N_2O	Nitrous oxide
NFS	National Farm Survey
NUE	Nitrogen use efficiency
P	Phosphorus
PUE	Phosphorus use efficiency

Dairy: Economic and Social Sustainability

Gross Margin per ha 2018

€1,728

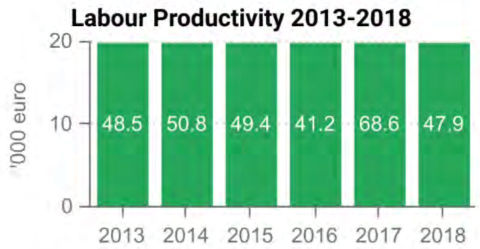


Viability 2018

73%

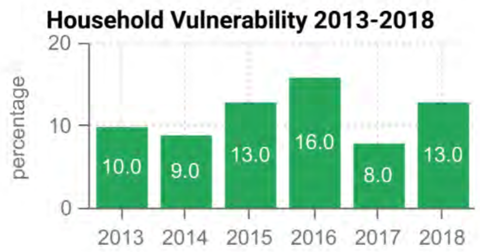
Productivity of Labour Unit 2018

€47,947



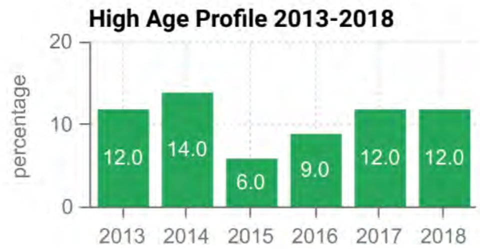
Household Vulnerability 2018

13%



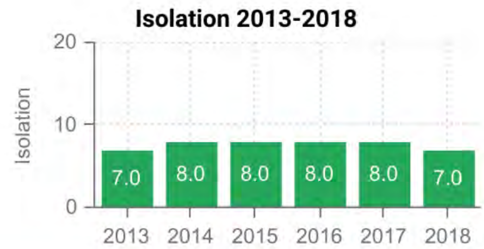
High Age Profile 2018

12%



Isolation 2018

7%

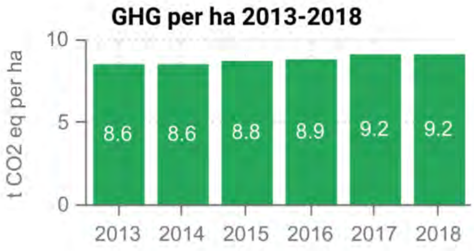


Source: Teagasc National Farm Survey

Dairy: Environmental Sustainability

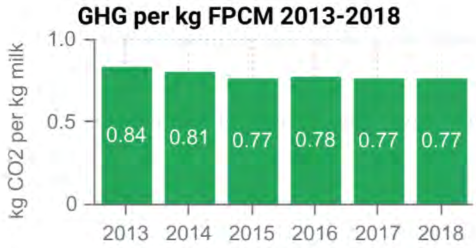
CO2 eq per ha 2018

9.2



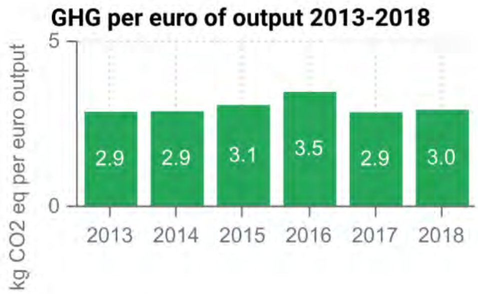
CO2 Eq per kg FPCM 2018

0.7



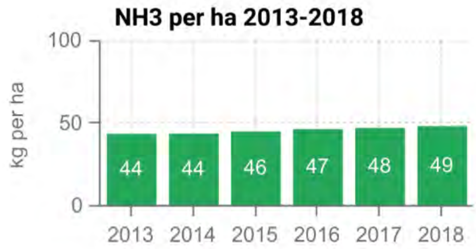
CO2 Eq per euro of output 2018

3.0



NH3 kg per ha 2018

49



N Balance kg per ha 2018

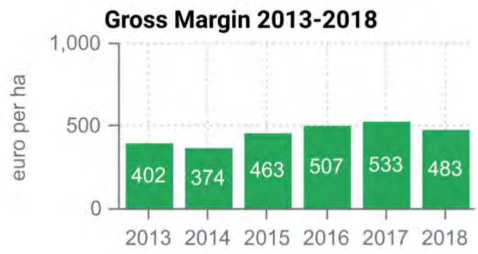
201

Source: Teagasc National Farm Survey

Cattle: Economic and Social Sustainability

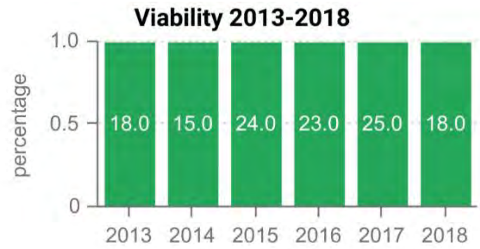
Gross Margin per ha 2018

€483



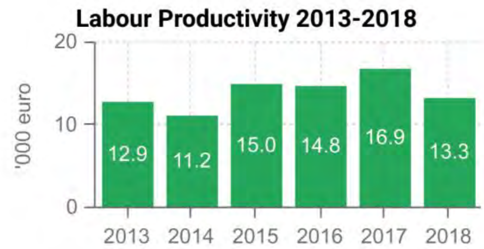
Viability 2018

18%



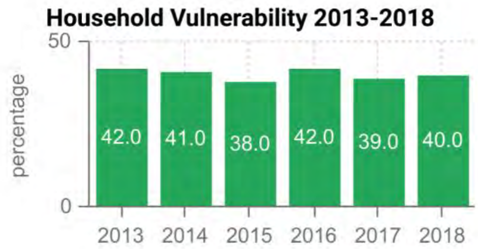
Productivity of Labour Unit 2018

€13,344



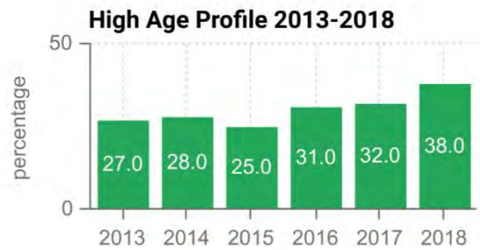
Household Vulnerability 2018

40%



High Age Profile 2018

38%



Isolation 2018

24%

Source: Teagasc National Farm Survey

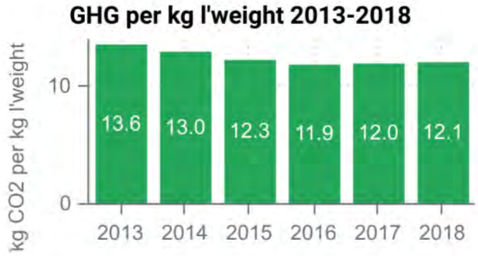
Cattle: Environmental Sustainability

CO_2 eq per ha 2018

4.5

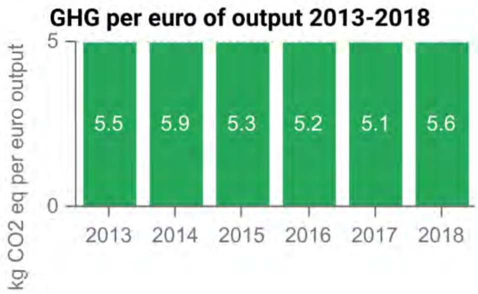
CO_2 eq per kg of liveweight 2018

12.1



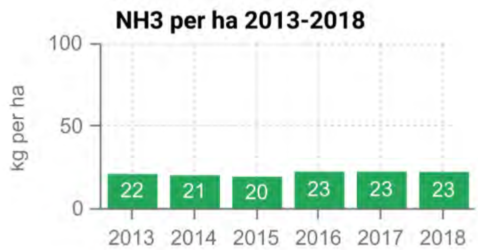
CO_2 per euro of output 2018

5.6



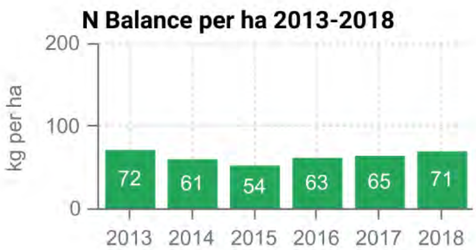
NH_3 kg per ha 2018

23



N Balance kg per ha 2018

71



Source: Teagasc National Farm Survey

Sheep: Economic and Social Sustainability

Gross Margin per ha 2018

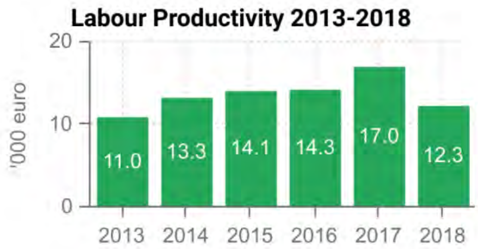
€400

Viability 2018

20%

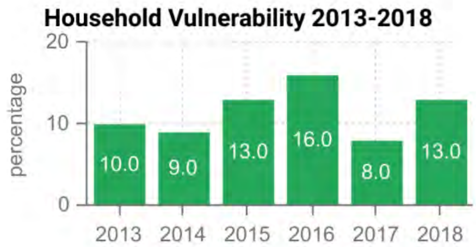
Productivity of Labour 2018

€12,316



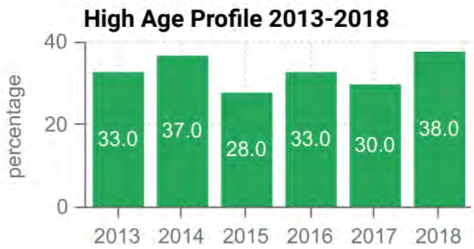
Household Vulnerability 2018

13%



High Age Profile 2018

38%



Isolation 2018

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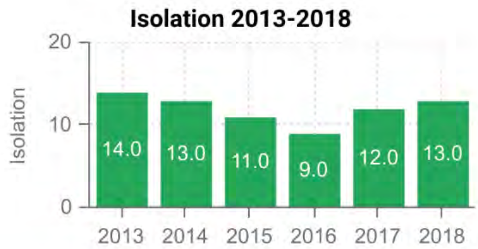
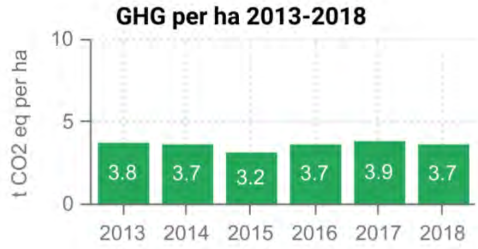


Source: Teagasc National Farm Survey

Sheep: Environmental Sustainability

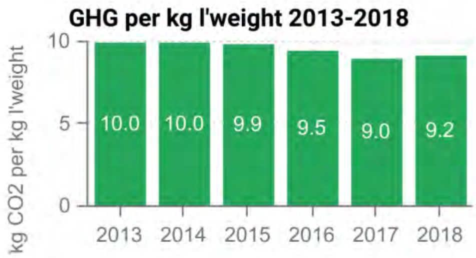
CO_2 eq per ha 2018

3.7



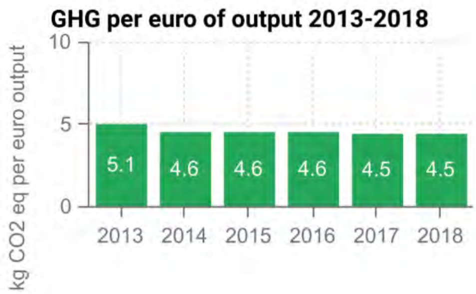
CO_2 per kg liveweight 2018

9.2



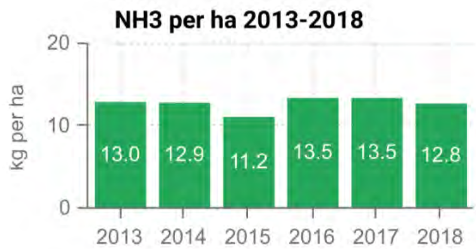
CO_2 per euro of output 2018

4.5



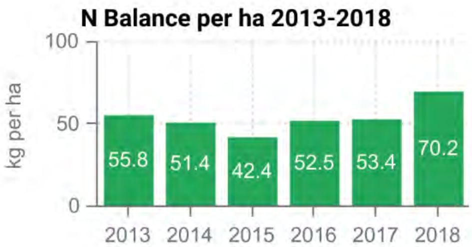
NH_3 kg per ha 2018

12.8



N Balance kg per ha 2018

70.2

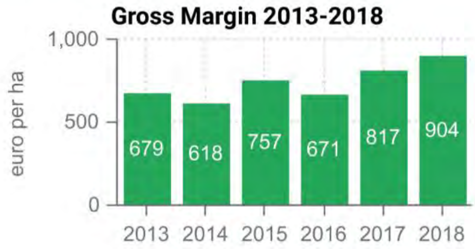


Source: Teagasc National Farm Survey

Tillage: Economic and Social Sustainability

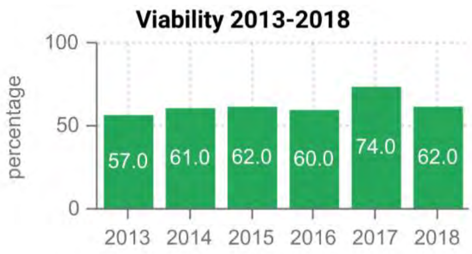
Gross Margin per ha 2018

€904



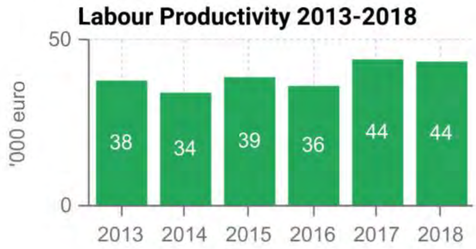
Viability 2018

62%



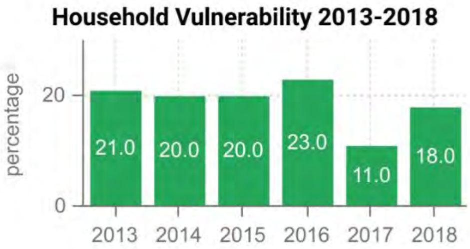
Productivity of Labour Unit 2018

€43,620



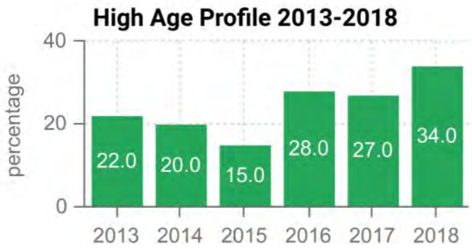
Household Vulnerability 2018

18%



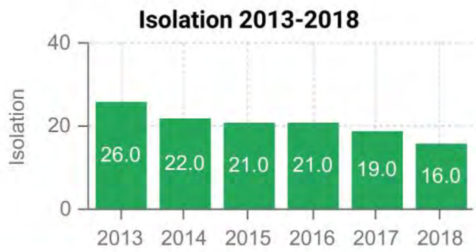
High Age Profile 2018

34%



Isolation 2018

16%

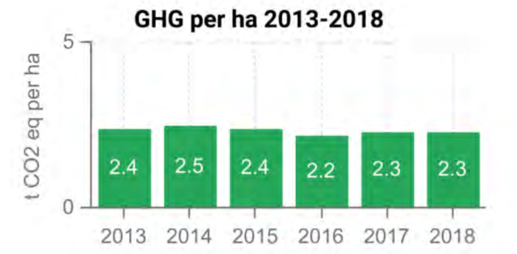


Source: Teagasc National Farm Survey

Tillage: Environmental Sustainability

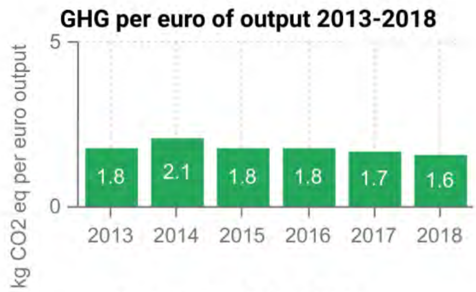
C02 eq per ha 2018

2.3



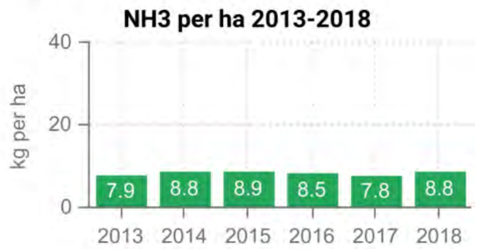
CO2 eq per euro of output 2018

1.6



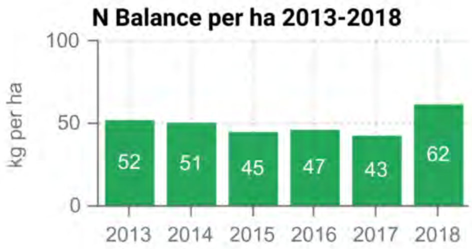
NH3 kg per ha 2018

8.8



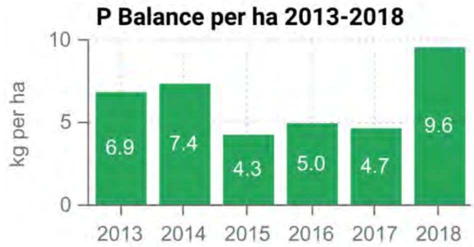
N Balance kg per ha 2018

62



P Balance kg per ha 2018

9.6



Source: Teagasc National Farm Survey

1. Introduction - Agricultural Sustainability

Globally, we face the grand challenge of trying to feed a growing human population, while attempting to minimise the environmental impacts of food production, especially in the context of climate change, water quality and biodiversity loss. Agricultural production must be both intensive and sustainable if these dual objectives are to be achieved simultaneously. To sustainably feed a growing global population, agricultural output must be increased without impacting on the capacity for future production or compromising the environment. This is the overarching objective of the EU Farm to Fork Strategy published in May 2020 (European Commission, 2020)

Agricultural systems are complex and tend to have multiple goals and wide-reaching effects, which must be considered holistically. To measure and track the diverse elements of Irish farm systems, this report considers Irish agricultural production (and its component farm systems) in terms of its economic, environmental and social sustainability. Additionally, it evaluates Irish farmers' adoption of innovations, which will be central in driving the sector towards increased sustainability as well as productivity.

2. Measuring Farm Level Sustainability

The measurement of agricultural sustainability is challenging, as it is a broad concept covering diverse elements which may vary through time and space. As such, relevant indicators are required to assess the sustainability status of Irish farms. Such metrics can highlight particular areas of concern or trends through time and indicate areas where improvement may be needed.

Deriving a sustainability indicator set is difficult, as it requires detailed, accurate and consistent farm-level measurements and data across a wide range of physical, socioeconomic and demographic farm attributes. The Teagasc National Farm Survey (NFS) provides such a dataset. The NFS is a representative sample of almost 900 farms across Ireland, and data from the NFS represent the Irish component of the European Union's Farm Accountancy Data Network (FADN) dataset[1]. The survey collects data on an ongoing basis, with the results published annually. Weights reflective of the national farm population are applied to the individual survey farms so that nationwide representation is achieved in terms of size and farm type for the principal farm systems in Ireland. This is important to ensure that aggregations can be made at an appropriate scale (for example, based on farm system type), and are capable of highlighting potential links or trade-offs between different indicators, depending on how individual farms are managed.

The Teagasc NFS is based on a nationally representative stratified random sample, which is selected annually in conjunction with the Central Statistics Office (CSO). Each farm is assigned a weighting factor so that the results of the survey are representative of the national population of farms (90,875 farms are represented in this report). Within the Teagasc NFS, farms are classified into major farming systems according to the standardised EU typology as set down by EU Commission regulation and applied by the EU Farm Accountancy Data

[1] The Teagasc NFS sampling frame is restricted to farms over €8,000 of standard output (equivalent to 6 dairy cows, 6 hectares of wheat or 14 suckler cows). A total of 90,875 farms are represented in this study for 2018. A small farm survey is conducted periodically to assess position on smaller farms (Dillon et al., 2017).

Network (a more detailed explanation and the correspondence between the farm systems used in the NFS and the farm types set out in the EU farm typology can be found in the Teagasc National Farm Survey report by Dillon et al., 2019). This report presents results for the four dominant farm systems in Ireland, namely, dairy, cattle, sheep and tillage.

As the appropriate data are produced on an annual basis, it is possible to generate and compare indicators over time, even as methodologies are updated and data requirements evolve accordingly. This is demonstrated through a time-series analysis for a number of key indicators presented in this report. It is expected that, based on scientific advances and emerging areas of interest (e.g. scientific and policy), the sustainability indicator set will continue to evolve and remain informative and relevant. Our aim is that as indicator methodologies develop, they will still be capable of being generated using Teagasc NFS data, ensuring the on-going inter-temporal assessment of the sustainability performance of Irish farm systems. Furthermore, as the NFS is part of the EU Farm Accountancy Data Network (FADN) there is scope for comparative analysis with the sustainability performance of farms in other EU Member States as set out in the EU Farm to Fork strategy (EU Commission, 2020).

3. Description of Sustainability Indicators

The indicators described here follow on those published in previous Teagasc sustainability reports (Hennessy et al., 2013; Lynch et al., 2016; Buckley et al., 2019). Updates presented here are based on methodological refinements, as well as additional data on agricultural activities of Irish farms collected and published by the Teagasc NFS. In particular, it should be noted that there have been methodological developments in the estimation of greenhouse gas emissions since the previous report was published and these are set out in detail in Buckley et al. (2019. For this reason, the historical times series for some of the sustainability indicators presented in this report will differ from those presented in earlier Teagasc Sustainability reports (Hennessy et al., 2013; Lynch et al., 2016; Buckley et al., 2019). This approach to revising historic sustainability indicators so as to ensure they reflect our current scientific knowledge, mirrors the approach used by the Environmental Protection Agency (EPA) and other relevant agencies.

As depicted in Figure 1 and described in the following section, the Teagasc Sustainability Report's indicators are grouped into four categories: **economic, environmental, social** and **innovation**.

Figure 1: Sustainability overview

3.1 Economic Indicators

Economic viability is essential to ensure that a farm system can sustain itself and that farming families are adequately compensated for their owned capital and labour that is used within the farm business. At a national level, agriculture is an important component of the Irish economy. The NFS is equipped to generate economic indicators, as one of its main objectives is to submit this type of data to the European Commission through the EU FADN. As such, financial and technical data collected through the NFS are reported to Brussels on an annual basis. The economic sustainability indicator set is, therefore, relatively comprehensive and (relatively unconstrained by issues relating to data availability) designed to cover a range of important economic measures. The following economic indicators are presented in the report:

a) Economic Return to Land

The economic productivity of land is measured as gross output (€) per hectare of utilised agricultural area (UAA). Gross output is defined as total sales less purchases of livestock & crops, plus value of farm produce used in the household plus receipts for hire work, service fees etc. It also includes the net change in inventories, which for cows, cattle and sheep are calculated as the change in numbers year on year valued at closing inventory prices. All non-capital grants, subsidies and premium payments are also included in gross output, as are income from land and quota lettings. Inter-enterprise transfers are then deducted to avoid double counting.

b) Profitability of Land

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.

c) Productivity of Labour

In the NFS, a distinction is made between family labour, which is generally unpaid and therefore not costed, and hired labour, which in accounting terms represents a production cost to the farm. The return on unpaid family labour is measured as family farm income per unpaid family labour unit. For consistency in measurement of farm labour input across the EU, a labour unit is defined as a person over 18 years old, working at least 1,800 hours a year (it is not possible to report in excess of one labour unit per person, 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 years respectively.

d) Economic Viability

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

e) Market Orientation

The market orientation is measured as the proportion of gross 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 gross output of the farm.

Table 1: Overview of Economic Indicators

Indicator	*Measure*	*Unit*
Economic return to land	Gross output per hectare	€ / hectare
Profitability	Market based gross margin per hectare	€ / hectare
Productivity of Labour	Family Farm Income per unpaid labour unit	€ / unpaid labour unit
Economic Viability	Economic viability of farm business	1=viable, 0=not viable
Market Orientation	Output derived from market rather than subsidies	%

3.2 Environmental Indicators

Agriculture can generate positive or negative environmental impacts depending on the specific activities undertaken on the farm. Agriculture is the principal land use in Ireland; hence environmental sustainability in agriculture is key to achieving national level objectives relating to the environment. The current set of NFS based environmental indicators focus on greenhouse gas (GHG) emissions, ammonia emissions, nitrogen and phosphorus use. Indicators that are currently under development include, metrics relating to biodiversity and these will be included in future Teagasc sustainability reports once the relevant scientific work needed to establish indicators and consistently collect the related data has concluded.

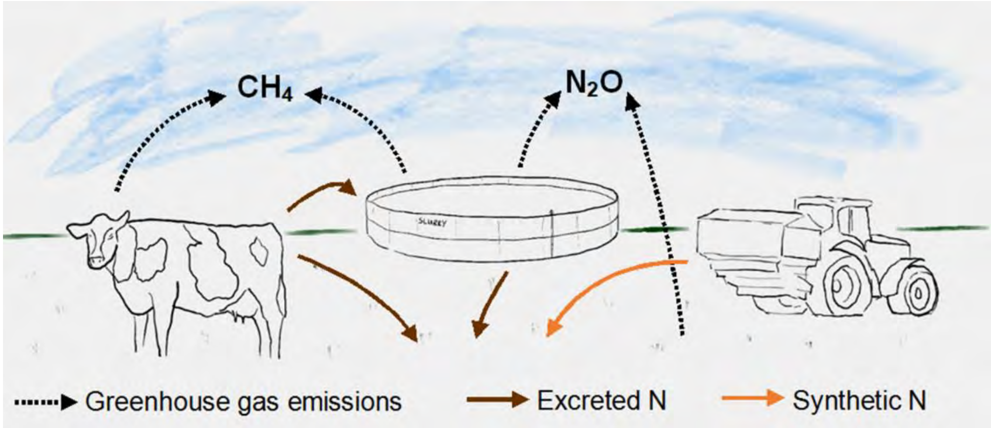
1. Greenhouse gas emissions

To minimise the extent and impacts of climate change, action is required to reduce global greenhouse gas emissions. Agriculture is the largest contributor to Irish greenhouse gas emissions by sector, with 34% of the national emissions total in 2018 (EPA, 2020). The agricultural sector is under pressure to reduce its emissions in the context of Ireland's commitment to reduce national GHG emissions. The National Climate Action Plan has set an emissions reduction target for 2030 of between 10-15% for the agriculture sector (Government of Ireland, 2019). Maintaining or even increasing food production will be very difficult, while at the same time reducing aggregate emissions (Breen et al., 2010).

Intergovernmental Panel on Climate Change (IPCC) Methodology*:* The GHG emissions indicators in this report are in the first instance calculated following the IPCC methodology accounting conventions and Irish emission factors as employed in the 2018 National Inventory Report for Ireland (Duffy et al., 2020). The three main agricultural emissions categories are methane (CH_4) emissions from enteric fermentation by ruminant livestock, CH_4 and nitrous oxide (N_2O) emissions from the production and storage of livestock manures, and N_2O emissions resulting from the application of manures and synthetic fertilisers to agricultural soils. Additional emission associated with crop residues and liming are also included in the analysis of this report.

A complicating factor inherent in a farm based approach, (as opposed to a national emissions inventory approach to emissions measurement), is that animals move between farms via inter-farm sales. Accordingly, an animal inventory approach is used here, whereby the CH_4 emissions and manure production of each livestock category are adjusted to reflect the portion of the year an animal is present on the farm. For reporting purposes, all non-carbon dioxide (CO_2) emissions are converted to CO_2 equivalents (CO_2 e) using appropriate global warming potentials for CH_4 and N_2O which are respectively 25 and 298 times greater than the GWP of CO_2.

Figure 2: 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 (relevant quantities used are estimated by using national average prices (CSO, 2019; SEAI, 2019)) and by applying national level emissions factors to these quantities.

Using the IPCC methodology, the main indicators developed include:

a. **Total agricultural emissions** are measured per farm, with emissions also disaggregated to show the emissions originating from different farm enterprises (dairy, cattle, sheep and crops).
b. **Agricultural greenhouse gas emissions per unit of output/hectare** are derived so that the total emissions of the farm can be decomposed into components relating to each of the farm's main agricultural outputs (milk, cattle or sheep live-weight and crop outputs). In addition, agricultural based GHG emissions per € of output and per hectare are used to illustrate GHG emissions per € of output that are generated on farms with dissimilar levels of agricultural output.
c. **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 GHG emissions are considered separately from agricultural GHG emissions.

Methodological Update

It should be noted that greater granularity and data is now available to estimate agricultural GHG emissions compared to the indicators published in earlier reports (Buckley et al., 2019). Specifically, emissions associated with crop residues (category 3.D.1.4 in inventory) and liming (category 3.G in inventory) are now included in the analysis. Additionally, greater granularity is applied to the chemical fertiliser element of GHG emissions (3.D.1.1 Inorganic N Fertilizers) where fertiliser specific emission factor are now applied to the specific quantities of fertilisers applied (e.g. CAN, Urea etc.) at farm level.

LCA Methodology: An alternative method to the IPCC approach to measuring GHG emissions is the LCA approach, which accounts for emissions through the entire food production supply chain. LCA is a holistic systems approach that aims to quantify the potential environmental impacts, e.g. GHG emissions, generated throughout a product's life cycle, from raw-material acquisition through production, use, recycling and final disposal. Thus, it accounts for all GHG emissions from the farm up to the point of product sale. It is generally expressed per unit of product produced. The LCA approach attempts to capture all emissions associated with a product. It therefore ignores national boundaries and seeks to enumerate all emissions along the chain, irrespective of country of origin.

Considerably more data are required to conduct an LCA study or to produce a carbon footprint analysis for each product produced on a farm. At present such detailed data are only available for dairy farms participating in the NFS and as such it was only possible to conduct a carbon LCA based footprint analysis of milk production using NFS data. The Moorepark Dairy LCA model was used for this analysis (O'Brien et al., 2014). This model, which is accredited by the National Carbon Trust (UK), has previously been used to estimate the carbon footprint of milk production on a number of Teagasc research farms, as well as a sample of farms supplying a particular Irish dairy processor. The system boundaries of the LCA model are defined to include all emissions associated with the dairy production system up to the point where milk is sold from the farm. The advantage of applying the Dairy LCA model using NFS data is that the Teagasc NFS is nationally representative of Irish milk production and thus reflects the full spectrum of dairy farming conditions in the country and as such allows for the production of a nationally representative LCA based carbon footprint measure.

Additional data over and above those normally collected by the Teagasc NFS were required to make the Moorepark LCA model operational using NFS data and these data are only available since 2013. The additional data include information on the length of the grazing season, slurry spreading methods used, timing of slurry application, use of agricultural contractors and type of electricity provider. As with the other indicators presented in this report, emphasis should not be placed on the absolute level of the carbon footprint measure, but rather the direction in which the indicator evolves over time. The main objective of this research is to establish indicators with which progress in sustainability performance can be documented and evaluated.

2. Ammonia

Ammonia (NH_3) is an air pollutant contributing to eutrophication and acidification of terrestrial and aquatic ecosystems. It is also an indirect source of a potent greenhouse gas nitrous oxide (Sutton et al., 1992). The EU and its Member States are parties to the Convention on Long-Range Transboundary Air Pollution (CLRTAP), which regulates trans-boundary air pollutants, including ammonia (NH3). Within the EU, NH_3 emissions are regulated through the National Emissions Ceiling (NEC) Directive (EU, Commission 2016). Over 99% of Ireland's ammonia emissions originate within agriculture, with their source being animal waste and the application of synthetic fertilisers (EPA, 2019). The fact that ammonia emissions in Ireland come almost exclusively from agriculture means that any future national ammonia reduction target for Ireland would de facto represent a reduction target to be achieved by the agriculture sector. From 2020, Ireland has an ammonia ceiling of 112.2 kilotonnes per annum, representing a 1% ammonia reduction relative to the 2005 level. A further reduction target of 5% relative to the 2005 level (to a ceiling of 107.6 kilotonnes per annum) is to be achieved by 2030. The national inventory accounting methodology as applied by the Environmental Protection Agency (Duffy et al., 2019) in conjunction with activity data from the NFS is used for estimating NH_3 emission indicators across different farm systems in this report, the main indicators developed include:

a. **Total agricultural emissions** are measured per farm, with emissions also disaggregated to show the emissions originating from different farm enterprises (dairy, cattle, sheep and fertilisers).
b. **Ammonia emissions per unit of output/hectare** are derived so that the total NH_3 emissions of the farm can be decomposed into components relating to each of the farm's main agricultural outputs (milk, cattle or sheep live-weight and crop outputs). In addition, NH_3 emissions per € of output and per hectare are used to illustrate emissions per € of output that are generated on farms with dissimilar levels of agricultural output.

3. Nutrient Use Efficiency

Nitrogen (N) and Phosphorus (P) use indicators follow a nutrient accounting approach based on Buckley et al. (2015). N and P exports from the farm are subtracted from imports to the farm to give a farm gate balance. Exports comprise the N and P component of milk, crops, wool and livestock sold (including livestock for slaughter) from the farm. Imports are comprised 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 those farms importing and/or exporting slurry are excluded from N and P balance indicators calculations. It should be noted that the N and P indicators do not provide estimates of losses to water, as such losses are complex and driven by site specific biophysical factors and weather conditions. N and P balances are used as an indicator of potential risk of loss of nutrients, all other things being equal, and cover most of the key management decisions over which the farmer has direct control.

Nitrogen use - Nitrogen (N) is an important element in agricultural production, but the loss of excess N poses a significant risk to the aquatic environment. The nitrogen use indicators follow an input-output accounting methodology as described below.

a. **Nitrogen balance** (per hectare farmed), is used as an indicator of the potential magnitude of nitrogen surplus, which reflects the risk of nutrient losses to water bodies, all other things being equal. It is calculated on the basis of N inputs less N outputs on a per hectare basis at the farm gate level.
b. **Nitrogen use efficiency** (NUE) is used to highlight the proportion of N retained in the farm system (N outputs / N inputs). This is a generic measure allowing temporal comparisons at the farm gate level.
c. **Nitrogen surplus per unit of output produced** is a measure derived so that the total N surplus of the farm can be decomposed into components relating to each of the farm's main outputs (milk, cattle or sheep live-weight and crop outputs). For dairy systems, it is also expressed in kg of milk produced per kg of N surplus.

Phosphorus use - Similar to nitrogen, phosphorus (P) is an important element in agricultural production and its loss poses a significant risk to the aquatic environment. Phosphorus use indicators, like N use indicators, also follow an input-output accounting methodology described previously. However, it should be noted that unlike N, phosphorus can remain in the soils for significant periods of time and is available to be stored and mined, hence P balance and efficiency should be interpreted with caution without reference to the soil P status of the farm.

a. **Phosphorus balance** (per hectare farmed), is used as an indicator of the potential magnitude of phosphorus surplus which may result in nutrient losses to water bodies all other things being equal. It is calculated on the basis of P inputs less P outputs on a per hectare basis at the farm level.

d. **Phosphorus use efficiency** (PUE) is used to highlight the proportion of P retained in the farm system (P outputs / P inputs). This is a generic measure allowing temporal comparisons at the farm gate level.

Table 2: Overview of Environmental indicators

Indicator	***Measure***	***Unit***
Ag. GHG emissions per farm	GHG emissions	Tonnes CO_2 equivalent / farm
Ag. GHG emissions per hectare	GHG emissions per hectare	Tonnes CO_2 equivalent / hectare
Ag. GHG emissions per kg of output	GHG emissions efficiency	kg CO_2 equivalent / kg output *AND* kg CO_2 e / € output
Energy GHG emissions per farm	Farm GHG energy use efficiency	kg CO_2 equivalent / kg output
Energy emissions per kg of output	Energy GHG emissions efficiency	kg CO_2 equivalent / kg output *AND* kg CO_2 e / € output
Ammonia emissions per farm	NH_3 emissions	Tonnes NH_3 equivalent / farm
Ammonia emissions per hectare	NH_3 emissions per hectare	Tonnes NH_3 equivalent / hectare
Ammonia emissions per kg of output	NH_3 emissions efficiency	kg NH_3 equivalent / kg output *AND* kg NH_3 / € output
Nitrogen (N) balance	N transfer risk	kg N surplus / ha^{-1}
Nitrogen (N) use efficiency	N retention efficiency	% N outputs / N inputs
N surplus per kg of output	N emissions efficiency	kg N surplus / kg output
Phosphorus (P) balance	P transfer risk	kg P surplus / ha^{-1}
Phosphorus (P) use efficiency	P retention efficiency	% P outputs / P inputs

3.3 Social Indicators

A farm will only be sustainable if employment in the industry can provide a suitable economic return for the labour used, 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 may exit the sector, or there may be a lack of new farming entrants 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 well-being in the broader rural community. The design of social sustainability indicators is subjective in nature and on-going efforts are being made to improve the farmer, animal and community well-being aspects of social sustainability measurement within the Teagasc NFS. Based on the data currently available from the NFS, the following indicators are reported:

a) 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 farmer's spouse has no off-farm employment income source.

b) 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 (e.g. willingness to adopt new technologies).

c) 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.

d) Isolation risk

Isolation risk is also measured using a binary variable, depending on whether or not the farmer lives alone.

e) 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.

Table 3: Overview of 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 farmer	Hours worked on the farm

3.4 Innovation Indicators

More efficient production has the potential to increase profitability, while reducing negative environmental and social effects, thereby assisting progress towards more sustainable agriculture. Innovations that can lead to increased sustainability may be novel technologies, newly developed or applied, or may arise from the adoption of established and better management techniques. Hence, it is important to measure uptake of such innovations to ensure that updated science and knowledge is being translated into actual farmer practices and secondly that the use of these technologies gives the anticipated environmental, economic or social benefits. As a result, the innovation indicators selected here are a combination of specific technologies or practices employed by the farmer, as well as farmer membership in groups which may be positively associated with increased adoption of broader innovations. All of the innovation indicators are scored as binary variables, either whether a specific technology or practice is used or whether a farmer is a member of the given group. Innovation indicators can be especially useful when evaluated in conjunction with those relating to economic 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 dairy farm management practice from which farms could build on and improve herd health performance, breeding and milk yield.
- ***Discussion group membership*** was selected as indicating the degree of interaction with extension services and peers.
- ***Spring slurry spreading*** (spreading at least 50% of total slurry between January and April) was identified as an important practice to minimise losses to the environment and maximise grass production.
- ***Low emission slurry spreading*** low emission slurry spreading or LESS (trailing shoe, trailing hose or injection methods) increases nitrogen retained in slurry and reduces the need for chemical fertiliser, as well as reducing nitrogen losses to the environment.
- ***Liming*** **and** ***Reseeding*** were identified as important practices in grassland management.

Cattle and sheep innovation indicators

Sheep and drystock cattle systems used a common set of innovation indicators (except for low emission slurry spreading which was reported for cattle systems only). These are:

- ***Discussion group membership*** was selected as indicating the degree of interaction with extension services and peers.
- ***Spring slurry spreading*** (spreading at least 50% of total slurry between January and April) was identified as an important practice to minimise losses to the environment and maximise grass production.
- ***Low emission slurry spreading*** low emission slurry spreading or LESS (trailing shoe, trailing hose or injection methods) increases nitrogen retained in slurry and reduce the need for chemical fertiliser, as well as reducing nitrogen losses to the environment.
- ***Liming*** **and** ***Reseeding*** were identified as important practices in grassland management.

Tillage innovation indicators

- ***Forward selling*** was selected as an innovative financial risk management strategy for tillage farms.
- ***Discussion group membership*** was selected as indicating the degree of interaction with extension services and peers.
- ***Liming*** was identified as important practices in arable production.
- ***Growing a main break crop*** (oilseed rape, peas, beans, linseed) was identified as best practice for tillage farms for disease and pest control.

Table 4: Overview of Innovation indicators

Dairy	***Cattle***	***Sheep***	***Tillage***
Discussion Group	Discussion Group	Discussion Group	Discussion Group
Liming	Liming	Liming	Liming
Spring slurry spreading*	Spring slurry spreading*	Spring slurry spreading*	Forward Selling
Low emission slurry spreading	Low emission slurry spreading	Reseeding	Break crop
Reseeding	Reseeding		
Milk Recording			

*(>50% slurry spread during the period January - April)

4. Sustainability Indicator Results 2018

The main diagrams used to express sustainability indicator results are provided below. Boxplots are used to display continuous data and allow the visualisation of the statistical distribution of the results for the population represented. The boxplots used here show the 10th, 25th, 50th, 75th and 90th percentiles of the NFS sample's population weighted distribution. An annotated example is shown in Figure 3 below, using data on gross margin per hectare for dairy farms. The value of the percentiles reflect the distribution of results. For example, the 50th percentile (the median) in Figure 3 lies at approximately €1,400 per hectare, meaning that 50% of farms had a gross margin per hectare below this value (and conversely, 50% of farms had a gross margin per hectare greater than this value). A shorter range between percentiles indicates farms within this range have similar levels of performance.

In the dairy example below, the distance between the 90th and 75th percentiles is greater than the distance between the 50th and 75th percentiles, indicating that a larger number of dairy farms were closer to this central range, with a wider spread among farms earning significantly more. 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 4 below. To reflect how a given (non-economic) indicator relates to the economic performance of a farm, for most indicators, farms are segmented by performance into a top, middle and bottom performing third, where performance is based on gross margin per hectare. This is also demonstrated in the example in Figure 4, where it can be seen in this hypothetical case that 88% of the top third of dairy farms ranked by gross margin (GM) per hectare were economically viable, compared to 34% for the bottom third.

Figure 3: Example Boxplot Gross Margin € per hectare

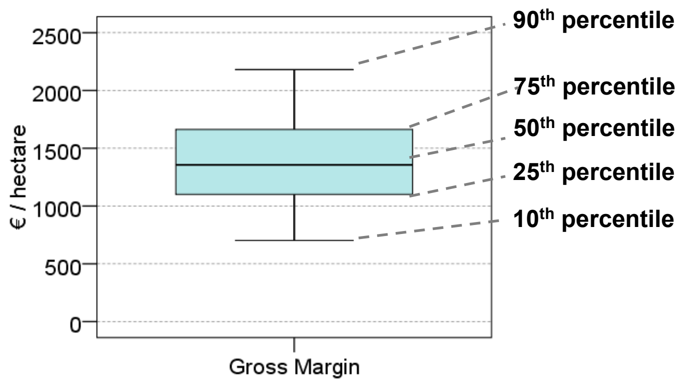
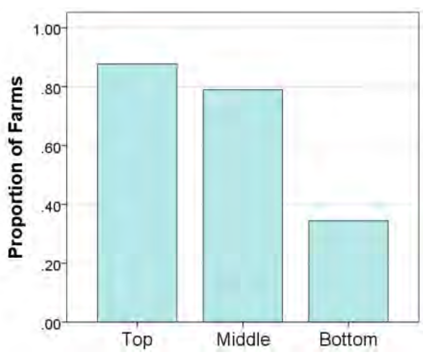


Figure 4: Example Bar Chart Proportion of farms

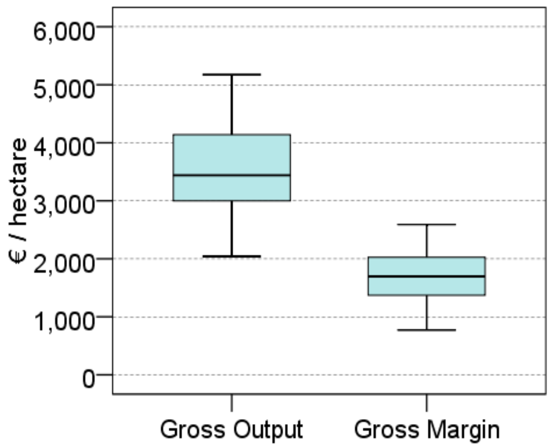


4.1 Dairy Farms

Economic Sustainability Indicators

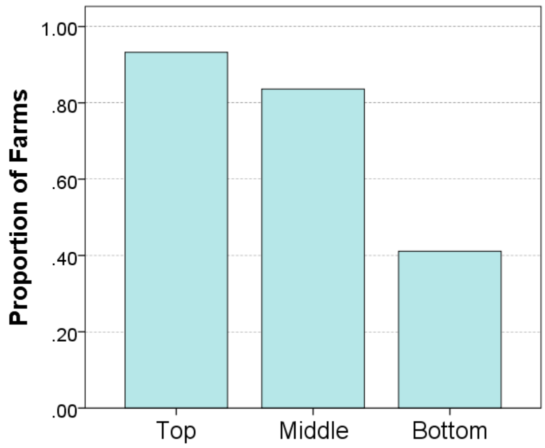
In 2018, the average dairy farm output per hectare was €3,637, and the average market gross margin per hectare was €1,728. Median values were slightly lower as shown in Figure 5.

Figure 5: Economic Return and Profitability of Land: Dairy Farms



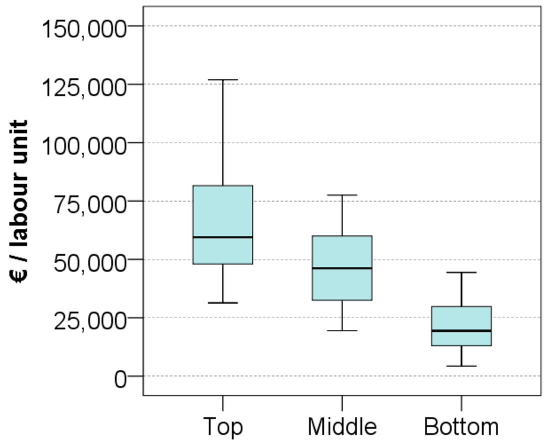
Overall 73% of dairy farms were economically viable in 2018. This ranged from 93% for the top third of economic performing dairy farms to 41% for the bottom third as shown in Figure 6.

Figure 6: Economic Viability: Dairy Farms



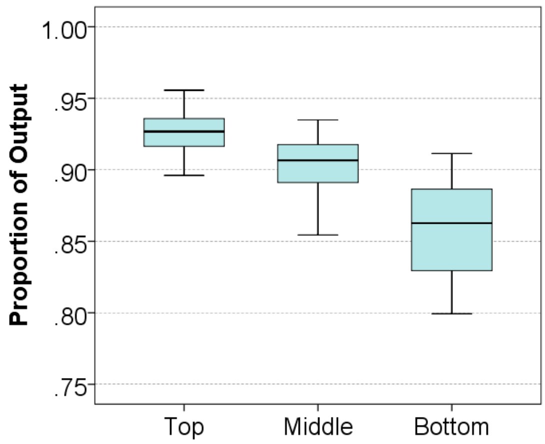
Average income per labour unit (unpaid family labour) for dairy farms in 2018 was €47,947. Average income per labour unit was €72,193, €48,395 and €22,884 for the top, middle and bottom performing farm groupings respectively. However, there was a large range in the return to labour for dairy farms, especially for the higher performing farms, as shown in Figure 7.

Figure 7: Productivity of Labour: Dairy Farms



On average, dairy farms derived 89% of gross output directly from the market in 2018. The degree of market orientation was highest for the top third of dairy farms and the range was largest among the bottom third, as illustrated in Figure 8.

Figure 8: Market Orientation: Dairy Farms



Environmental Sustainability Indicators

Figure 9 indicates that the average dairy farm produced 536.5 tonnes of agricultural GHG emissions (in CO_2 equivalents) in 2018. It should be noted that this measure is based on the IPCC definition of agricultural emissions, and is not based on a full life-cycle assessment that would include embedded emissions in agricultural inputs, such as purchased feed. The majority of dairy farm emissions, 62%, were from milk based output, with 37.5% allocated to beef production on these farms (this would include cull cows and calf sales and transfers). The remaining emissions, less than 1%, were associated with sheep and crop production on dairy farms.

Figure 9: Agricultural GHG Emissions for the average Dairy Farm

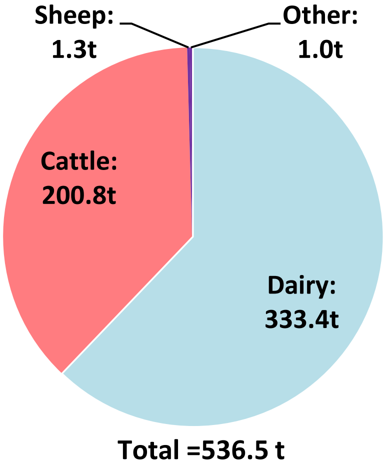
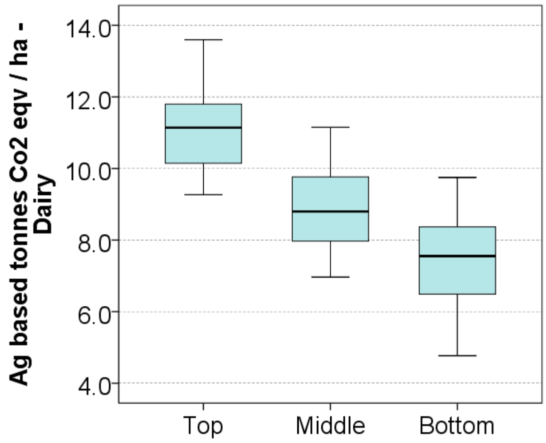


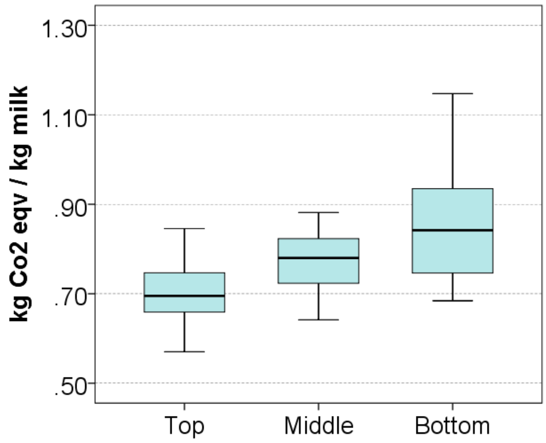
Figure 10 shows the average amount of CO_2 equivalent per hectare generated across dairy farms. The average dairy farm emitted 9.2 tonnes of CO_2 equivalent per hectare. Economically better performing dairy farms tend to operate at higher intensities and this is reflected in their higher emissions of GHG per hectare.

Figure 10: Agricultural GHG Emissions per hectare: Dairy Farms



When emissions allocated to dairy output are expressed per kilogramme of milk output, the average farm emitted 0.78 kg CO_2 equivalent per kg of milk produced.[2] Figure 11 shows that farms with the best economic performance also have the lowest emissions intensity per kg of milk produced.

Figure 11: Agricultural GHG Emissions per kg of milk: Dairy Farms

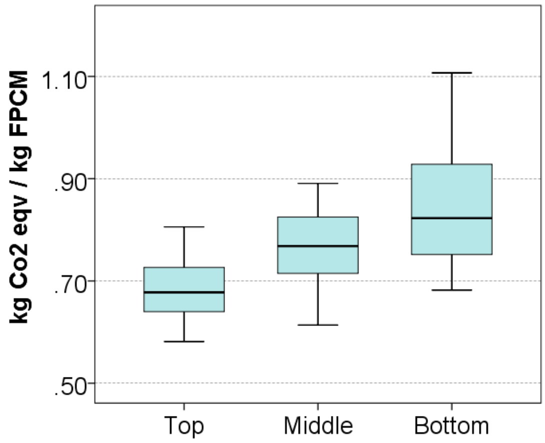


Emissions allocated to dairy output are also expressed per kg of fat and protein corrected milk (FPCM), which is standardized to 4% fat and 3.3% true protein per kg of milk. The average farm emitted 0.77 kg CO_2 equivalent per kg of FPCM produced.

Figure 12 also shows that farms with the best economic performance also have the lowest emissions intensity per kg of FPCM produced.

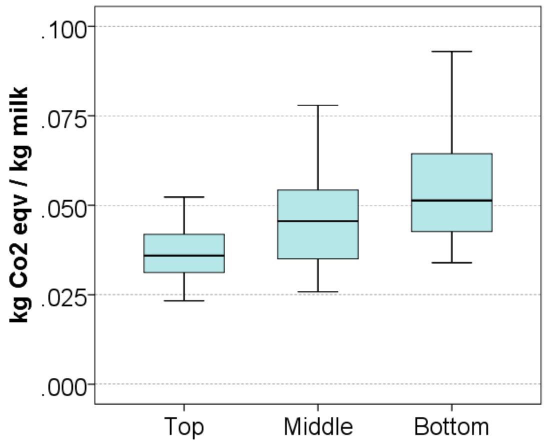
[2] Convert kg to litre by multiplying by 1.03

Figure 12: Agricultural GHG Emissions per kg of FPCM: Dairy Farms



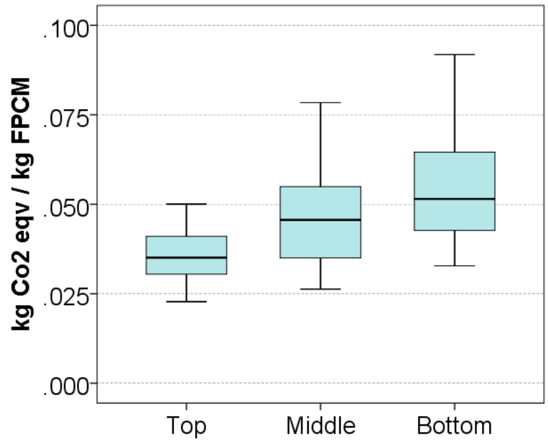
The average energy and fuel based GHG dairy farm emissions were 0.0498 kg CO_2 equivalent per kg of milk in 2018. Figure 13 indicates that as with agricultural GHG emissions intensity per kg of milk, lower energy usage related GHG emissions per kg of milk produced is evident among farms with better economic performance.

Figure 13: Energy use related GHG Emissions per kg of Milk: Dairy Farms



The average energy and fuel based GHG emissions were 0.0497 kg CO2 equivalent per kg of FPCM produced as shown in Figure 14. This indicator again shows that the top economic performers were more efficient in terms of FPCM produced per kg of energy related CO2 emissions.

Figure 14: Energy GHG Emissions per kg of FPCM: Dairy Farms



Using the LCA approach (including both agricultural and energy based emissions) the farm average carbon footprint of milk was 1.19 kg CO_2 equivalent per kg of FPCM. This level is consistent with results produced by Bord Bia using a similar approach with farm level data collected via the Bord Bia Origin Green programme (Murphy, 2020). Figure 15 again shows that lower emissions per kg of FPCM (on an LCA basis) was more prevalent among the group of higher economic performing farms.

Figure 15: Total LCA based GHG emissions (Agriculture & Energy) per kg of FPCM: Dairy Farms

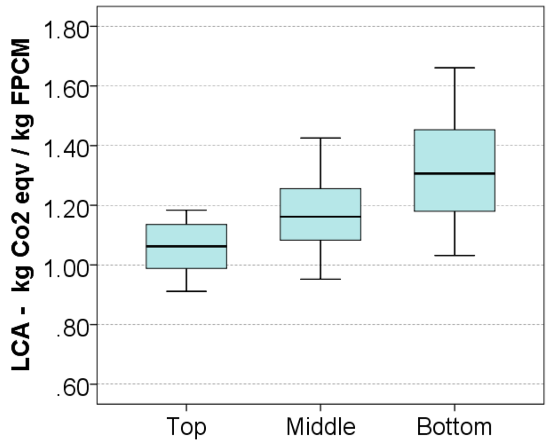
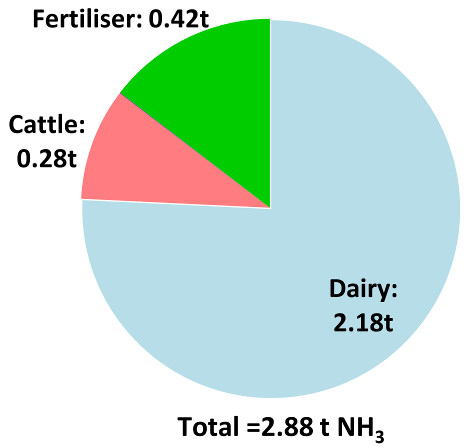


Figure 16 indicates that the average dairy farm produced approximately 2.88 tonnes of ammonia (NH_3) emissions in 2018, based on the EPA national inventory methodology. The majority of dairy emissions, 76%, were from milk based output, with 10% allocated to beef output (includes cull cows and calf sales /

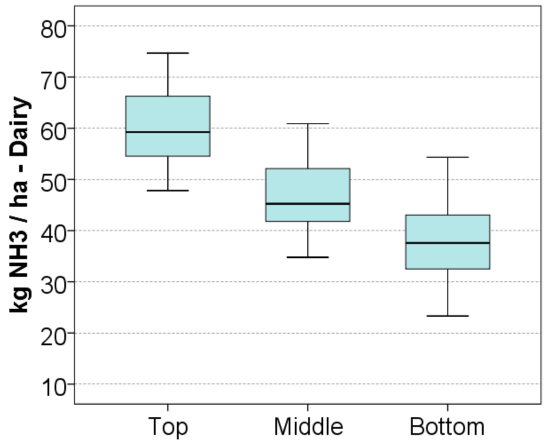
transfers mainly). The remaining emissions are those associated with chemical N fertiliser applications.

Figure 16: Total Ammonia Emissions for the average Dairy Farm



The average dairy farm emitted 48.8 kg of NH_3 per hectare across the entire farm. Economically better performing farms tend to operate at higher intensities and hence this is reflected by higher emission per hectare of ammonia as shown in Figure 19.

Figure 17: Ammonia Emissions kg per hectare: Dairy Farms



The average dairy farm emitted 0.0059 kg of NH_3 per kg of FPCM produced. Figure 18 again shows that the top economic performing dairy farms produced milk at a lower NH_3 emissions intensity compared to the middle and bottom cohorts. This result was replicated in the outcome on a kg of milk output basis as shown in Figure 19.

Figure 18: Ammonia Emissions per kg of FPCM: Dairy Farms

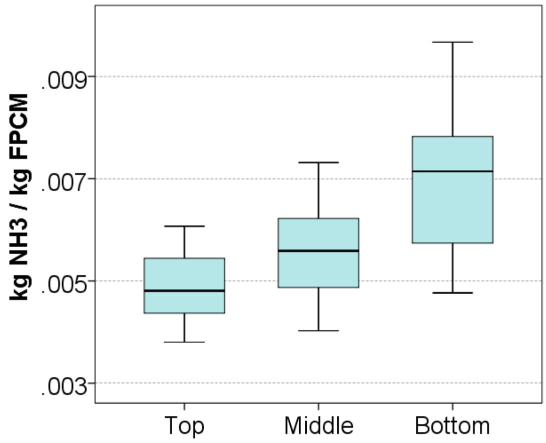
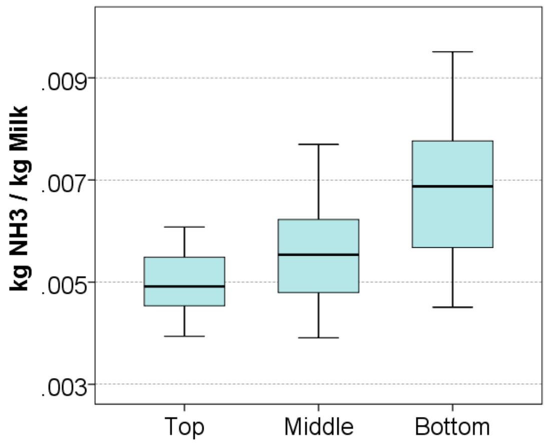
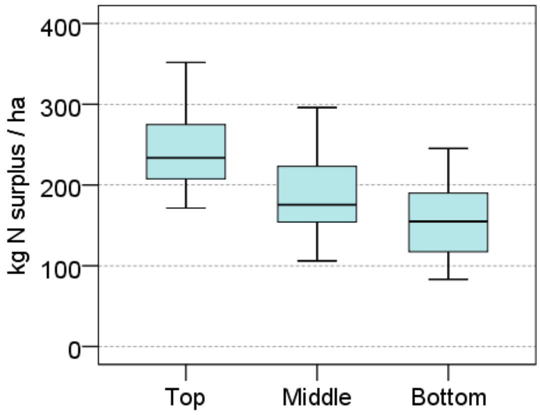


Figure 19: Ammonia Emissions per kg of Milk: Dairy Farms



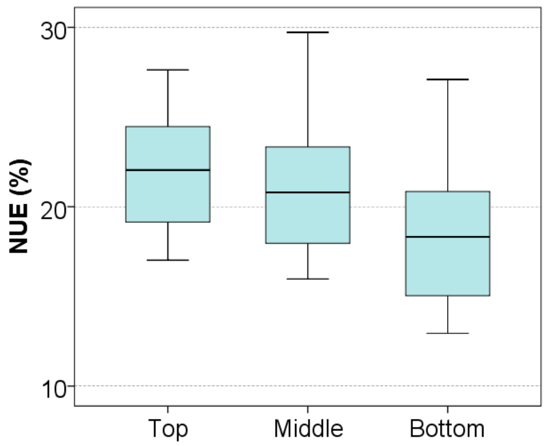
Nitrogen balance (excess of N inputs over outputs) averaged 200.7 kg N surplus per hectare across all dairy farms in 2018. Figure 20 indicates that higher N surpluses per hectare are related to higher economic performance; this is due to the greater production intensity on economically better performing farms.

Figure 20: N Balance per ha: Dairy Farms



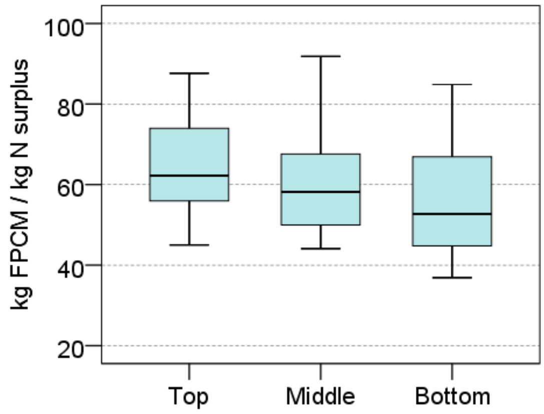
The average dairy farm had a NUE of 21.5%. Figure 21 demonstrates the slightly higher N use efficiency was evident among the higher economic performing farmers, with the largest range prevalent among the middle and bottom cohorts.

Figure 21: N Use Efficiency: Dairy Farms



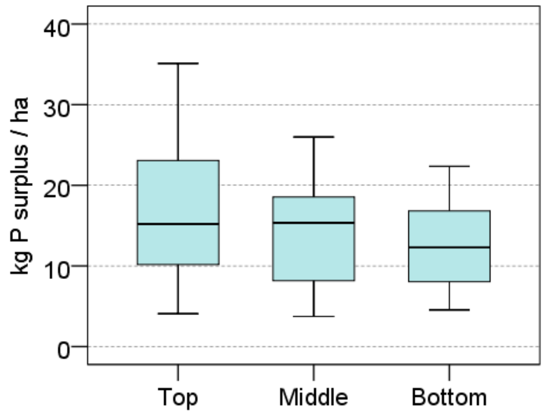
On average dairy farms produced 63.6 kg of FPCM per kg of surplus nitrogen. Figure 22 shows that higher NUE of milk production was linked with higher economic performance, with the top and middle cohorts producing more kg of FPCM per kg of surplus nitrogen.

Figure 22: NUE of Milk Production by product



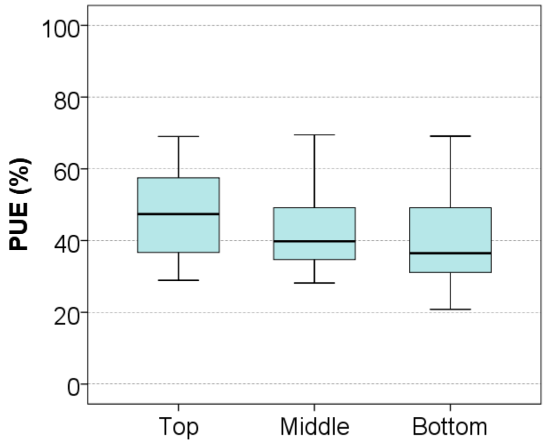
Phosphorus balance (excess of inputs over outputs) averaged 15.6 kg P surplus per hectare across all dairy farms. Figure 23 shows that there was a larger range of results, especially for the top performers.

Figure 23: P Balance per ha: Dairy Farms



The average dairy farm had a P use efficiency of 48.7%. Figure 24 indicates higher P use efficiency was again more prevalent among the higher economic performing farmers.

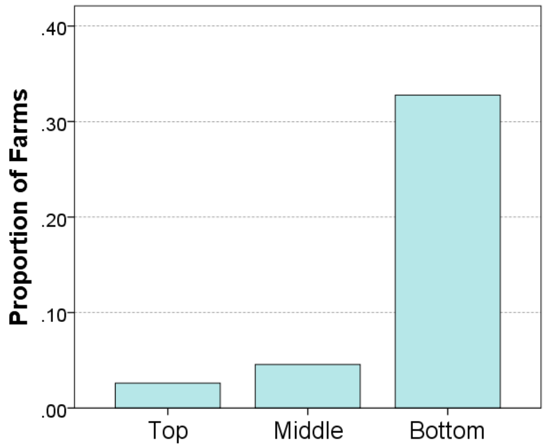
Figure 24: P Use Efficiency: Dairy Farms



Social Sustainability Indicators

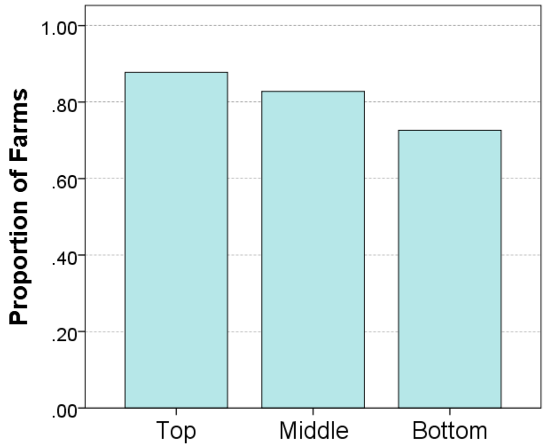
A minority of all dairy farm households, 13%, fell into the vulnerable category (non-viable and no off-farm employment). Figure 25 shows that there were considerable numbers of households at risk among those farms with the lowest gross margin (33% among bottom third).

Figure 25: Household Vulnerability: Dairy



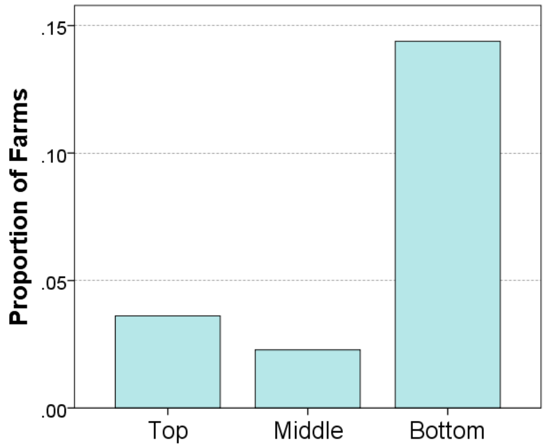
Overall, 81% of dairy farmers had received formal agricultural education of some description. Figure 26 shows that agricultural training rates were slightly higher across the middle and top performing cohorts.

Figure 26: Agricultural Education: Dairy



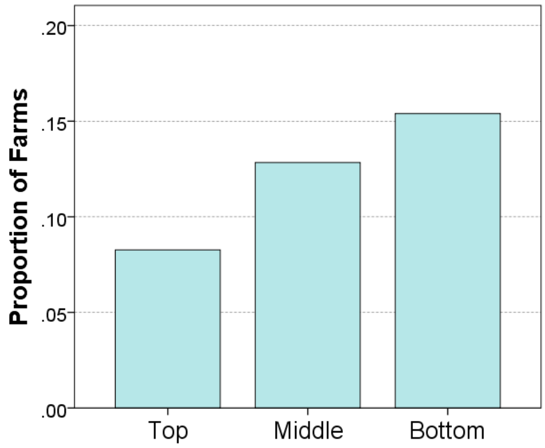
Only 7% of dairy farmers were living alone and were thus classified as being at risk of isolation. Figure 27 indicates that the risk was lowest for the middle preforming cohort.

Figure 27: Isolation Risk: Dairy Farms



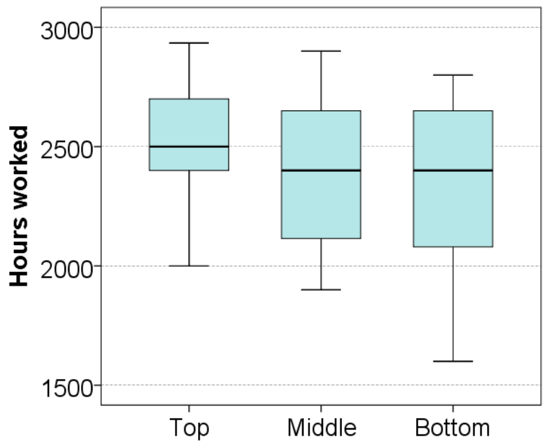
Across all dairy farms, 12% were identified as having a high age profile. Figure 28 shows that this was highest for the weaker economically performing dairy farms.

Figure 28: High Age Profile: Dairy Farms



On average, dairy farmers worked 2,397 hours per year on-farm (approximately 46 hours per week). Figure 29 shows that hours worked was highest for farms in the top 1/3, ranked by economic performance. However, this figure does not take into consideration off-farm employment, or the share of hours worked by hired staff or family members.

Figure 29: Hours Worked: Dairy Farm Operator

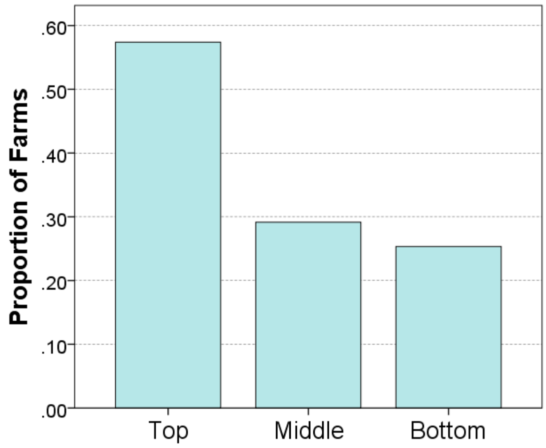


Dairy Innovation Indicators

The innovation indicators analysed for dairy farms were, the use of milk recording, membership of a dairy discussion group, whether at least 50% of slurry was spread in the period January-April, use of low emission slurry spreading equipment as well as liming & grass reseeding rates.

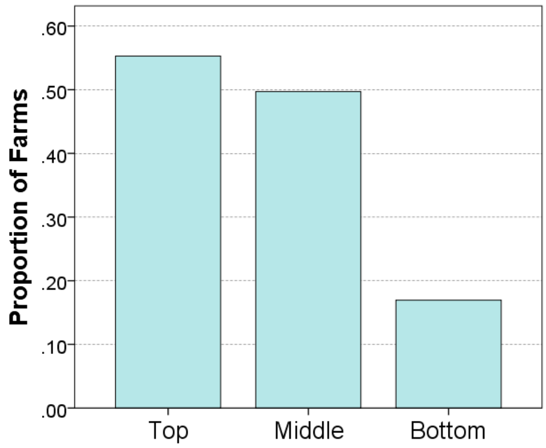
Figure 30 shows that those farms with better economic performance were more likely to use milk recording. Over 57% of the dairy farmers in the top group were milk recording, compared to 25% in the bottom group.

Figure 30: Milk Recording: Dairy Farms



Better economic performance was more prevalent among discussion group members. Membership rates were higher across the top group, at over 55%, compared to 17% in the bottom cohort, as shown in Figure 31.

Figure 31: Discussion Group: Dairy Farms



The application of the majority of slurry in early spring was slightly higher across the top and middle performing cohorts, as shown in Figure 32.

Figure 32: Spring Slurry: Dairy Farms

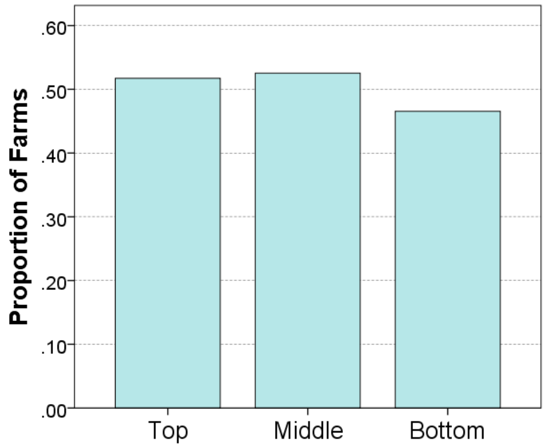


Figure 33 illustrates that greater use of low emissions slurry spreading equipment was associated with better economic performance. Nearly 10% of farmers in the top performing cohort used this technology, compared to 4% in the bottom performing cohort.

Figure 33: Low emissions slurry spreading: Dairy Farms

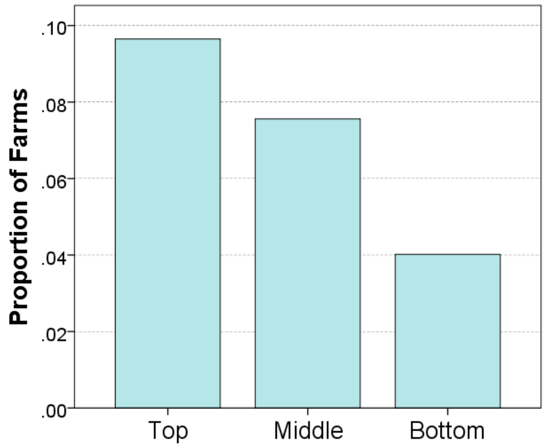


Figure 34 shows that liming was more prevalent among with higher economic performers, with 31-32% of the top and the middle performing group engaging with this activity in 2018, compared to 23% for the bottom group.

Figure 34: Liming: Dairy Farms

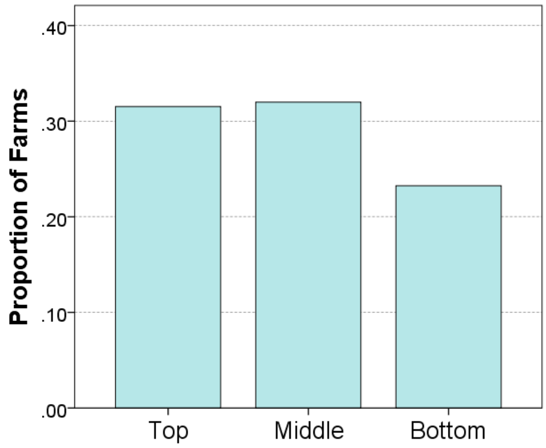
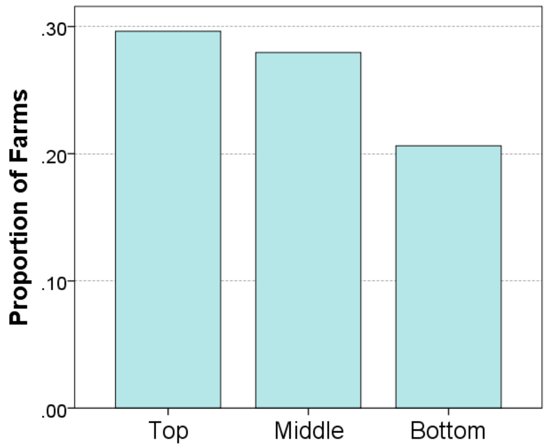


Figure 35 shows that reseeding was also more common across with higher economic performing farms. A higher percentage of farmers in the top group (30%) engaged in reseeding of grassland compared to the bottom group (20%) in 2018.

Figure 35: Reseeding: Dairy Farms



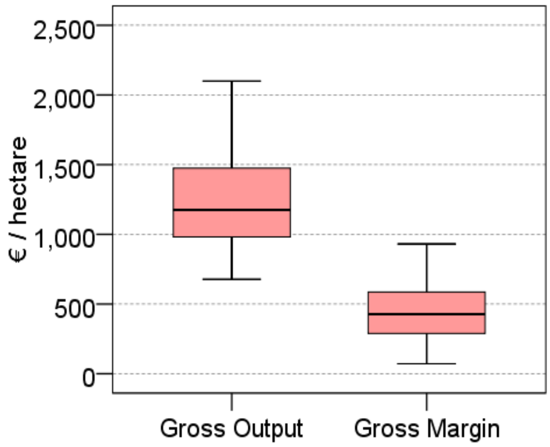
4.2 Cattle Farms

Cattle farms include both cattle rearing (mainly suckler based) and cattle finishing systems. Results for the economic, environmental and social sustainability indicators in 2018 are presented below.

Economic Sustainability Indicators

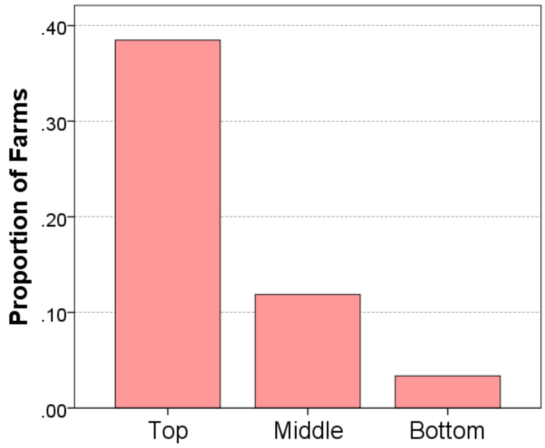
The average output per hectare for cattle farms was €1,312, and the average gross margin per hectare was €483. There was a large range in farm performance as shown in Figure 36.

Figure 36: Economic Return and Profitability of Land: Cattle Farms



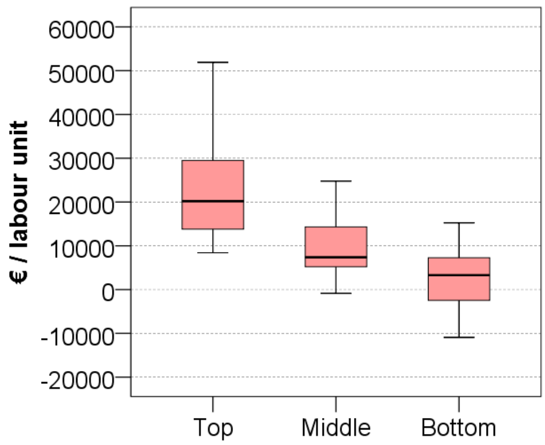
Only 18% of all cattle farms in the Teagasc NFS were defined as economically viable. As shown in Figure 37 the proportion was 38%, 12% and 3% respectively, for the top, middle and bottom cohorts of farms by economic performance.

Figure 37: Economic Viability: Cattle Farms



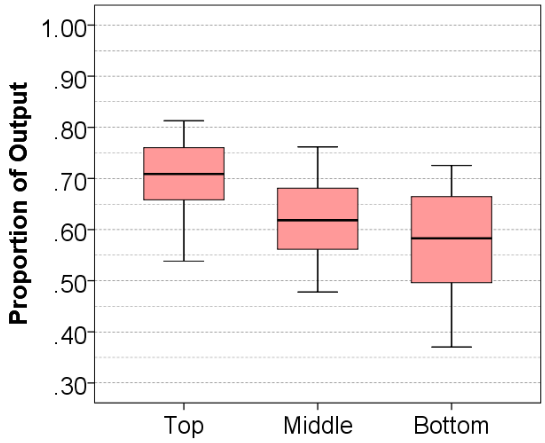
Across all cattle farms, the average income per labour unit was €13,344 in 2018. Figure 38 shows that this distribution was skewed by the top third of farms, which included a large number of higher earners, with a mean income per labour unit of €25,926, compared with €10,428 and €3,255 for the middle and bottom cohorts of cattle farms respectively. Median income per farm across the groups was €20,193, €7,365 and €3,300 respectively.

Figure 38: Productivity of Labour: Cattle



Market based output accounted for 62% of gross output across all cattle farms, with the remaining 38% accounted for by direct payment receipts. Figure 39 shows greater market orientation was more likely on farms with better economic performance.

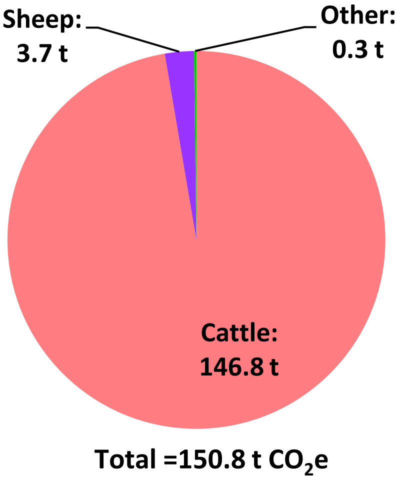
Figure 39: Market Orientation: Cattle Farms



Environmental Sustainability Indicators

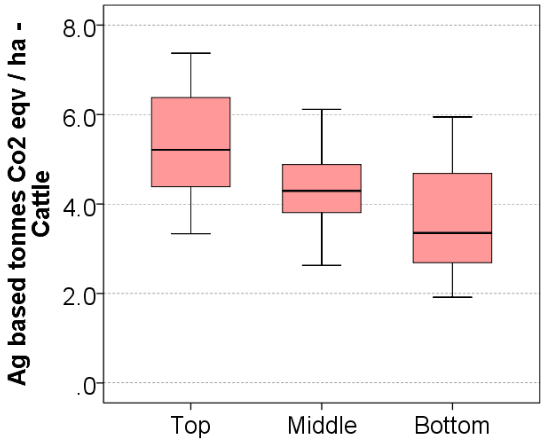
The average cattle farm produced 150.8 tonnes CO_2 equivalents of agricultural GHG emissions in 2018. Figure 40 shows that beef production was the principal source, generating 97% of these emissions. Sheep were responsible for approximately 2% of total emissions on Irish cattle farms, and a very small proportion (less than 0.32%) was derived from other enterprises on these farms.

Figure 40: Agricultural GHG Emissions for the average Cattle Farm



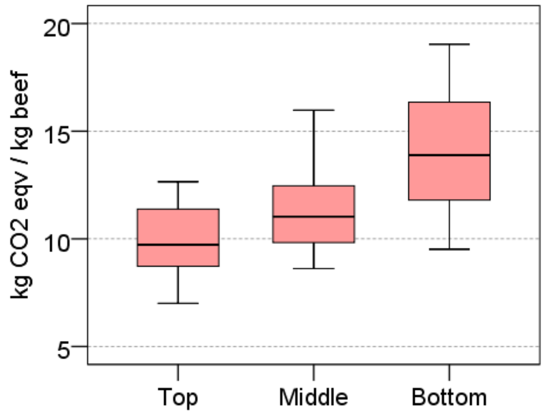
The average cattle farm emitted 4.5 tonnes of CO_2 equivalents of agricultural GHG emissions per hectare in 2018. Emissions per hectare were higher for the more profitable cattle farms, which also tended to be stocked at a higher intensity.

Figure 41: Agricultural GHG Emissions per hectare: Cattle Farms



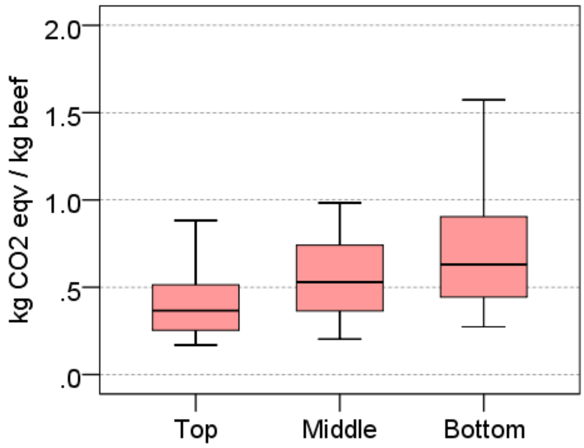
The emissions generated by cattle can be expressed in terms of their live-weight output (estimated using CSO price data). Figure 42 illustrates that there is a large range of emissions per kg of beef live-weight output. A positive association exists between emissions efficiency and economic performance. The top performing third of farms emitted, on average, 10.1 kg CO_2 equivalent per kg of live-weight beef, compared with 14.5 kg for the bottom performing third of cattle farms. The average level of GHG emissions across all farms was 12.1 kg CO_2 equivalent per kg beef of live-weight produced.

Figure 42: Agricultural GHG Emissions per kg live-weight beef produced: Cattle Farms



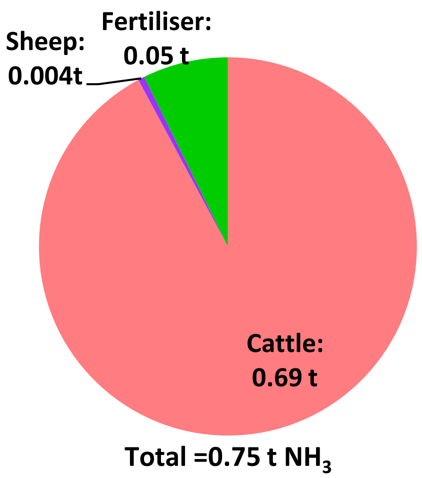
On average, electricity and fuel based GHG emission across all cattle farms was 0.60 kg of CO_2 equivalent per kg beef live-weight produced. Figure 43 illustrates that energy based GHG emissions per unit of product was also lower on farms with better economic performance. The top third produced an average of 0.45 kg CO_2 energy-based emissions per kg of live-weight beef produced, while for the bottom performing third this figure was 0.77 kg.

Figure 43: Energy use related GHG Emissions per kg live-weight beef: Cattle Farms



The average cattle farm emitted 0.75 tonnes of ammonia (NH_3). In all 92% of total NH_3 emissions were linked with beef production, 7% were associated with chemical N fertiliser use and the remaining proportion by the sheep enterprise on cattle farms, as shown by Figure 44.

Figure 44: Total Ammonia Emissions for the average Cattle Farm



On average, cattle farm emitted 22.9 kg of NH_3 per hectare in 2018. This ranged from 28.3 kg per hectare for top performing cohort, to 18.2 per hectare for the bottom third, as shown by Figure 45. Emissions per hectare were higher for the more profitable cattle farms, which also tend to be stocked at a higher intensity.

Figure 45: Ammonia Emissions per hectare: Cattle Farms

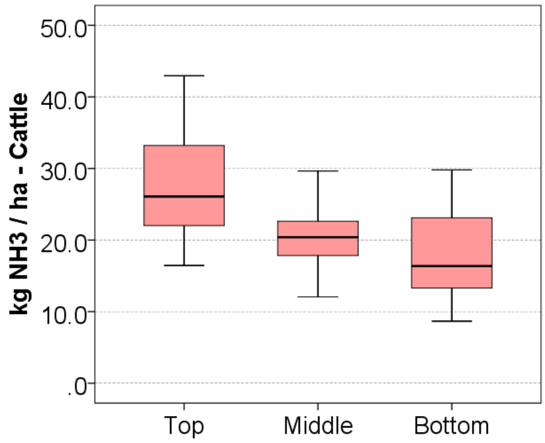


Figure 46 illustrates that, in terms of live-weight of beef produced, the more profitable cattle farmers have a lower level of ammonia intensity. There was a large range of results, especially for the bottom performing cohort of cattle farmers. On average, a kg of live-weight beef was produced at an intensity of 0.0602 kg of NH_3.

Figure 46: Ammonia Emissions per kg live-weight beef produced: Cattle Farms

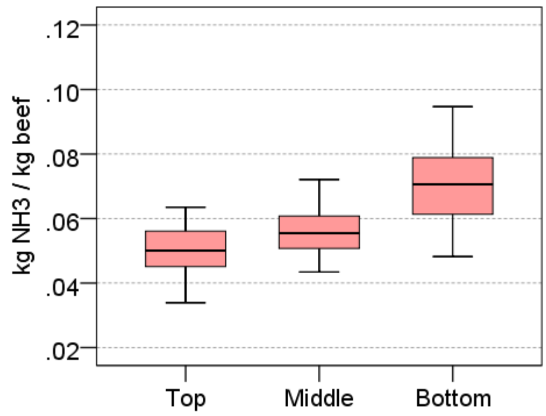
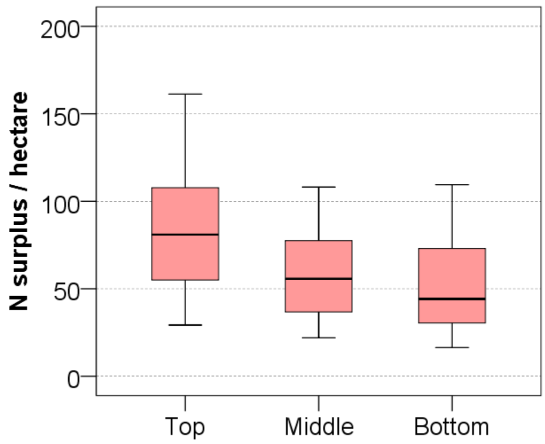


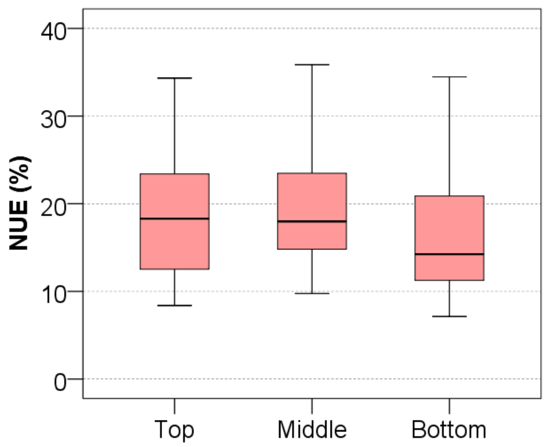
Figure 47 indicates that the nitrogen surplus per hectare tended to be higher on cattle farms that also performed better economically. In general, these farms are operated more intensively. The top performing third of cattle farms had an average nitrogen surplus of 93.1 kg N per hectare, compared to 56.2 kg N per hectare for the bottom third of farms.

Figure 47: N Balance per ha: Cattle Farms



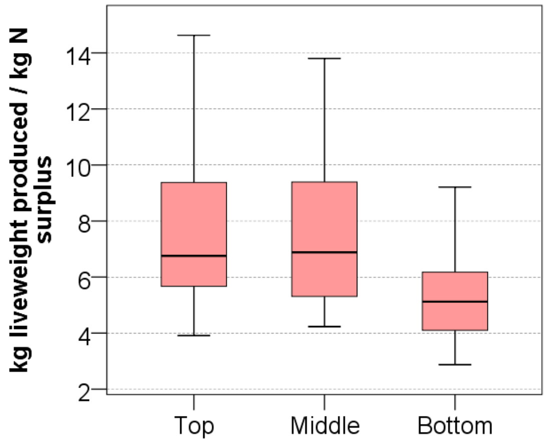
The average NUE across all cattle farms was 20.8%, but the range in NUE across the sample of cattle farms was significant, as shown in Figure 48. Despite the higher application rates, NUE tended to be higher on the farms with better economic performance.

Figure 48: N Use Efficiency: Cattle Farms



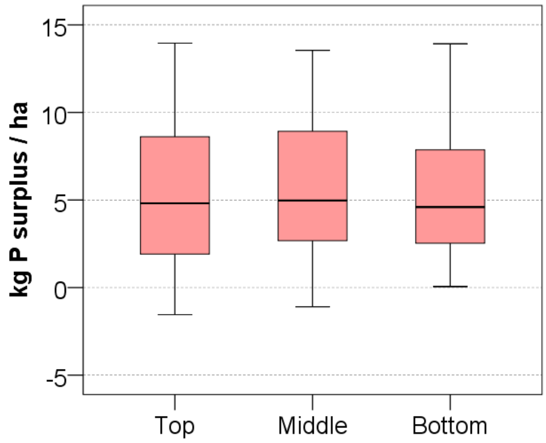
On average, cattle farms produced 8.7 kg of live-weight output per kg of N surplus. Higher NUE of beef production was prevalent on the top economic performing farms, with these top performers producing more beef live-weight per kg of surplus nitrogen, as illustrated in Figure 49.

Figure 49: NUE of beef production by product



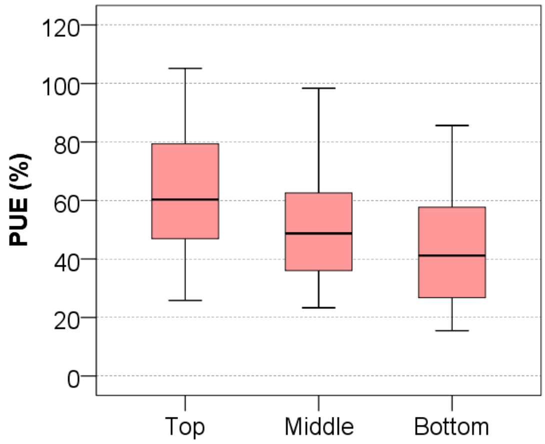
At the farm gate boundary, the P surplus across all cattle farms averaged 6.0 kg per hectare. The P surplus ranges differs little across the cohorts, as shown in Figure 50.

Figure 50: P Balance per ha: Cattle Farms



At the farm gate boundary, the average farm PUE across all cattle farms was 63.2%. Figure 51 shows that higher PUE was again more prevalent on farms that performed best in economic terms. PUE ranged from 68% for the top third to 50% for the bottom third of cattle farmers.

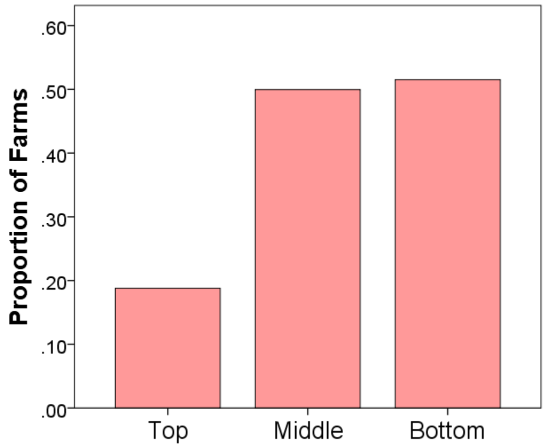
Figure 51: P Use Efficiency: Cattle Farms



Social Sustainability Indicators

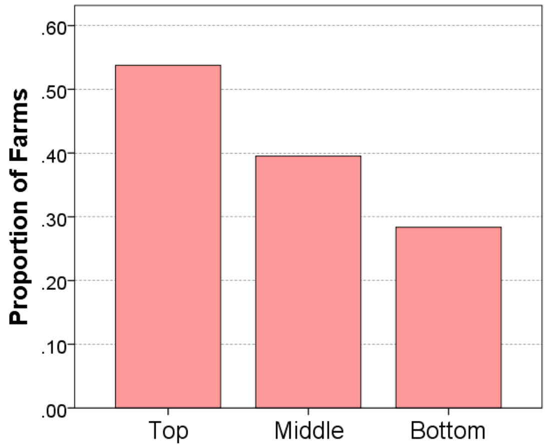
Overall, 40% of all cattle farms were considered vulnerable (non-viable farm business with no off-farm employment). Figure 52 confirms that this vulnerability was associated with weaker economic performance, with 50% and 52% of the middle and bottom third of farms deemed vulnerable, compared to 19% of the top third.

Figure 52: Household Vulnerability: Cattle



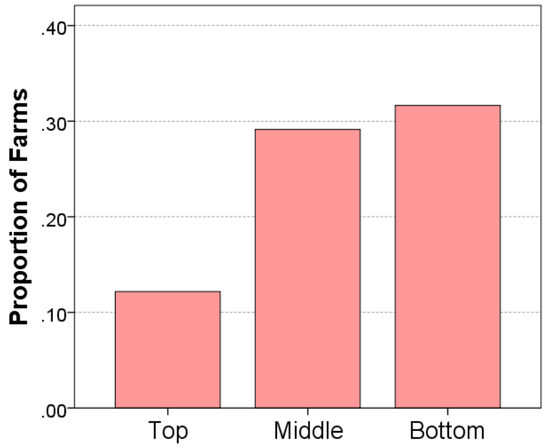
A total of 41% of cattle farmers had some form of agricultural education. Figure 53 indicates that educational attainment was positively associated with the better economic performing farms.

Figure 53: Agricultural Education: Cattle Farms



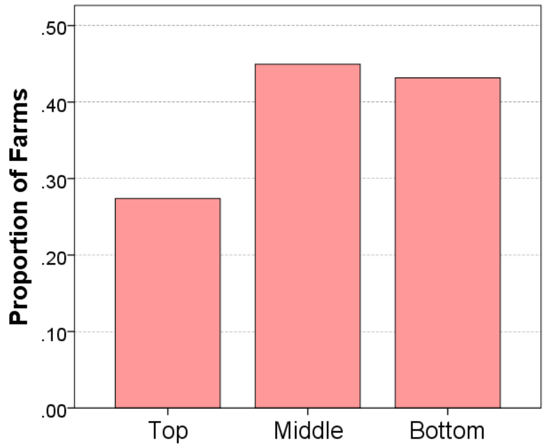
Overall, 24% of cattle farm operators were classified as being at risk of isolation; i.e. where the farmer lives alone. This was especially prevalent among farms with lower profitability, where 32% of farmers in the bottom third live alone, as shown in Figure 54.

Figure 54: Isolation Risk: Cattle Farms



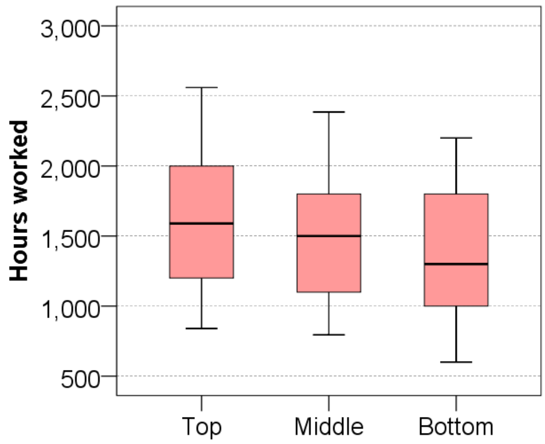
Additionally, 38% of cattle farms were classified as having a high age profile. As with other indicators of social sustainability, this was more prevalent among the weaker economic performing farms, as shown in Figure 55.

Figure 55: High Age Profile: Cattle Farms



The average cattle farm operator worked on farm for 1,513 hours over the year (an average of 29 hours per week). It should be noted that 41% of cattle farmers also work off-farm, so farm work hours are not necessarily indicative of overall work-life balance.

Figure 56: Hours Worked: Cattle Farms

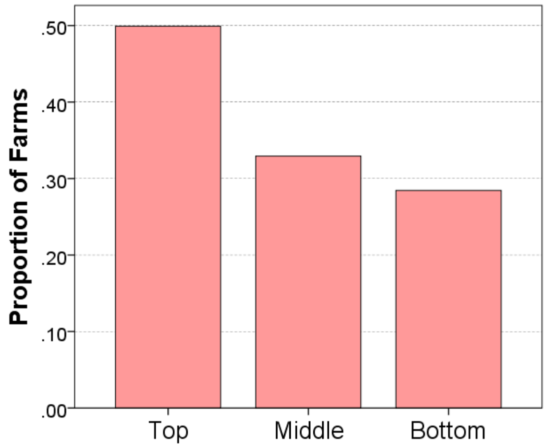


Cattle Farm Innovation Indicators

Five innovation indicators were examined for cattle farms: whether at least 50% of slurry was spread in the period January-April, whether low emission slurry spreading equipment was used, whether a farmer was applying lime, whether a farmer reseeded grassland and whether the farmers was a member of a discussion group.

Figure 57 shows that those in the top and middle groups by economic performance had higher spring-time slurry application rates compared to the middle and bottom cohorts.

Figure 57: Spring Slurry: Cattle Farms



The level of overall use of low emission slurry spreading equipment on cattle farm is low, as shown by Figure 58. However, the top economic performing cattle farms tended to make greater use of this technology.

Figure 58: Low emission slurry spreading: Cattle Farms

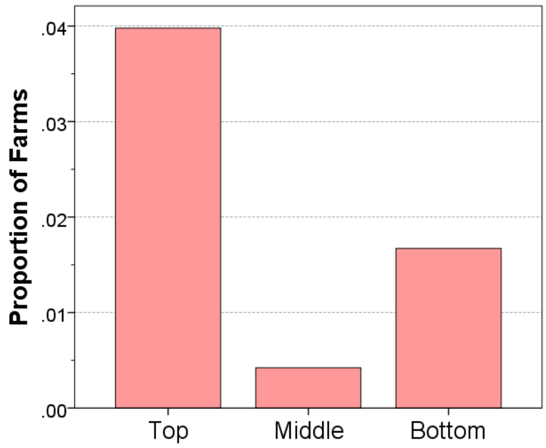


Figure 59 shows that liming rates were higher on the top performing cattle farm, at 21%, compared to 15% and 7% for the middle and bottom cohorts respectively.

Figure 59: Liming: Cattle Farms

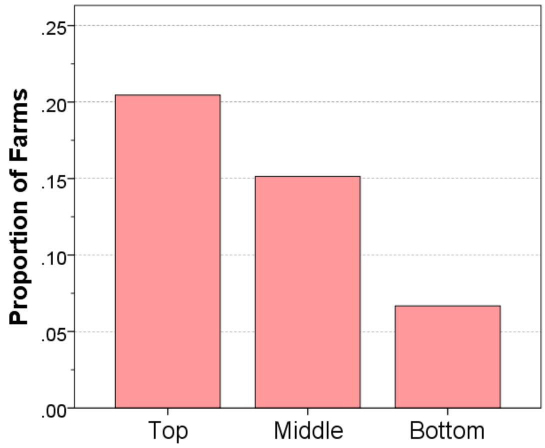
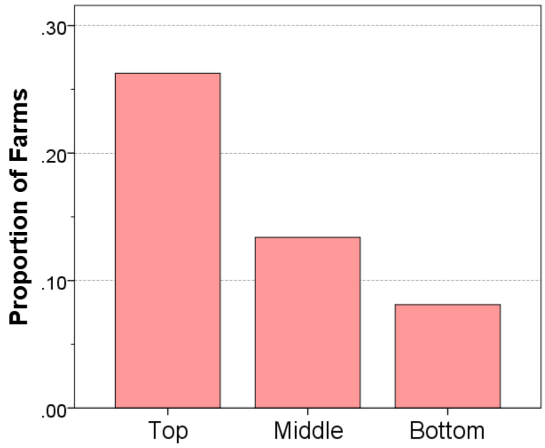


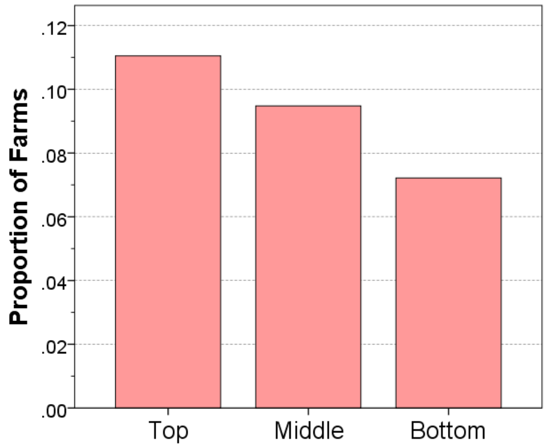
Figure 60 shows that at 26%, discussion group membership was more common among the higher economic performing farms, compared to just 8% in the bottom cohort.

Figure 60: Discussion Group: Cattle Farms



Higher levels of reseeding were reported among higher economic performing farms, as shown in Figure 61.

Figure 61: Reseeding: Cattle Farms

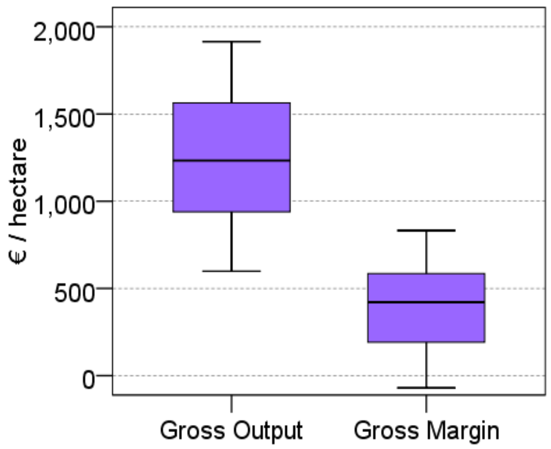


4.3 Sheep Farms

Economic Sustainability Indicators

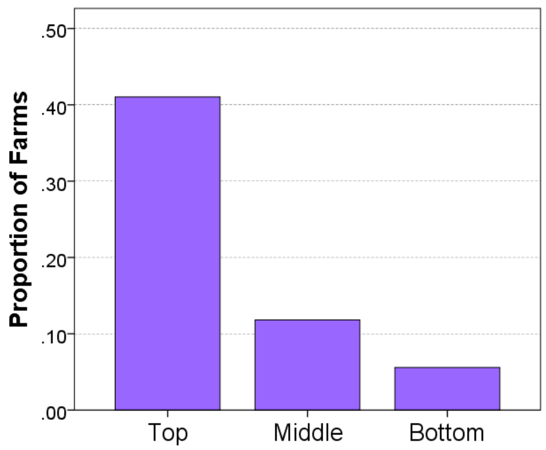
The average gross output per hectare for sheep farms was €1,322 in 2018, and the average gross margin was €400 per hectare.

Figure 62: Economic Return and Profitability of Land: Sheep Farms



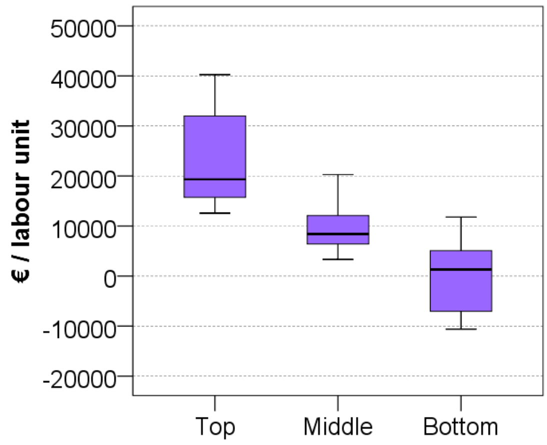
Across all sheep farms, 20% were defined as economically viable. Figure 63 shows that ranked by economic performance, the proportion of viable sheep farms ranged from 41% for the top third to 6% for the bottom third of farms.

Figure 63: Economic Viability: Sheep Farms



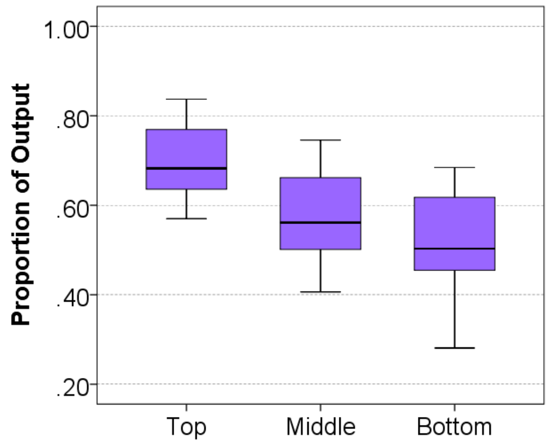
The average income per labour unit on sheep farms was €12,316. In common with cattle farms, there was a large range in economic performance, with the top third of sheep farms earning a mean income per labour unit of €24,634, compared with only €1,585 for the bottom third, which also had a large number of farms making net losses (see Figure 64).

Figure 64: Productivity of Labour: Sheep Farms



For the average sheep farm, approximately 59% of output was generated from the market, and 41% from direct payments. Figure 65 indicates that market orientation was positively associated with economic performance, with the top third of farms, based on economic performance, producing 71% of output from the market, compared with just 52% on average for bottom third.

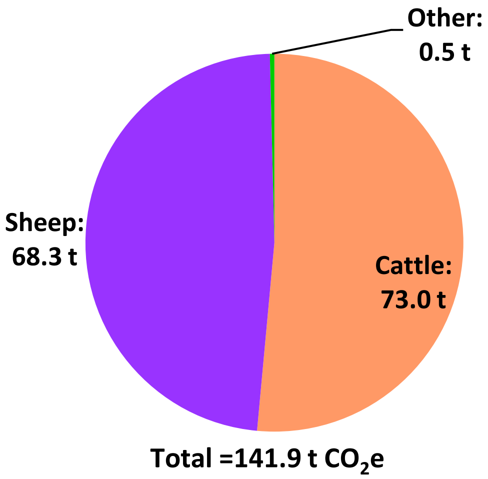
Figure 65: Market Orientation: Sheep Farms



Environmental Sustainability Indicators

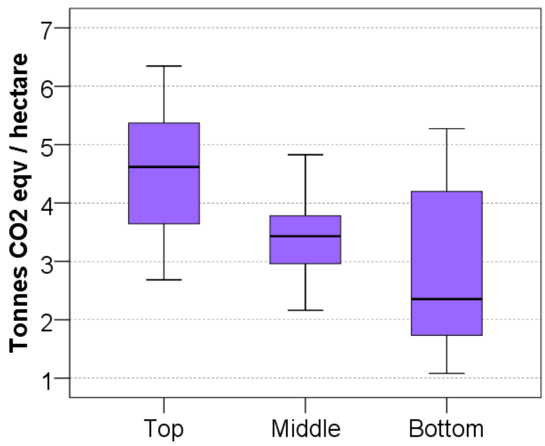
In 2018, the average sheep farm produced approximately 141.9 tonnes CO_2 equivalents of agricultural GHG emissions. Figure 66 indicates that just under half (48%) of these emissions were generated by the sheep enterprise, with over half (51.5%) generated by cattle enterprises present on specialist sheep farms, with the remaining 0.4% coming from other sources, mainly crop fertilisation.

Figure 66: Agricultural GHG Emissions for the average Sheep Farms



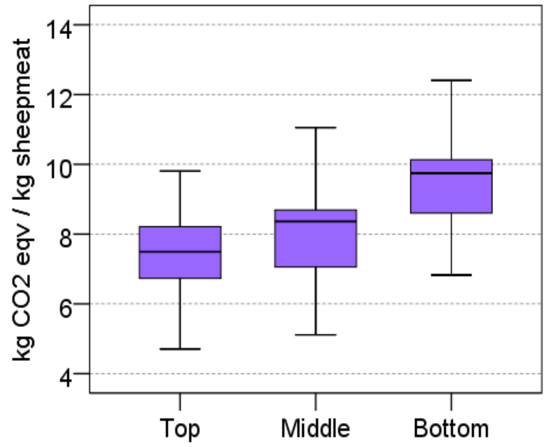
On average sheep farms emitted 3.7 tonnes of CO_2 equivalent per hectare. Higher emission per hectare were associated with the more profitable sheep farms, as shown in Figure 67, however there was a large range of results.

Figure 67: Agricultural GHG Emissions per hectare: Sheep Farms



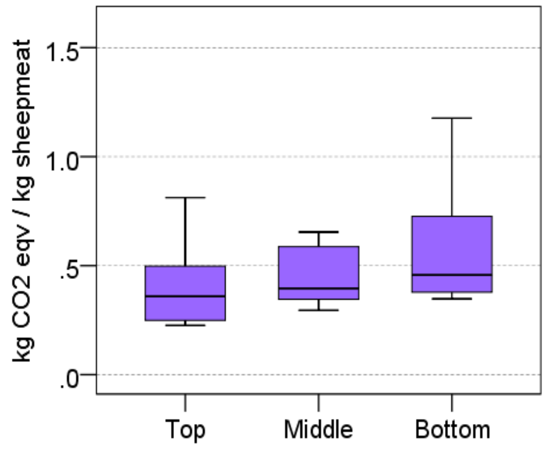
The GHG emissions generated by sheep are shown per kg of live-weight output produced (estimated using CSO price data (Hinchion, 2019). Figure 68 shows that the emissions intensity per kg of live-weight produced were negatively associated with economic performance. The top third of farms generated 7.4 kg CO_2 equivalent per kg live weight, compared to 9.2 and 11.7 kg CO_2 equivalent for the middle and bottom cohorts respectively.

Figure 68: Agricultural GHG Emissions per kg live-weight produced: Sheep Farms



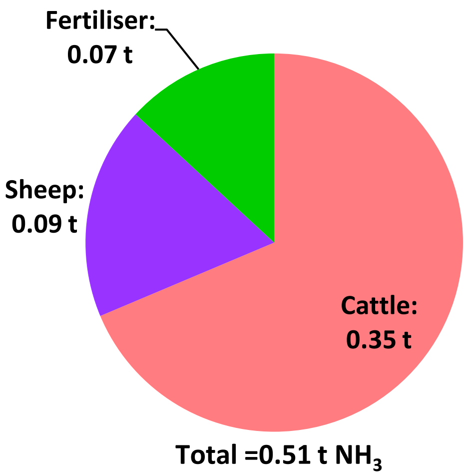
Better economic performance was also linked with lower electricity and fuel based GHG emissions per unit of output, as shown by Figure 69. The bottom third of farms in economic terms emitted 0.92 kg CO_2 equivalent per kg live-weight sheep meat produced from energy based emissions, compared to 0.40 kg CO_2 for the top third of sheep farms.

Figure 69: Energy use related GHG Emissions per kg live-weight produced: Sheep Farms



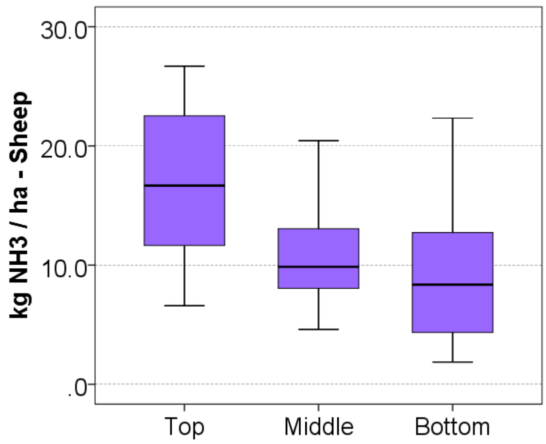
On average, a specialist sheep farm emitted 0.51 tonnes of NH_3 in 2018. Even though the main output on these farms is sheep based, the majority of the NH_3 emissions related to cattle production (67%), with only 18% relating to sheep production. The remaining portion related to chemical fertilisers applied.

Figure 70: Total Ammonia Emissions for the average Sheep Farm



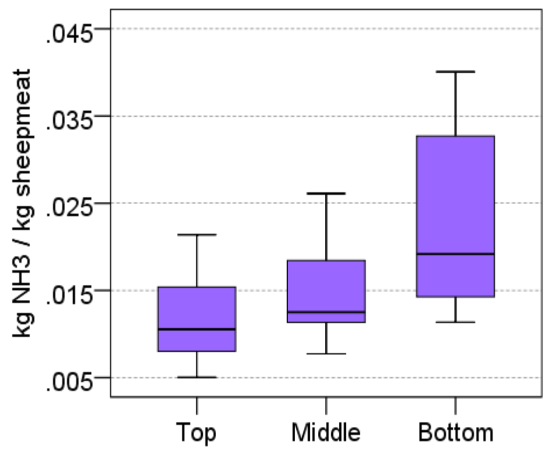
On average a specialist sheep farm emitted 12.8 kg of ammonia per hectare in 2018. Higher per hectare emissions were associated with economically better performing farms as shown in Figure 71, these farms tend to operate at a higher stocking intensity.

Figure 71: Ammonia Emissions per hectare: Sheep Farms



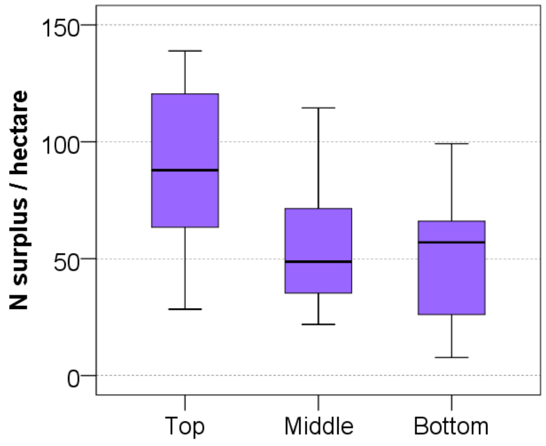
Lower ammonia emissions intensity of production was again more common among the better economically performing sheep farms. Farms in the top performing cohort economically produced a kg of live-weight sheep meat with a lower NH_3 emission intensity, as shown in Figure 72. On average sheep farmers produced 0.019 kg of NH_3 emissions per kg of live-weight sheep meat.

Figure 72: Ammonia Emissions per kg live-weight produced: Sheep Farms



As with cattle farms, the sheep farm nitrogen surplus per hectare was positively associated with economic performance, due to greater production intensity on the more profitable sheep farms, as shown in Figure 73. The top third of farms, ranked by gross margin per hectare, had an average nitrogen surplus of 86.8 kg per hectare, compared with 70.9 and 53.4 kg per hectare for the middle and bottom cohorts respectively.

Figure 73: N Balance per ha: Sheep Farms



The average NUE across all sheep farms was 24.7%. Higher NUE was again associated with better economic performance as shown in (Figure 74).

Figure 74: N Use Efficiency: Sheep Farms

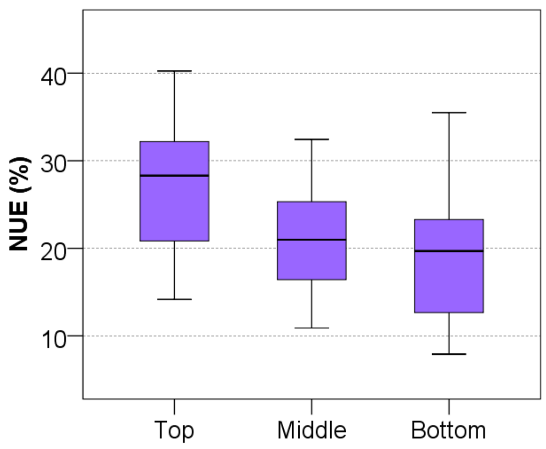
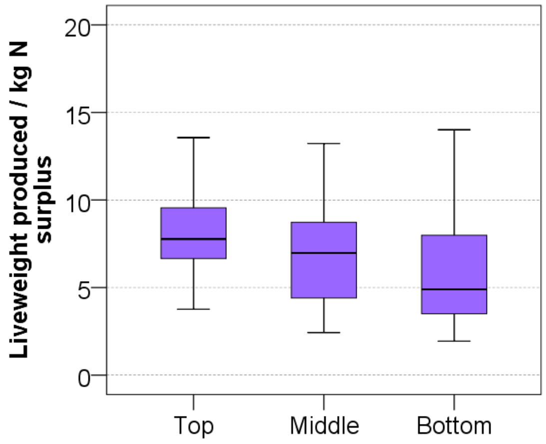


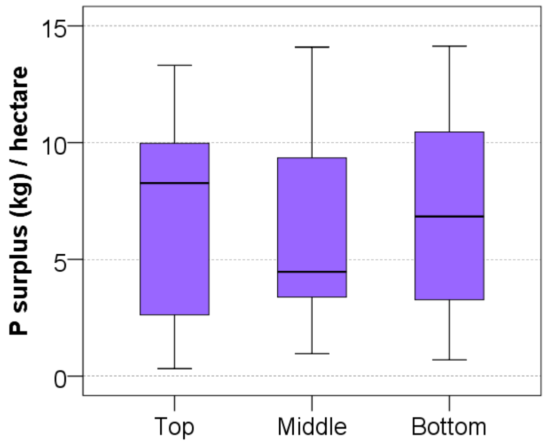
Figure 75 shows that the N surplus per kg of live-weight sheep meat produced tends to be positively associated with economic performance, with the top third producing more live-weight output per kg of N surplus generated. The average across all sheep farms was 7.7 kg.

Figure 75: NUE by product of Sheep Farms



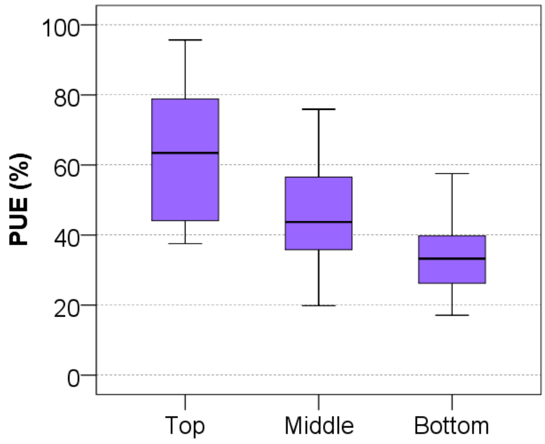
P balances across all specialist sheep farms were 4-8 kg per ha on average. There was a large range of results the 3 cohorts as seen by Figure 76.

Figure 76: P Balance per ha: Sheep Farms



Farm gate level PUE averaged 50.9% across all sheep farms. Figure 77 shows that higher PUE was associated with farms with better economic performance.

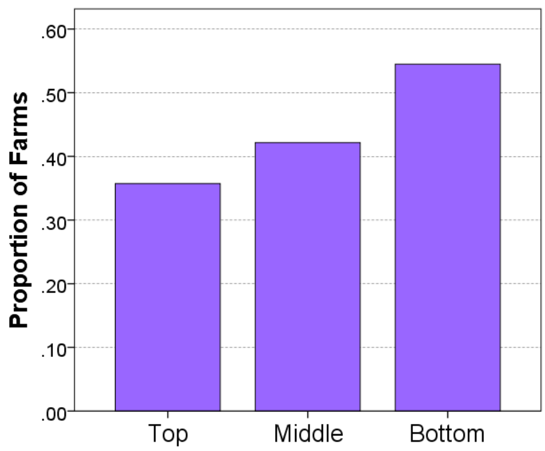
Figure 77: P use efficiency: Sheep Farms



Social Sustainability Indicators

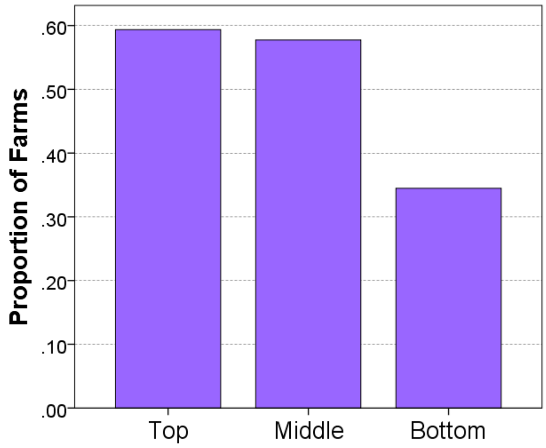
Forty-four per cent of all sheep farms were considered vulnerable in 2018. Figure 78 shows that this ranged from 36% for the top performing sheep farms to 55% for the bottom third.

Figure 78: Household Vulnerability: Sheep Farms



Overall, 49% of sheep farmers had received formal agricultural education. Figure 79 shows that agricultural training was associated with better economic performance.

Figure 79: Agricultural Education: Sheep Farms



On average, 13% of all specialist sheep farms were classified as being at risk of isolation. Figure 80 shows that this was significantly higher among the top performing cohort of sheep farms at 20%.

Figure 80: Isolation Risk: Sheep Farms

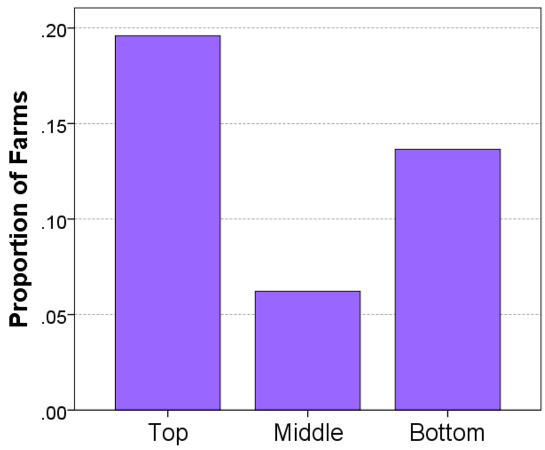
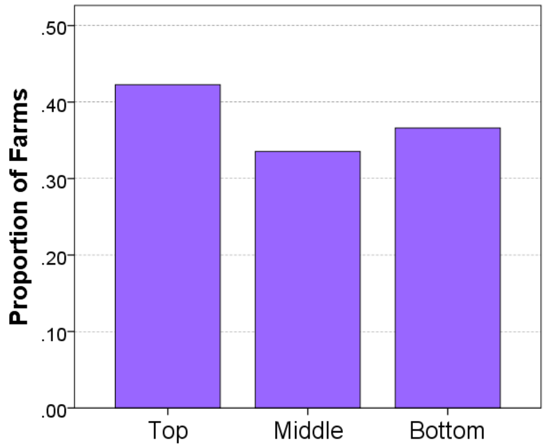


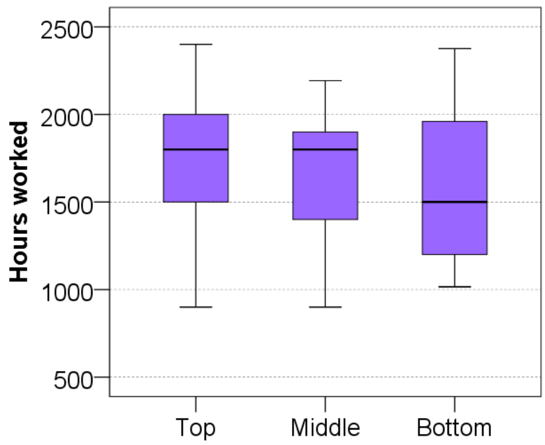
Figure 81 shows that the proportion of all specialist sheep farms with a high age profile averaged 38%, but was broadly similar across all three groups.

Figure 81: High Age Profile: Sheep Farms



Sheep farmers worked an average of 1,581 hours per year (or 30.4 hours a week). In common with cattle farms, it should be noted that this does not capture their true work/life balance, as 34% of sheep farmers are also engaged in off-farm work (Figure 82).

Figure 82: Hours Worked: Sheep Farms



Sheep Farm Innovation Indicators

The four innovation indicators selected for sheep farms were whether at least 50% of slurry was spread in the period January-April, whether a farmer was applying lime, whether a farmer was reseeding and whether or not the farm operator was a member of a discussion group.

Greater levels of springtime application of slurry were common across the top performing cohort at 32% compared 22% and 13% for the middle and bottom groups. However, it should be noted that sheep farms tend to be more associated with farm yard manure type storage systems, which might not lend themselves to early season application.

Figure 83: Spring Slurry: Sheep Farms

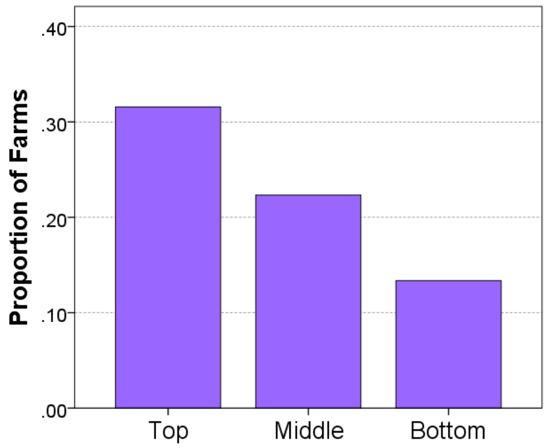


Figure 84 shows that liming activity was again more prevalent across the better economic performing farms, with 30% of the top performing cohort by economic performance engaged in liming, compared to 8% of the bottom group.

Figure 84: Liming: Sheep Farms

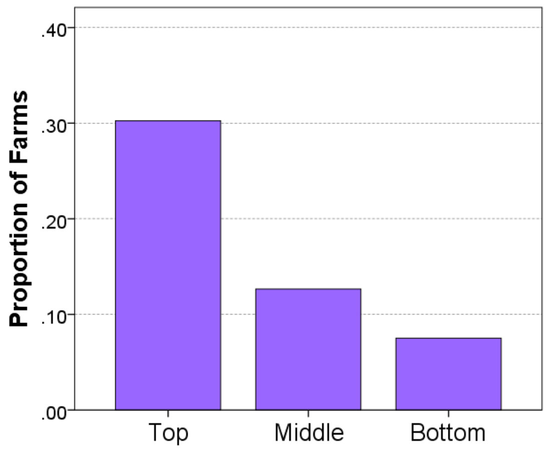


Figure 85 shows that higher levels of reseeding were associated with the sheep farms that performed better in economic terms.

Figure 85: Reseeding: Sheep Farms

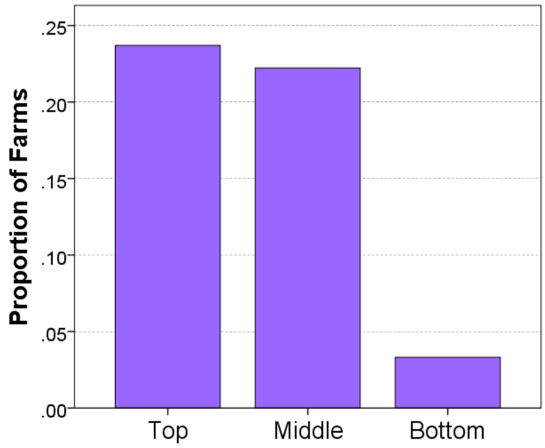
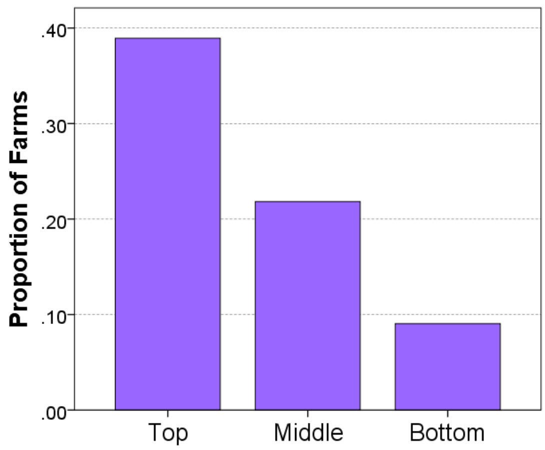


Figure 86 shows that membership of a discussion group was higher among the top third of farmers at 39%, compared to approximately 22% for the middle group and 9% for the bottom group.

Figure 86: Discussion Group: Sheep Farms

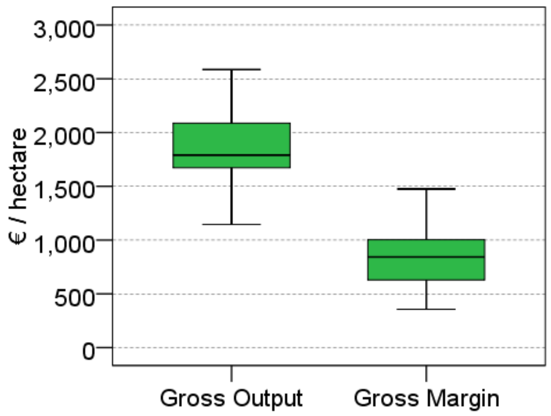


4.4 Tillage Farms

Economic Sustainability Indicators

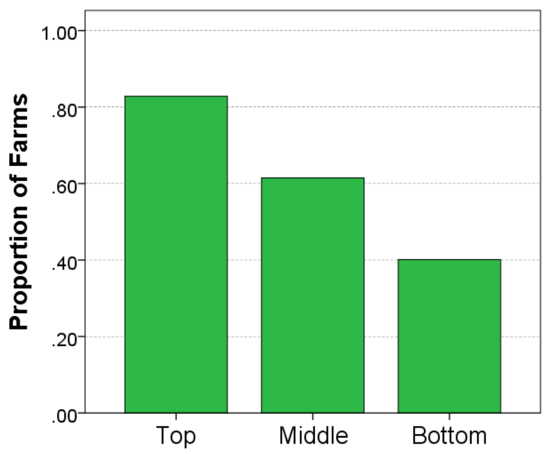
The average gross output per hectare for tillage farms was €1,852 and the average gross margin per hectare was €904 in 2018 .

Figure 87: Economic Return and Profitability of Land: Tillage Farms



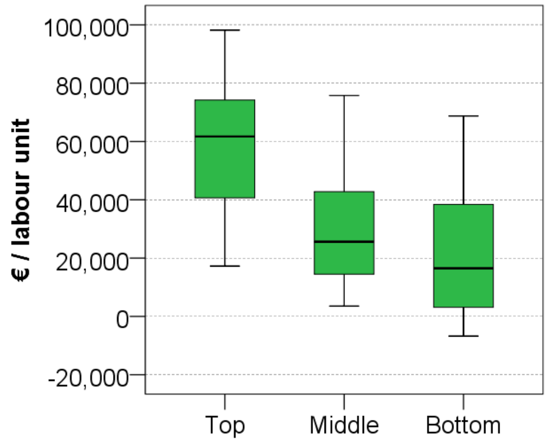
Overall, 62% of tillage farms were classified as economically viable. Figure 88 shows that the middle and bottom groups had lower levels of viability, at 62% and 40% respectively, compared to 83% for the top group.

Figure 88: Economic Viability: Tillage Farms



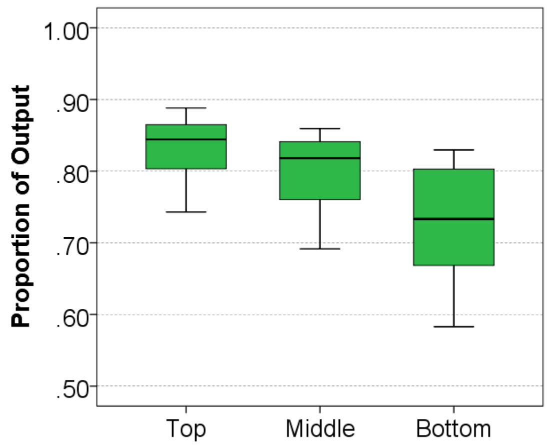
The average tillage income per labour unit (for unpaid family labour) was €43,620. Figure 89 shows that there is a large range in incomes on tillage farms, with the top one-third (ranked by gross margin per hectare) earning an average of €59,715 per labour unit, and the middle and bottom thirds earning €42,195 and €28,094 per labour unit respectively. For some of the most profitable tillage farms, income per labour unit is especially high, due to the large proportion of the labour utilised on tillage farms being supplied by hired labour (via the use of external contractors).

Figure 89: Productivity of Labour: Tillage Farms



Tillage farms received 78% of their output value from the market on average. Figure 90 shows that the top third of tillage farms derived 83% of farm output from the market, and the bottom third 73% on average.

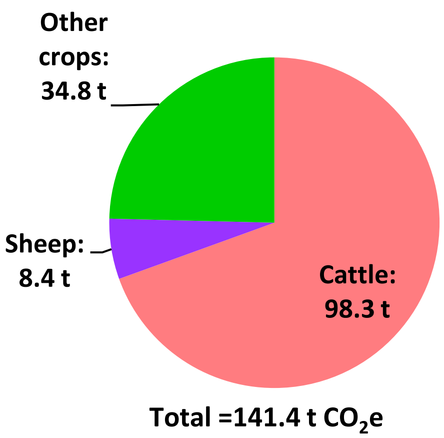
Figure 90: Market Orientation: Tillage Farms



Environmental Sustainability Indicators

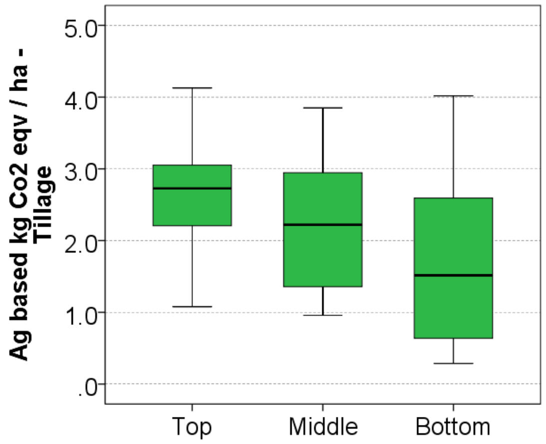
The average tillage farm produced 141.4 tonnes CO_2 equivalents of agricultural GHG emissions in 2018. This is illustrated in Figure 91, which shows that approximately 24.6% of GHG emissions were from crop production. Despite being specialised in crop production, 70% of tillage farm emissions were from cattle present on these farms, with a further 6% from sheep.

Figure 91: Agricultural GHG Emissions for the average Tillage Farm



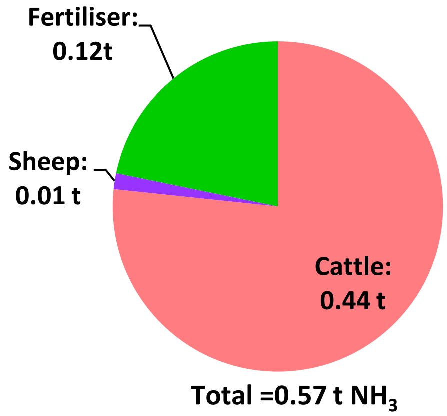
The average specialist tillage farm produced 2.3 tonnes CO_2 equivalents per hectare of agricultural GHG emissions in 2018. Higher emissions per hectare were again associated with higher economic performance.

Figure 92: Agricultural GHG Emissions per hectare: Tillage Farms



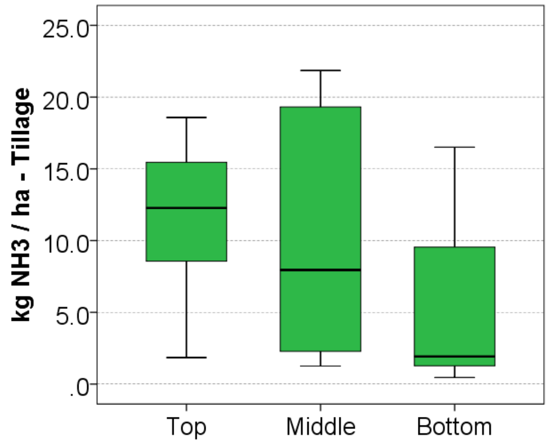
Tillage farms on average emitted 0.57 tonnes of NH_3 in 2018. Again, even though the main farm output is crop related, the bulk of emissions are associated with cattle rearing, at 77%. The remaining 22% of emissions was mostly associated with chemical fertiliser application.

Figure 93: Total Ammonia Emissions for the average Tillage Farm



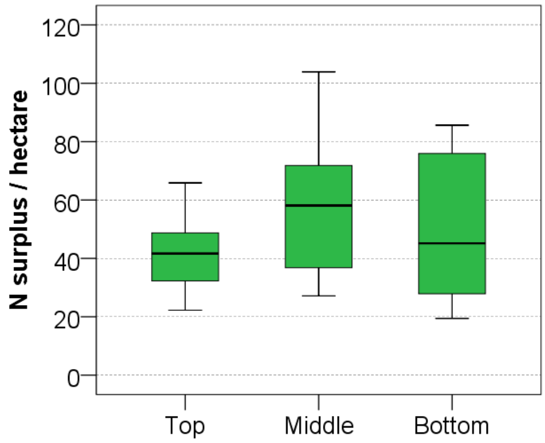
The average specialist tillage farm emitted 8.8 kg of NH_3 per hectare in 2018. Again, higher emissions per hectare were associated with higher economic performance. Economic performance tends to be positively associated with farm production intensity levels.

Figure 94: Total Ammonia Emissions per hectare: Tillage Farms



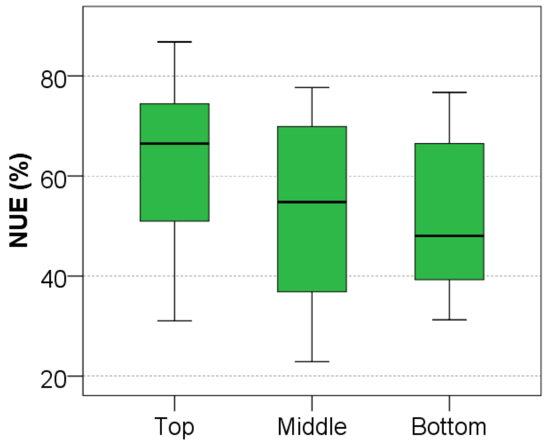
The average N surplus was 62.0 kg per hectare, but there was a large range in the farm results. Figure 95 shows higher N surpluses were aligned with higher economic performance. It should be noted that not all tillage farms from the Teagasc NFS are included here, as some tillage farms import manure, quantities of which are not currently recorded and are hence excluded from the analysis.

Figure 95: N Balance per hectare: Tillage Farms



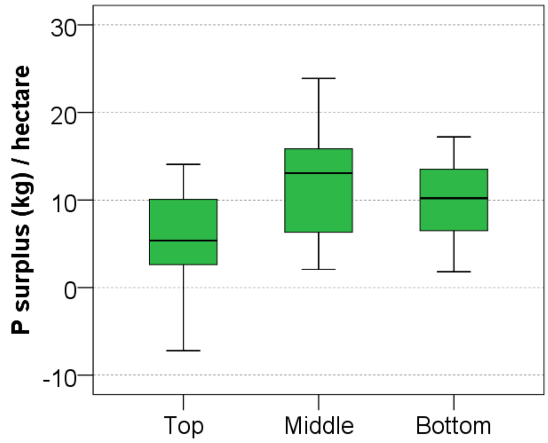
Across all tillage farms, the average NUE was circa 57%. Average NUE was higher for the top performing group (63%) compared to 51-53% for middle and bottom groups (as illustrated in Figure 96).

Figure 96: N Use Efficiency: Tillage Farms



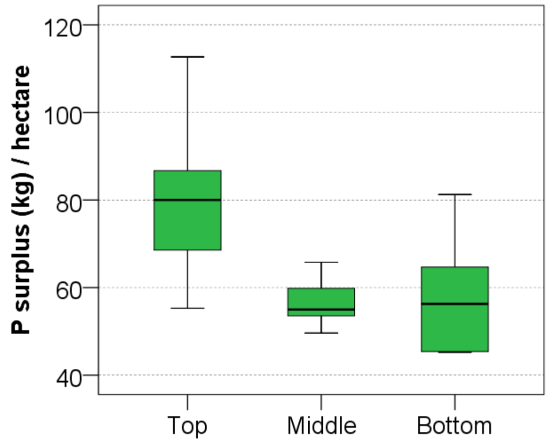
The average P balance across all tillage farms was 9.6 kg per hectare. However, as illustrated in Figure 97. There was a large range of results around these group averages, but better farms in economic terms tended to have lower P balances.

Figure 97: P Balance per hectare: Tillage Farms



PUE averaged circa 73.3% across all tillage farms. PUE tended to be higher across the top performing group, compared to the middle and bottom cohort as illustrated by Figure 98.

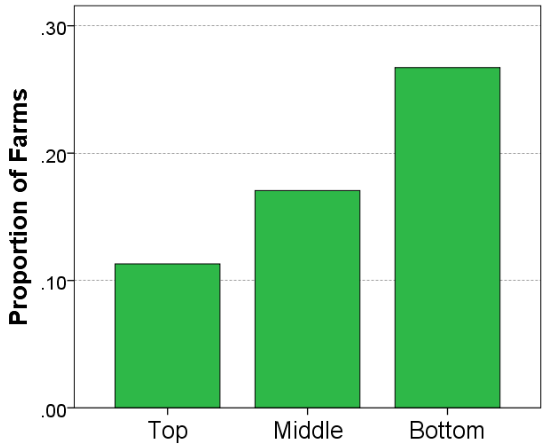
Figure 98: P Use Efficiency: Tillage Farms



Social Sustainability Indicators

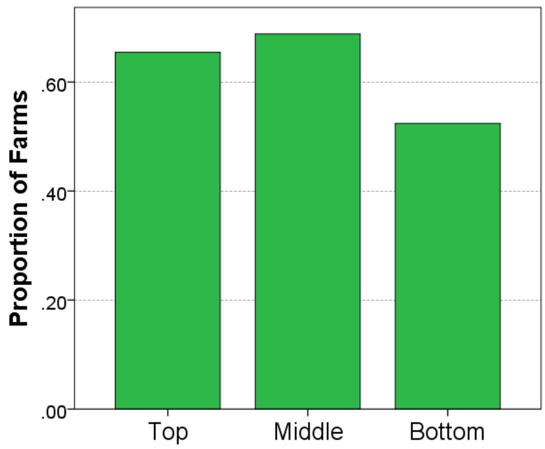
On average, a total of 18% of tillage farms are considered economically vulnerable. Figure 99 indicates that there is an inverse relationship between profitability & household vulnerability.

Figure 99: Household Vulnerability: Tillage



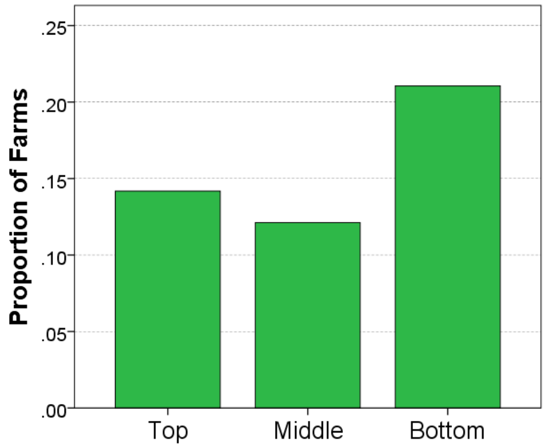
A total of 62% of tillage farmers had received some form of agricultural education or training. Figure 100 shows that this rate was slightly lower for the bottom performing third of tillage farms economically.

Figure 100: Agricultural Education: Tillage Farms



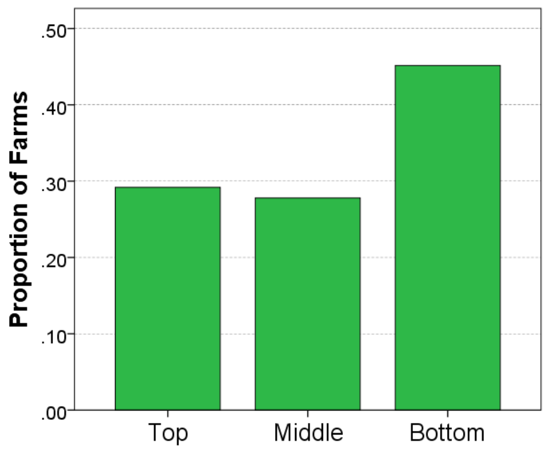
Overall, 16% of tillage farms were identified as being at risk of isolation (i.e. where the farm operator lived alone). At 21%, this rate was highest across the bottom performing cohort, as illustrated by Figure 101.

Figure 101: Isolation Risk: Tillage Farms



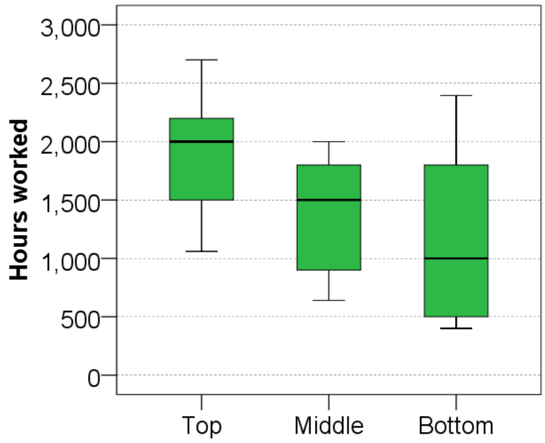
An average of 34% of tillage farms were identified as having a high age profile. Figure 102 shows that over 40% of farm households in the bottom group had a high age profile, compared to under 30% for the top and middle cohorts.

Figure 102: High Age Profile: Tillage Farms



The average tillage farmer worked 1,504 hours per year (29 hours per week). However, Figure 103 shows that the average was considerably lower for the bottom third of farms, ranked by gross margin per hectare, at 1,236 hours per year (22 hours a week). Teagasc NFS data show that the bottom cohort tend to hire more contractors to do field work, hence reducing the farm operators own time contribution.

Figure 103: Hours Worked: Tillage Farms



Tillage Innovation Indicators

The innovation indicators examined for tillage farms were: liming rates, engagement in forward selling of crops, membership of a discussion group and growing of a break crop.

Figure 104 shows that, at 51%, the liming rates were higher for the top performing cohorts, compared to 32% and 12% for the middle and bottom performing cohort.

Figure 104: Liming: Tillage Farms

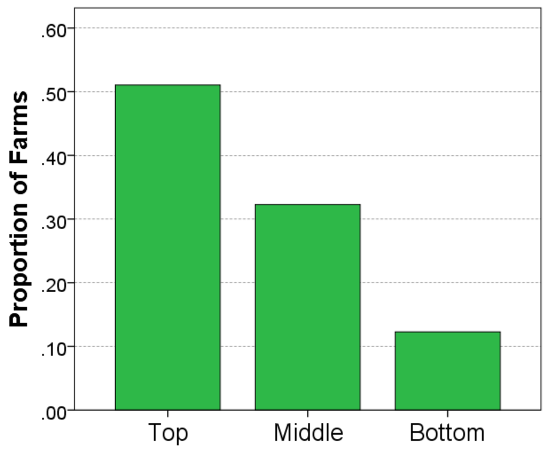


Figure 105 shows that the top performing cohorts were twice as likely to forward sell crops (9%), compared to the middle and bottom groups (3.5%).

Figure 105: Forward selling: Tillage Farms

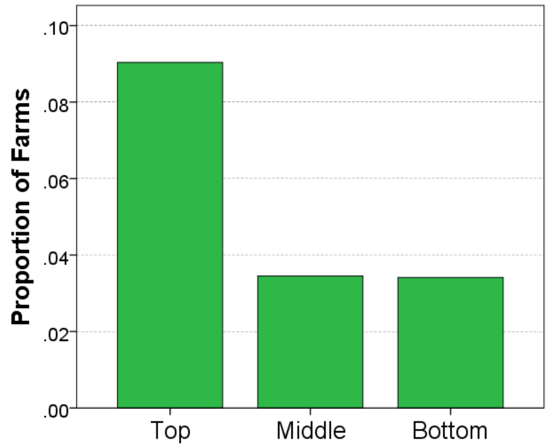


Figure 106 shows that those farms where the operator was a member of a discussion group performed better economically. On average between 22-23% of farms in the top and middle groups respectively were discussion group members, compared to 12% for the bottom cohort.

Figure 106: Discussion Group: Tillage Farms

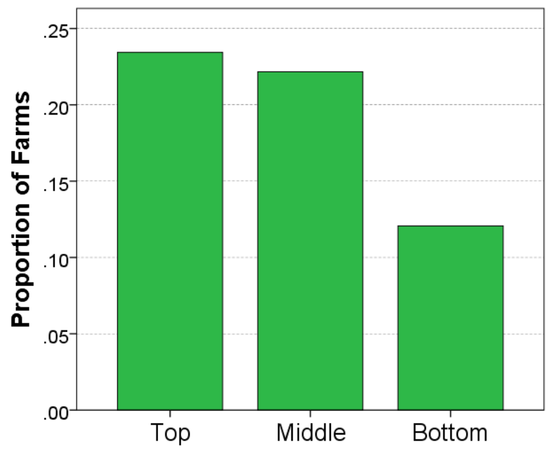
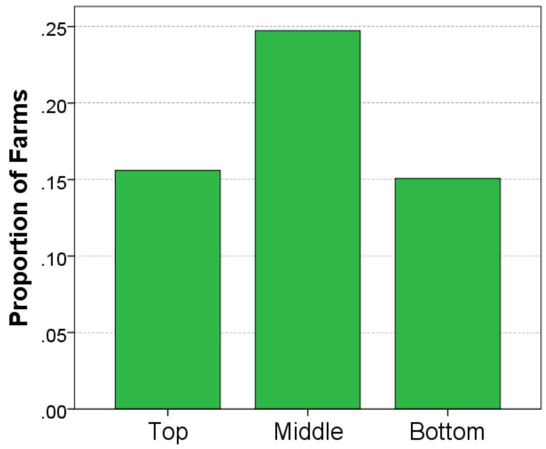


Figure 107 shows that, at 24%, the middle cohort were the most likely to grow a break crop, compared to 15% for the top and bottom cohorts.

Figure 107: Break Crops: Tillage



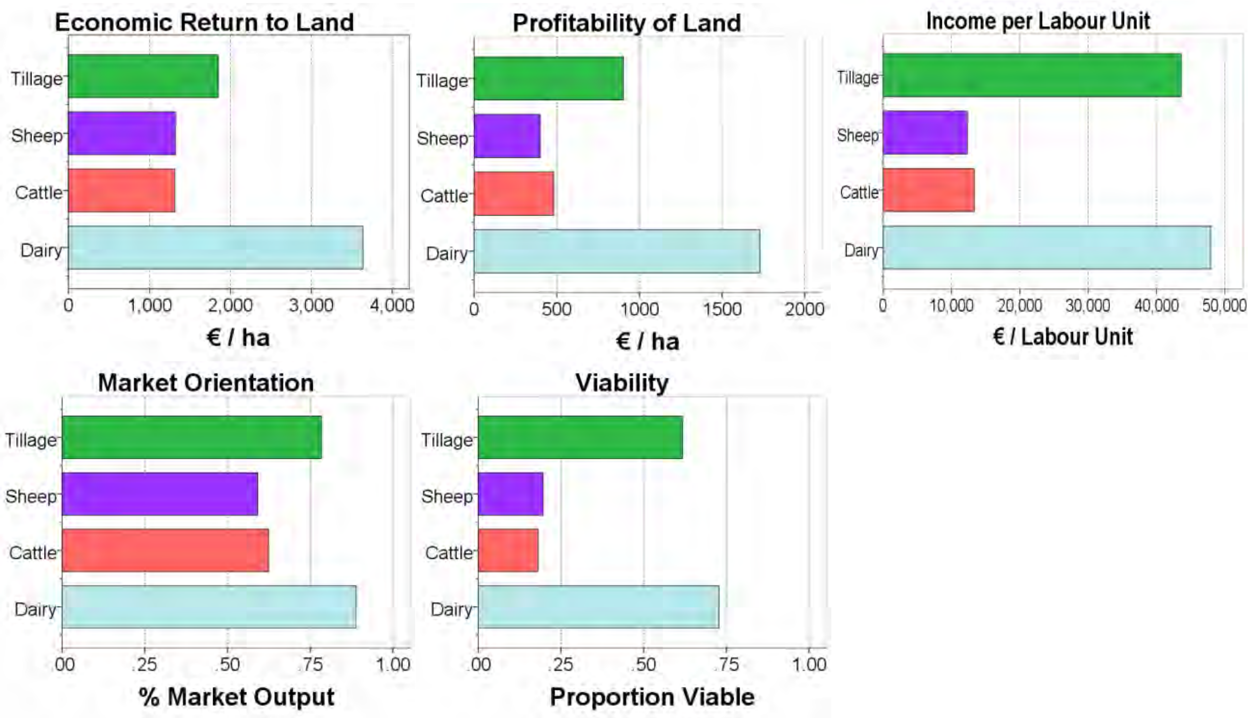
5. Farm System Comparisons 2018

Economic Indicators: A comparison of economic sustainability across different farm types is shown in Figure 108 below. In general, dairy farms show the strongest economic performance, significantly ahead of all other systems in terms of economic return and profitability on a per hectare basis.

Tillage was ahead of both cattle and sheep (which were similar) for economic return and profitability of land per hectare, but was slightly lower than dairying in terms of income per labour unit. Cattle farms, and especially sheep farms, returned significantly lower income per labour unit in comparison to dairying and tillage farms in 2018.

The farm systems are most similar in terms of market orientation, with dairy and tillage having the greatest share of gross output from the market. Cattle and sheep farms are most at risk financially, with only around 25% within both of these systems classed as economically viable. Dairy farms were the most economically viable, followed by tillage systems.

Figure 108: Economic Sustainability: Farm System Comparison 2018 (average per system)



It is important to note that these are average values for each farm type and that earlier analysis has highlighted the range around these average values in the case of each farm system type. Averages, while useful do not tell the full story. In some cases, the extent of the distribution around the average is such that there may be an overlap in the distribution of performance between different farm systems.

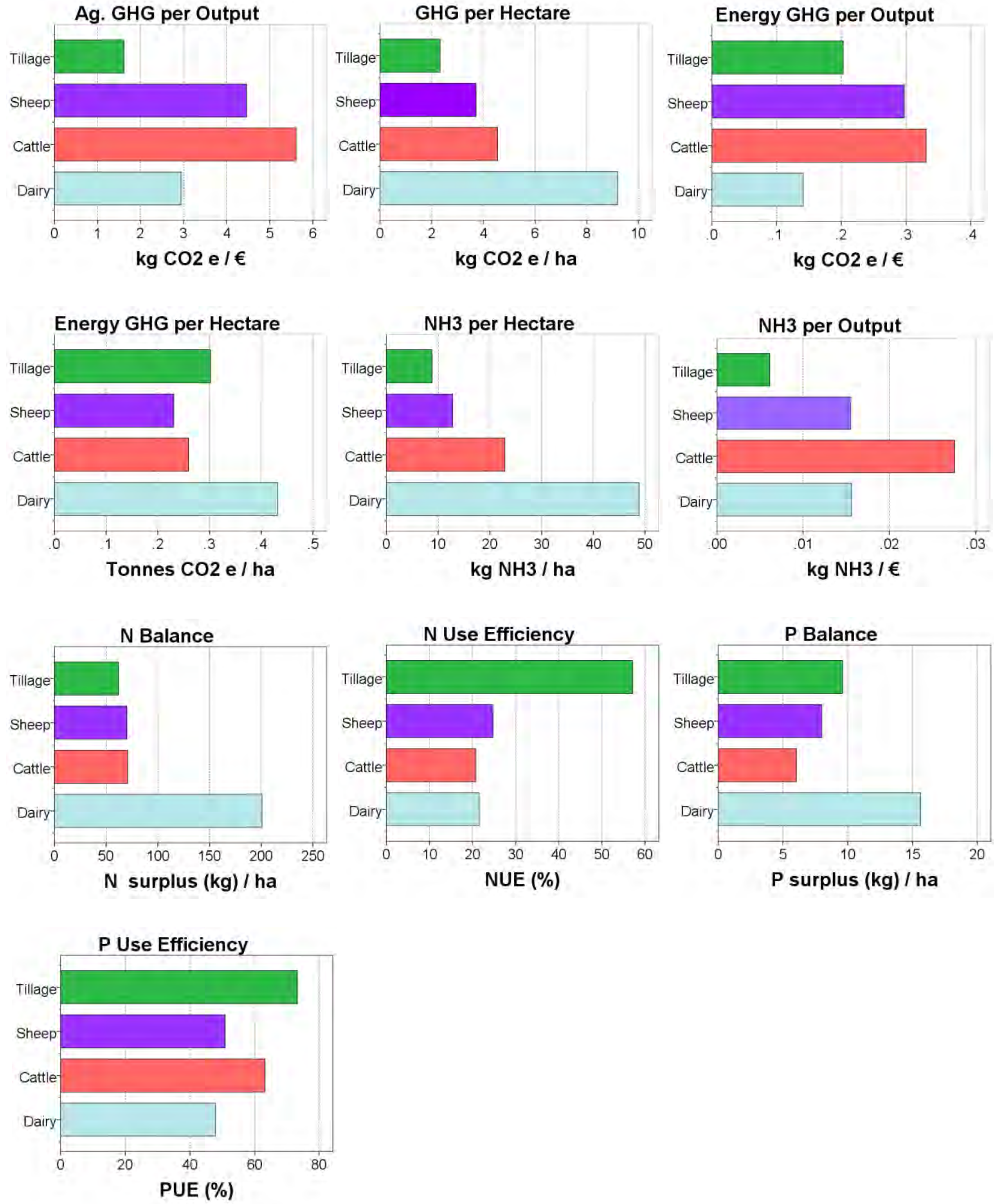
Environmental Indicators: The environmental sustainability of farms is more difficult to compare directly across different farm systems, as the indicators are more directly linked with the type of farming undertaken and the different outputs produced. More detail can be revealed by comparing within farm type variations (see previous section), but some shared environmental indicators across different farm types are presented in Figure 109.

Bovine based farming systems typically have higher greenhouse gas emissions per hectare than the tillage system, but this is to be expected due to the greater emissions associated with animal production as opposed to crops, especially in ruminant systems. On a per hectare basis, dairy farms show the highest emissions. Dairy farm emissions per hectare are significantly greater than any other system, due to the greater production intensity on these farms. Dairy emissions per hectare are a function of greater stocking rates, more energy intensive diets for dairy cows and higher use of chemical fertilisers than the other livestock systems. In terms of kg of GHG emissions per euro of output generated, cattle and sheep farms had much higher emission levels per hectare due to the lower value/volume of output compared to dairy systems.

In common with GHG emissions, ammonia emissions per hectare were significantly higher on dairy farmers compared to all other systems in 2018. Cattle farms had the next highest level of emissions per hectare (though on average these were only half those of the average dairy farms) followed by sheep and tillage farms. In terms of ammonia (NH_3) emission per euro of market output generated, cattle farms emitted the highest level of ammonia (due to the generally lower levels of output) followed jointly by dairy and sheep farms. Tillage farms have the lowest level of ammonia emission per euro of output generated due to the lower number of livestock on these farms.

Dairy farms have the largest N surplus per hectare due to the greater levels of livestock production intensity per hectare in this system. In terms of the input-output accounting NUE metric, dairying is similar to the other livestock systems, while tillage farms have greater NUE on average. It should be noted, however, that this analysis excludes tillage farms with manure imports and that tillage systems by their nature will have higher NUE as the nitrogen is not cycling through an animal (and subject to the various loss pathways). Dairy farms had the highest farm gate level P balances, significantly higher than those of the cattle, sheep and tillage systems. However, this metric should be interpreted with caution as reference to a soil test is required to establish optimal P balance on farms and such soil test data are not available for farms in the NFS. PUE was highest on tillage farms, which was higher than that observed across all of the livestock systems.

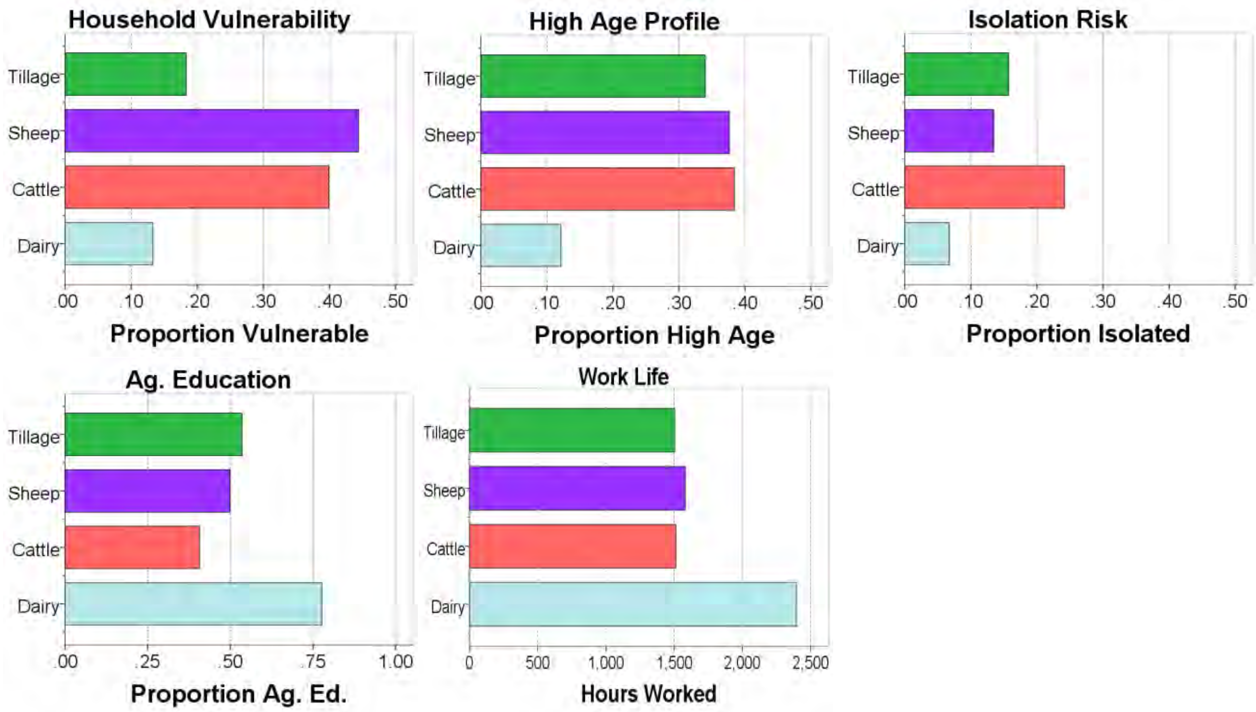
Figure 109: Environmental Sustainability: Farm System Comparison 2018 (average per system)



Social Indicators: Comparison of the social sustainability indicators of different farm types (in Figure 110) shows a similar overall trend to the economic performance indicators shown in Figure 108, with dairy and tillage farms being distinct from cattle and sheep systems, with respect to their social sustainability performance, but with some notable exceptions. The greater labour intensity of dairying is illustrated by the longer hours worked, although it should be noted that other farm systems are more likely to incur hours of off-farm employment, which if combined with hours worked on the farm would significantly increase total labour input by those farmers, across all of their work activities.

Given that there were lower levels of economic viability across cattle and sheep farms (see Figure 108) these systems were also more likely to have a more vulnerable household structure (non-viable with no off-farm employment within the household). Cattle and sheep farms were also more likely to have a high age profile, while cattle and tillage farms were more inclined to be farmed by farmers living alone. However, there was less variation for these measures than for other social sustainability indicators. On average, dairy and tillage farmers were more likely to have attained agricultural education or training than cattle or sheep farmers.

Figure 110: Social Sustainability: Farm System Comparison 2018 (average per system)



6. Time Series Comparisons with a three year rolling average: 2013-2018

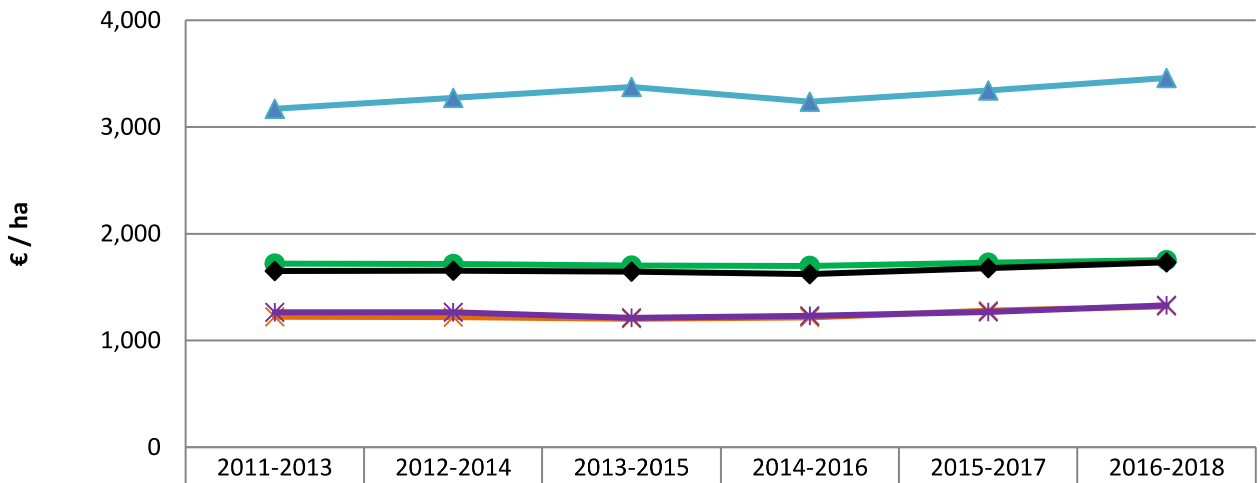
Building on research presented in previously published Teagasc Sustainability reports (Hennessy et al., 2013; Lynch et al., 2016, Buckley et al., 2019), we can track the evolution of farm-level sustainability indicators over time. The figures presented below highlight changes in indicator scores, with averages presented across all farm types. As short term input and output price volatility and weather events in a given year can occur and distort intertemporal trends, results below are presented on the basis of a three year rolling average (i.e. the result for 2013 is based on the average of the years 2011 to 2013 inclusive and is labelled as such). Annual average results for each indicator are also provided in Appendix 1.

It is important to appreciate that some factors influencing the various indicator measures shown here are partially within the control of an individual farmer (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 output prices, weather conditions, soil quality). 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 one year movements in such time series. The reported values containing both the signal and noise components and the use of the three year moving average based indicators allows for the signal component of the indicator to be more apparent.

6.1 Economic sustainability indicators

Figure 111 shows that the value of economic return to land (gross output (€) per hectare) tended to increase over the study period. However, across individual farm systems, there are notable differences; dairy farms have significantly higher levels of output per hectare compared to all other systems. Tillage farmers were next highest, ahead of cattle and sheep systems.

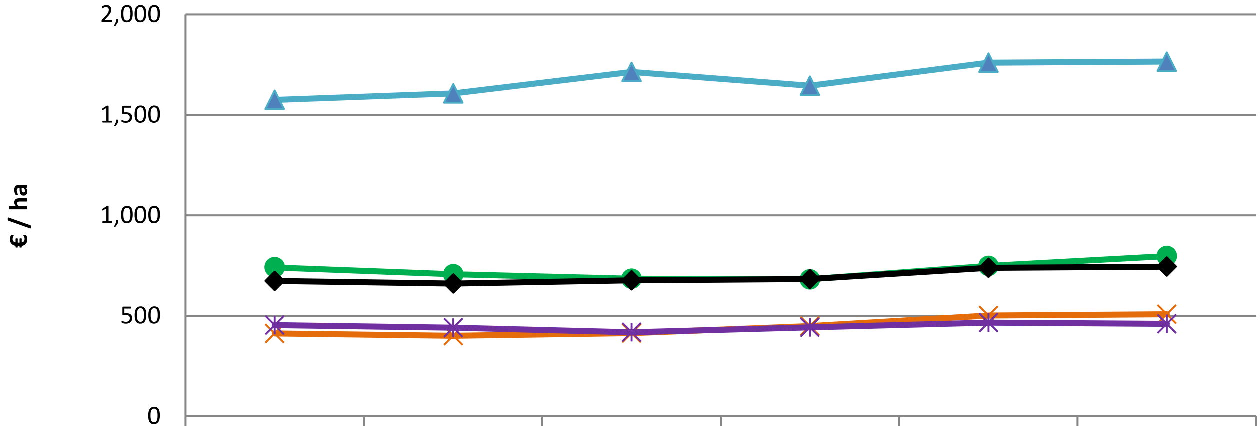
Figure 111: Economic Returns to Land: 3 year rolling average 2013-2018



	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018
Dairy	3,171	3,274	3,374	3,236	3,341	3,459
Cattle	1,223	1,218	1,203	1,217	1,279	1,320
Sheep	1,264	1,263	1,212	1,230	1,267	1,329
Tillage	1,719	1,718	1,702	1,698	1,730	1,753
All Farms	1,651	1,655	1,644	1,622	1,679	1,732

The profitability of land (gross margin per hectare) in dairying was again significantly higher than for all other systems and tended to increase over the years, significantly so at the end of the study period. Tillage farms again had the second highest gross margin per hectare. The lowest gross margins per hectare were returned by cattle and sheep farms, as illustrated in Figure 112.

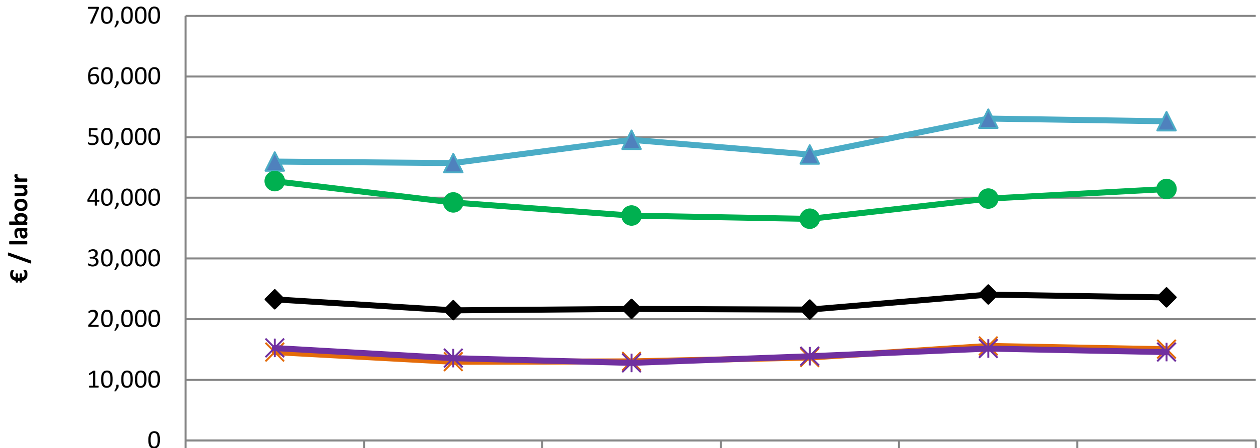
Figure 112: Profitability of Land: 3 year rolling average 2013-2018



	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017	2015-2018
Dairy	1,575	1,607	1,715	1,645	1,759	1,766
Cattle	413	401	413	448	501	508
Sheep	453	440	418	442	466	460
Tillage	741	707	685	682	748	797
All Farms	674	660	676	682	738	744

Figure 113 reveals that comparisons of farm income per labour unit follow broadly similar trends as the gross output and gross margin per hectare indicators. However, the differences between farm types when income per labour unit are compared are not as pronounced as in the case of gross output and gross margin, with some adjustment to reflect different labour intensities of each production system. Returns to labour were significantly higher on dairy and tillage farms, compared to cattle and sheep systems.

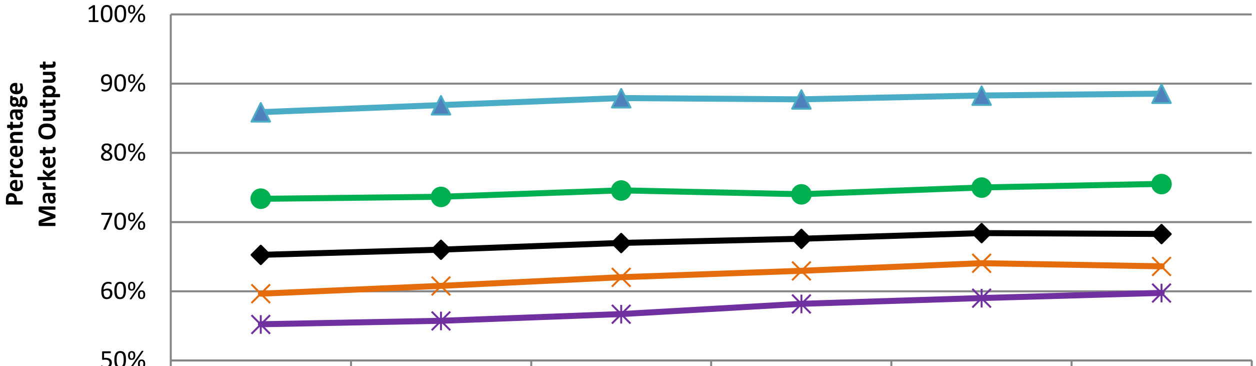
Figure 113: Productivity of Labour: 3 year rolling average 2013-2018



	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018
Dairy	45,998	45,731	49,544	47,118	53,066	52,594
Cattle	14,562	12,968	13,049	13,688	15,582	15,021
Sheep	15,231	13,545	12,787	13,892	15,144	14,542
Tillage	42,738	39,227	37,057	36,528	39,888	41,435
All Farms	23,241	21,450	21,695	21,565	24,049	23,572

Figure 114 illustrates that the average share of output derived from the market tended to increase between 2013 and 2018 when measured using a three year rolling average, rising from 65% to 68%. This is as a result of both a decrease in the value of direct payments, and an increase in market output. Dairying is the most market orientated of all the systems (86 to 89%) followed by tillage systems (73 to 76%). The market orientation of cattle systems increased from 60% at the start of the period to 64% at the end. A similar trend was evident for sheep systems where market orientation increased from 55% at the start of the period compared to 60% at the end of the period.

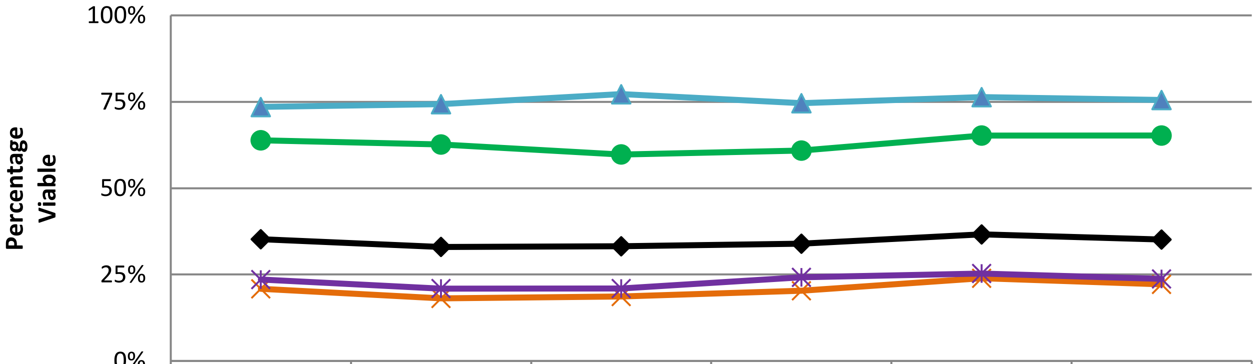
Figure 114: Percentage of Output Derived from Market: 3 year rolling average 2013-2018



	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018
Dairy	86%	87%	88%	88%	88%	89%
Cattle	60%	61%	62%	63%	64%	64%
Sheep	55%	56%	57%	58%	59%	60%
Tillage	73%	74%	75%	74%	75%	76%
All Farm	65%	66%	67%	68%	68%	68%

The same trends over time are also observed in terms of farm economic viability. Dairy and tillage systems have significantly higher levels of viability (60 to 76%), compared to cattle or sheep farms (18 to 25%) over the period examined. Viability, as with the other economic indicators, was affected by sectoral output prices over the period examined.

Figure 115: Economic Viability: 3 year rolling average 2013-2018

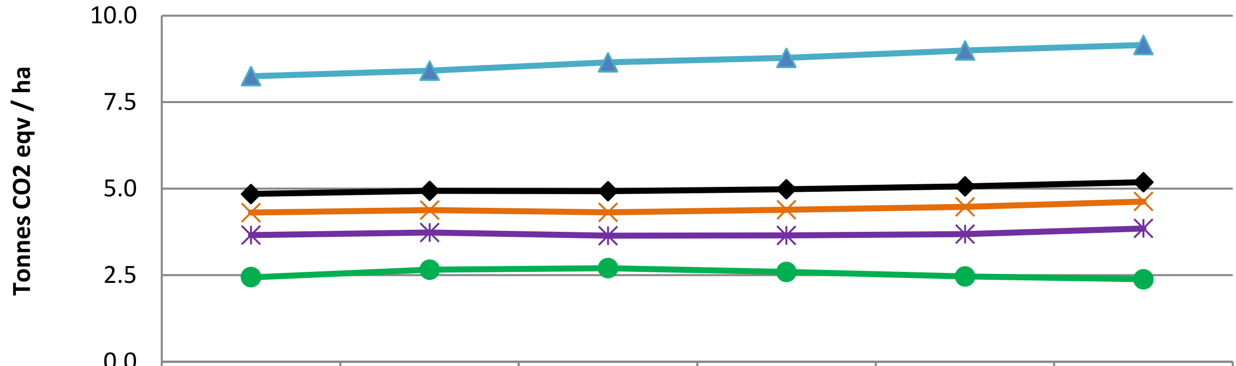


	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018
Dairy	74%	74%	77%	75%	76%	76%
Cattle	21%	18%	19%	20%	24%	22%
Sheep	24%	21%	21%	24%	25%	24%
Tillage	64%	63%	60%	61%	65%	65%
All Farm	35%	33%	33%	34%	37%	35%

6.2 Environmental sustainability indicators

Figure 116 shows that agricultural GHG emissions per hectare have been increasing over the study period (4.9 to 5.2 tonnes CO_2 equivalent per hectare). Due to the more intensive nature of production in dairy systems compared to all other grassland systems, agricultural GHG emissions per hectare are significantly higher, over double compared to other farm systems. The main trends observed are an increase in dairy emissions per hectare and relative stability in emission intensity per hectare across the other systems. The increase in dairy is the driver for the increase overall.

Figure 116: Ag. Greenhouse Gas Emissions per hectare: 3 year rolling average 2013-2018*

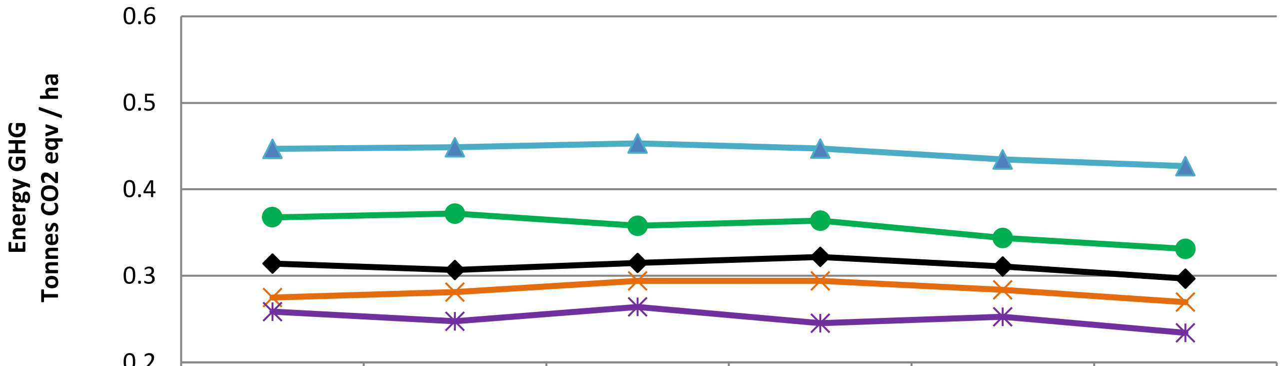


	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018
Dairy	8.3	8.4	8.6	8.8	9.0	9.2
Cattle	4.3	4.4	4.3	4.4	4.5	4.6
Sheep	3.7	3.7	3.6	3.7	3.7	3.9
Tillage	2.4	2.7	2.7	2.6	2.5	2.4
All Farms	4.9	4.9	4.9	5.0	5.1	5.2

*** Methodological update from previous report, with historical numbers revised accordingly.**

Figure 117 shows that energy based GHG emission generally remained stable over the study period. Energy based emissions were highest on dairy farms, since they are greater users of fuel and electricity.

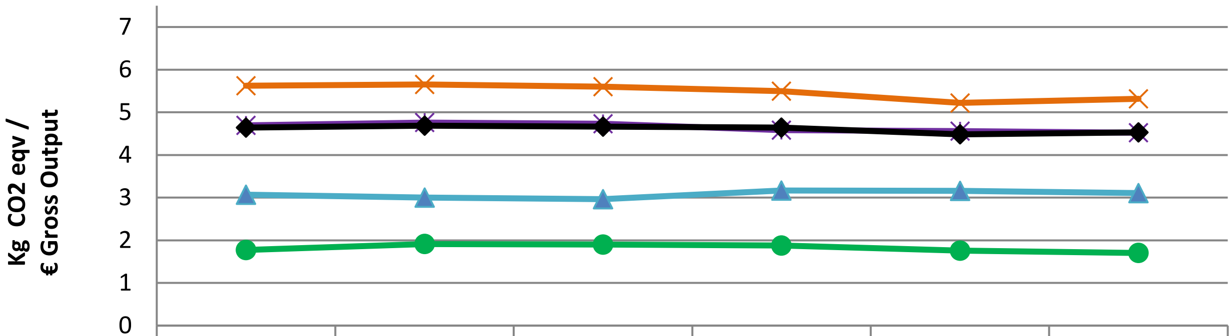
Figure 117: Energy Greenhouse Gas Emissions per hectare: 3 year rolling average 2013-2018



	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018
Dairy	0.45	0.45	0.45	0.45	0.43	0.43
Cattle	0.27	0.28	0.29	0.29	0.28	0.27
Sheep	0.26	0.25	0.26	0.25	0.25	0.23
Tillage	0.37	0.37	0.36	0.36	0.34	0.33
All Farms	0.31	0.31	0.32	0.32	0.31	0.30

Figure 118 illustrates that, over the years presented, agricultural GHG emissions per euro of gross output generated has remained relatively stable across all systems on a three year rolling average basis. Emissions per euro of output generated are significantly higher across cattle and sheep farms in all the years considered. These results are reflective of the greater financial return available from dairying and the lower emissions associated with non-livestock orientated tillage systems. The increase in dairy emissions per hectare, shown in Figure 116, are not reflected in a similar evolution in emissions per € output.

Figure 118: Ag. GHG Emissions per Euro output: 3 year rolling average 2013-2018*

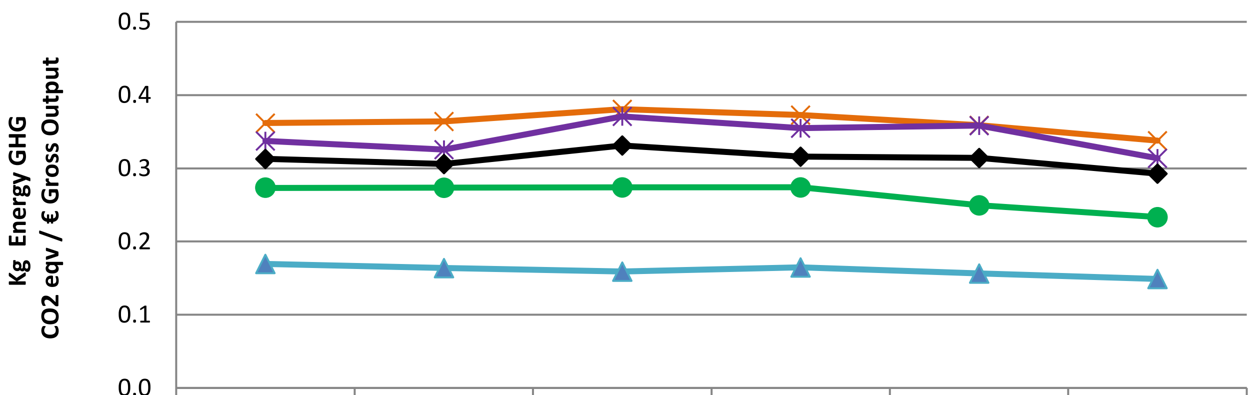


	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018
Dairy	3.1	3.0	3.0	3.2	3.2	3.1
Cattle	5.6	5.7	5.6	5.5	5.2	5.3
Sheep	4.7	4.8	4.7	4.6	4.6	4.5
Tillage	1.8	1.9	1.9	1.9	1.8	1.7
All Farms	4.6	4.7	4.7	4.6	4.5	4.5

*** Methodological update from previous report, with historical numbers revised accordingly.**

Figure 119 illustrates energy based GHG emissions per euro of market based gross output. Results follow a similar pattern to that of agricultural based emissions, where energy emissions per euro of output are significantly higher across cattle and sheep farms compared to dairying, over the period presented. Across all farm systems, energy emissions per euro of output showed a declining trend over the study period.

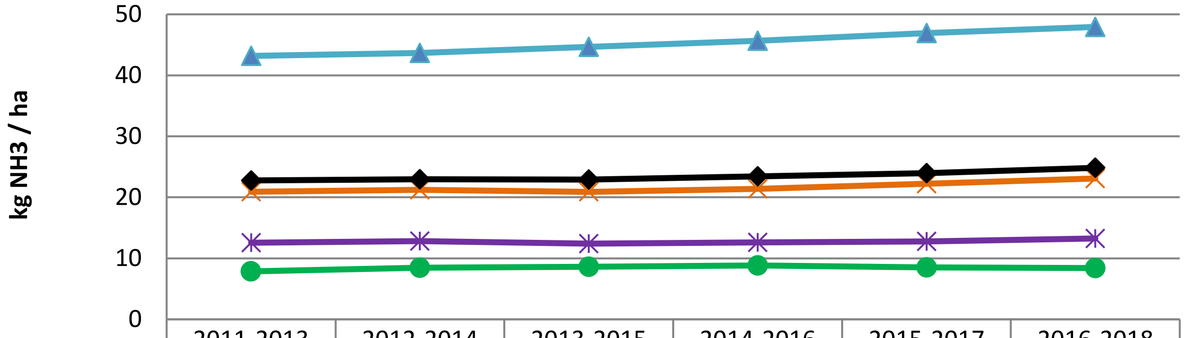
Figure 119: Energy GHG Emissions per Euro output: 3 year rolling average 2013-2018



	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018
Dairy	0.17	0.16	0.16	0.16	0.16	0.15
Cattle	0.36	0.36	0.38	0.37	0.36	0.34
Sheep	0.34	0.33	0.37	0.35	0.36	0.31
Tillage	0.27	0.27	0.27	0.27	0.25	0.23
All Farms	0.31	0.31	0.33	0.32	0.31	0.29

Figure 120 illustrates that on a three year rolling average basis across all farms, ammonia (NH_3) emissions per hectare were relatively static between the start and middle of the period presented, but have increased more recently. Again, due to the more intensive nature of production, NH_3 emissions per hectare are significantly higher for dairy systems compared to all other grassland systems and especially tillage. The main trends show an increase in average dairy, cattle and sheep farm emissions per hectare towards the end of the study period.

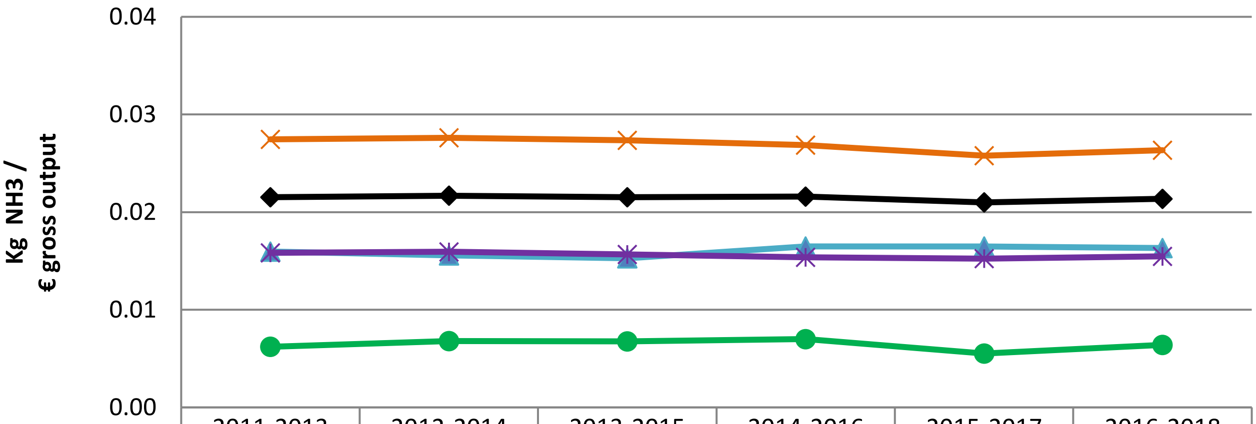
Figure 120: kg of Ammonia Emissions per hectare: 3 year rolling average 2013-2018



	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018
Dairy	43.2	43.7	44.7	45.7	46.9	47.9
Cattle	20.9	21.2	20.9	21.4	22.2	23.1
Sheep	12.6	12.8	12.4	12.6	12.8	13.3
Tillage	7.9	8.5	8.6	8.8	8.5	8.4
All Farms	22.8	23.0	22.9	23.4	24.0	24.8

Figure 121 illustrates NH_3 emissions per euro of market based gross output. Results indicate that emissions per euro of output were higher on cattle farms compared to all other systems over the study period. This is a function of the low levels of output on these farms. Dairy and sheep farms had very similar levels of NH_3 emissions per euro of output generated (due to high output value and low levels of emissions respectively). Tillage farms had the lowest emissions per euro of market based output.

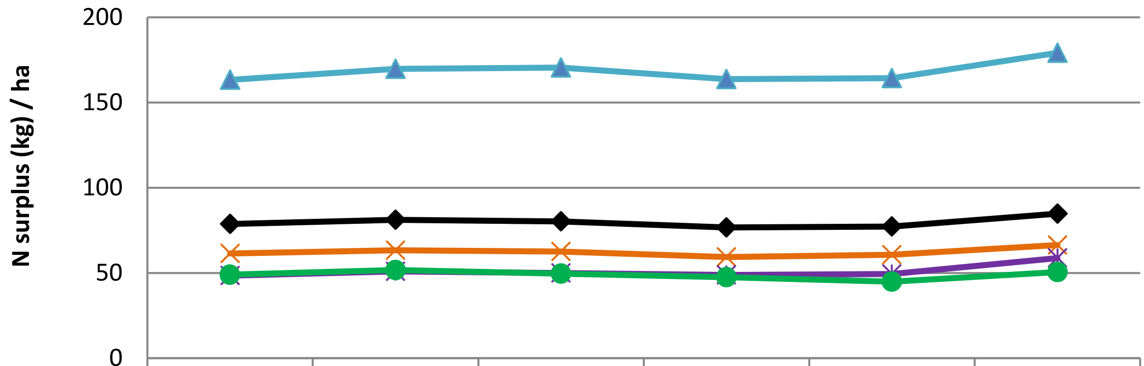
Figure 121: Ammonia (NH_3) Emissions per Euro Output: 3 year rolling average 2013-2018



	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018
Dairy	0.016	0.016	0.015	0.016	0.016	0.016
Cattle	0.027	0.028	0.027	0.027	0.026	0.026
Sheep	0.016	0.016	0.016	0.015	0.015	0.015
Tillage	0.006	0.007	0.007	0.007	0.006	0.006
All Farms	0.022	0.022	0.022	0.022	0.021	0.021

Across all farm systems, the N balance per hectare was slightly higher at the end versus the start of the period presented. Again due to the more intensive nature of production, N surpluses were significantly higher for dairy farms compared to all other systems. Due to the non-livestock orientated nature of production on tillage farms, N surpluses were on average lowest across these farms over the period presented. N surpluses are affected by a range of factors, some within and some (such as variability in the weather) outside the farmer's control. Higher N surplus years tended to be allied to poorer annual weather conditions. Even with the smoothing impact of using a three year moving average indicator, the adverse weather conditions in 2018 were sufficient to produce an increase in the N Balance indicator for the 2016-2018 period.

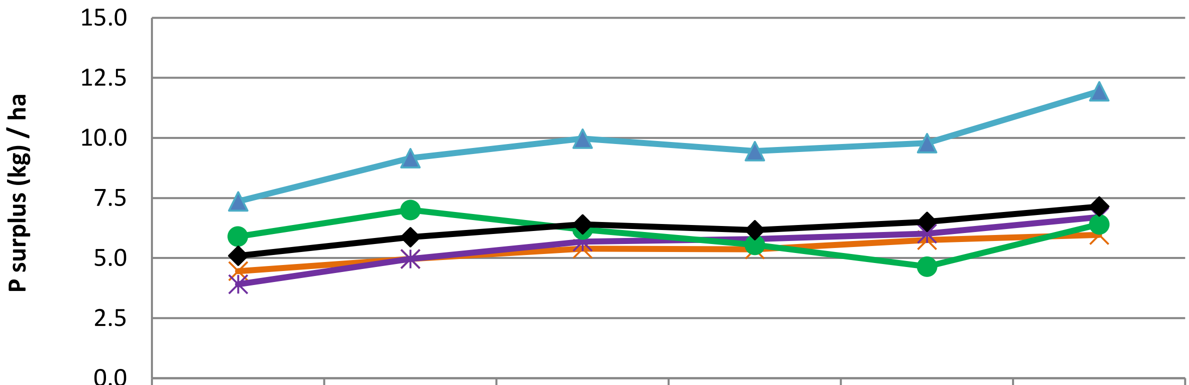
Figure 122: Nitrogen Balance per ha: 3 year rolling average 2013-2018



	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018
Dairy	163.3	169.8	170.4	163.7	164.2	179.1
Cattle	61.4	63.2	62.5	59.3	60.6	66.4
Sheep	48.4	50.8	49.9	48.8	49.4	58.7
Tillage	49.0	51.7	49.5	47.5	44.9	50.5
All Farms	78.7	81.1	80.2	76.7	77.2	84.8

Figure 123 illustrates that P balances tended to increase over the study period. P surpluses were significantly higher on dairy farms compared to all other systems post-2013.

Figure 123: Phosphorus (P) Balance per ha: 3 year rolling average 2013-2018



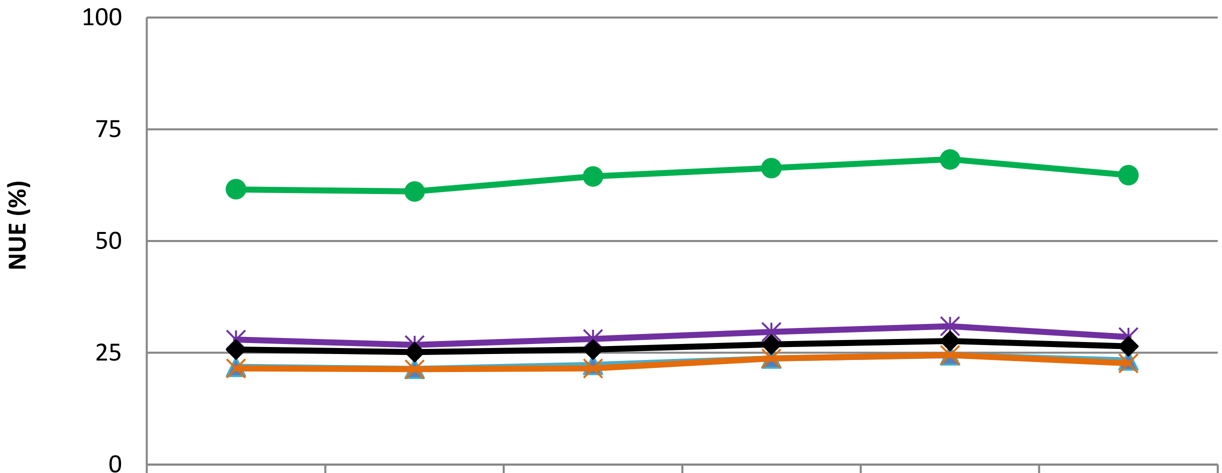
	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018
Dairy	7.4	9.2	10.0	9.5	9.8	11.9
Cattle	4.5	5.0	5.4	5.4	5.8	6.0
Sheep	3.9	5.0	5.7	5.8	6.0	6.7
Tillage	5.9	7.0	6.2	5.6	4.6	6.4
All Farms	5.1	5.9	6.4	6.2	6.5	7.1

It should also be noted that P fertiliser allowances were increased in 2014 following regulatory changes, which allowed more P to be applied to fields with sub-optimal soil P levels.

Farm gate level P balances must be interpreted with care, since establishing the optimal balance requires a soil test. Farmers are allowed to run significant farm gate level surpluses, if soil P status is sub optimal (deficient). In 2018, Teagasc analysed a total of 45,157 soil samples from dairy, drystock and tillage enterprises (Teagasc, 2019). Results indicate that 56% of samples taken from dairy farms, 63% taken from drystock farms and 54% taken from tillage farmer were P deficient (at either index 1 or 2 for phosphorus).

Figure 124 illustrates that across all farm systems NUE (N outputs / N inputs) has generally increased over the years when examined on a rolling three year moving average basis. Dairy and cattle farms tended to have the lowest NUE over the study period, although NUE was seen to improve slightly between the start and end of the period presented. Tillage NUE was generally significantly higher than all other systems due to the mainly non-livestock nature of this system. Weather effects in 2018 are reflected in the 2016-2018 data.

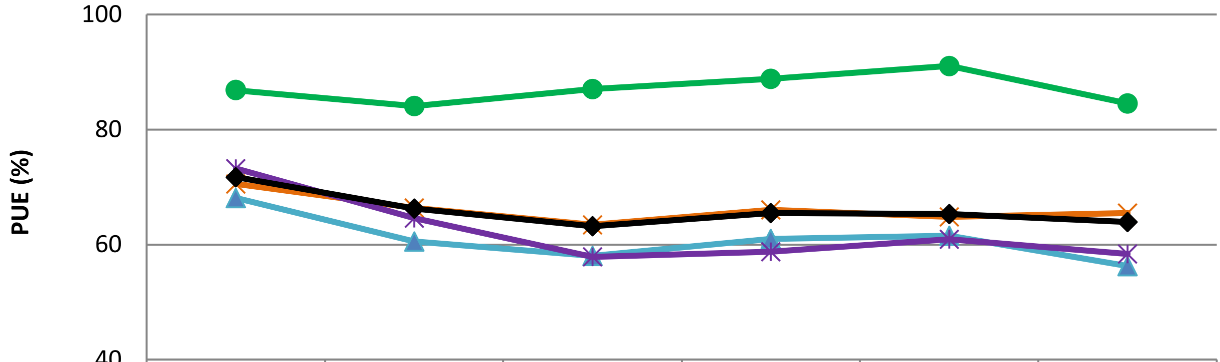
Figure 124: Nitrogen Use Efficiency: 3 year rolling average 2013-2018



	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018
Dairy	21.9	21.4	22.3	23.7	24.5	23.3
Cattle	21.6	21.3	21.5	23.7	24.5	22.7
Sheep	28.0	26.8	28.1	29.7	31.0	28.5
Tillage	61.6	61.1	64.5	66.3	68.3	64.7
All Farms	25.7	25.2	25.8	26.9	27.6	26.5

Figure 125 illustrates that, on a three year rolling average basis across all farm systems, PUE(P outputs / P inputs) has generally declined between the start and end of the period presented. Again it should also be noted that P fertiliser allowances were increased in 2014 following regulatory changes, which allowed more P to be applied to fields with sub-optimal soil P levels. Farm gate level based PUE must be interpreted with care, since establishing true PUE requires a soil test.

Figure 125: Phosphorus Use Efficiency: 3 year rolling average 2013-2018

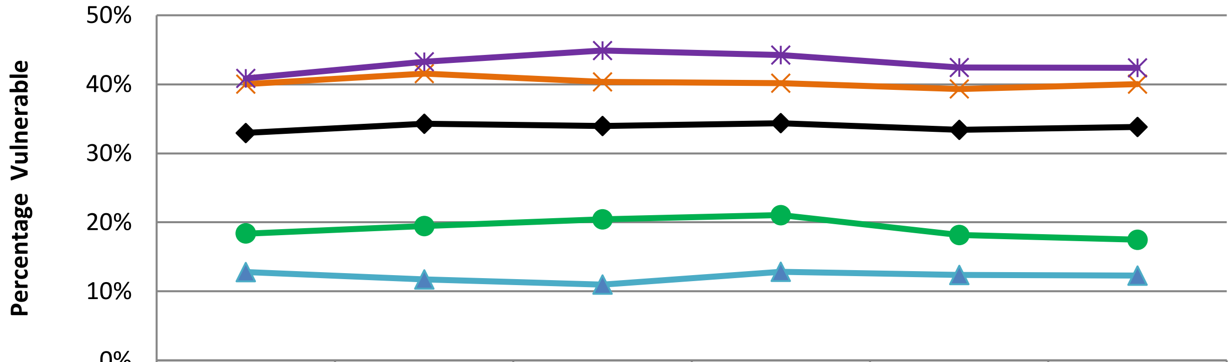


	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018
Dairy	68.1	60.6	58.0	61.0	61.6	56.3
Cattle	70.5	66.4	63.4	66.0	64.8	65.5
Sheep	73.2	64.6	57.8	58.8	60.9	58.4
Tillage	86.8	84.1	87.0	88.8	91.1	84.5
All Farms	71.7	66.3	63.2	65.5	65.3	63.9

6.3 Social Sustainability Indicators

Figure 126 shows that the rate of vulnerability (non-viable farm business and no off-farm employment) of all farming households has remained stable over the 2013-2018 period across all systems on a three-year rolling average basis at between 33 and 34%. Dairying and tillage systems tended to have significantly lower levels of household vulnerability than cattle and sheep systems.

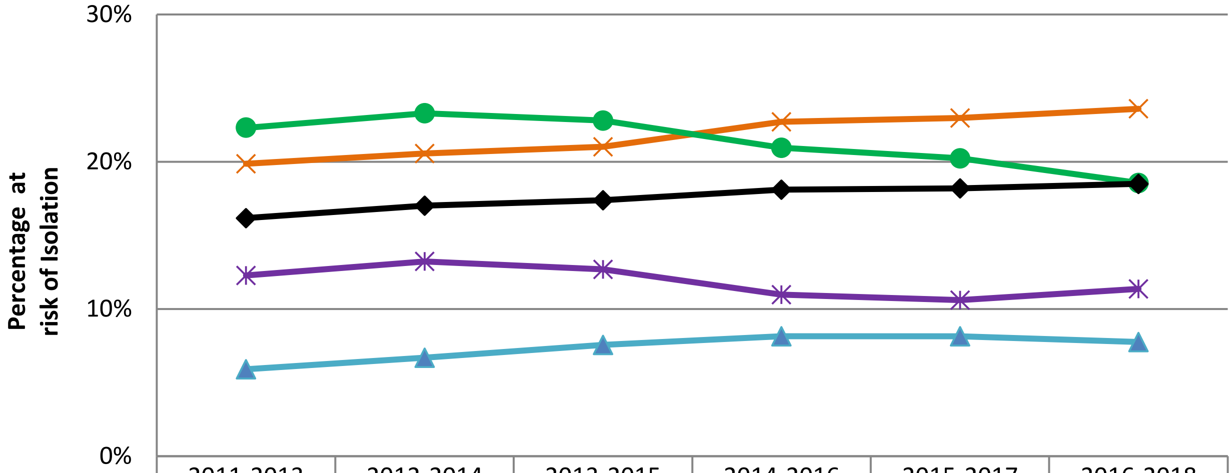
Figure 126: Farm Household Vulnerability: 3 year rolling average 2013-2018



	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018
Dairy	13%	12%	11%	13%	12%	12%
Cattle	40%	42%	40%	40%	39%	40%
Sheep	41%	43%	45%	44%	42%	42%
Tillage	18%	19%	20%	21%	18%	17%
All Farms	33%	34%	34%	34%	33%	34%

Figure 127 shows that the percentage of farmers at risk of isolation increased from the start (16%) to the end (19%) of the study period across all systems on a three-year rolling average basis. The percentage of tillage farmers at risk of isolation decreased over the study period (22% to 19%) while the percentage of cattle farmers at risk increased (20 to 24%) as did the risk for dairy farmers (6 to 8%). However, overall isolation risk tended to be higher on tillage and cattle farms compared to dairy and sheep based systems.

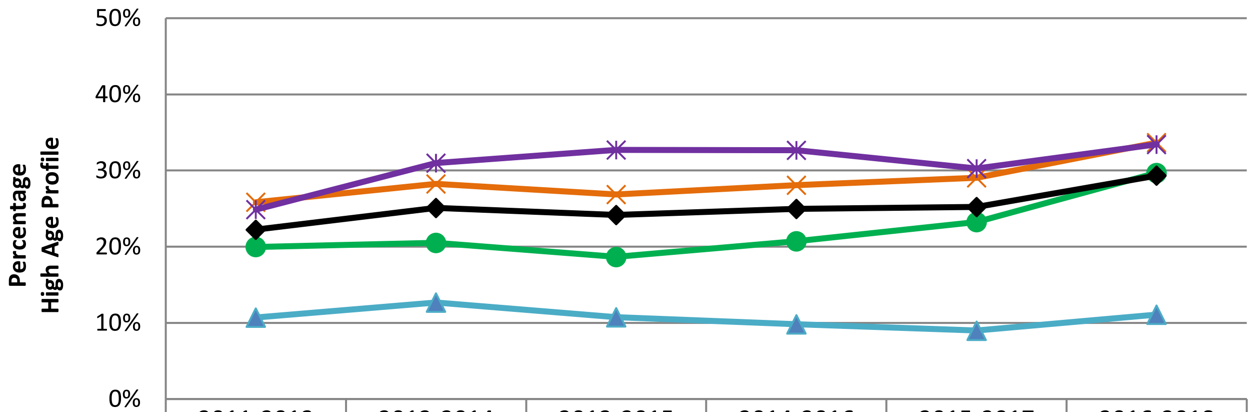
Figure 127: Isolation Risk: 3 year rolling average 2013-2018 (average per system)



	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018
Dairy	6%	7%	8%	8%	8%	8%
Cattle	20%	21%	21%	23%	23%	24%
Sheep	12%	13%	13%	11%	11%	11%
Tillage	22%	23%	23%	21%	20%	19%
All Farms	16%	17%	17%	18%	18%	19%

Figure 128 shows that the percentage of all farms with a high age profile increased between the start and end of the study period (22% to 29%) when measured on a three year rolling average basis. Dairy farms tended to have the lowest age profile across all the farm systems (9 to 13%), compared to other systems which tended to be double or treble this rate.

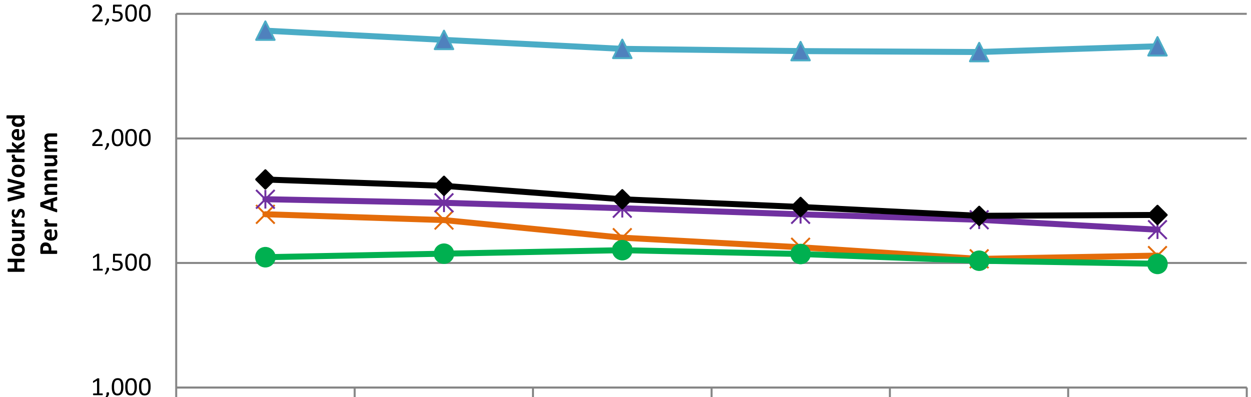
Figure 128: High Age Profile: 3 year rolling average 2013-2018 (average per system)



	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018
Dairy	11%	13%	11%	10%	9%	11%
Cattle	26%	28%	27%	28%	29%	34%
Sheep	25%	31%	33%	33%	30%	33%
Tillage	20%	21%	19%	21%	23%	30%
All Farm	22%	25%	24%	25%	25%	29%

Figure 129 shows that the hours worked on-farm per annum declined slightly across all farm types between 2013 and 2018 when measured on a three year rolling average basis. However, it is not clear to what extent this decline in hours worked on farm may or may not be matched by an increase in time engaged in off-farm employment. Given the increase in total national employment over the years considered, it is likely that farmers off-farm labour activity rates also increased over the study period. This caveat should be noted when using this measure of work/life balance. Hours worked on farm per annum were significantly higher on dairy farms, compared to all other farm systems.

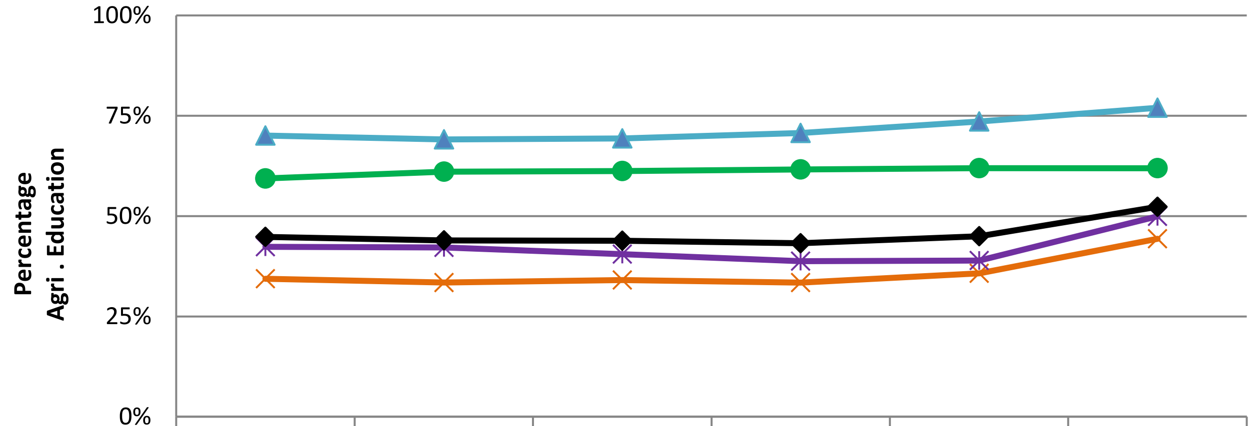
Figure 129: Hours Worked Per Annum: 3 year rolling average 2013-2018 (average per system)



	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018
Dairy	2,432	2,395	2,359	2,351	2,347	2,369
Cattle	1,696	1,672	1,601	1,562	1,516	1,529
Sheep	1,756	1,742	1,720	1,695	1,673	1,633
Tillage	1,523	1,537	1,551	1,536	1,509	1,497
All Farms	1,835	1,810	1,756	1,725	1,689	1,693

Figure 130 indicates that the percentage of famers who have received some form of agricultural education has remained consistent for the period 2013-2018 on a three year rolling average basis at between 43% and 45%. Significantly, higher levels of formal agricultural education were prevalent among dairy and tillage farmers, compared to cattle and sheep farms.

Figure 130: Formal Agricultural Education: 3 year rolling average 2013-2018 (average per system)



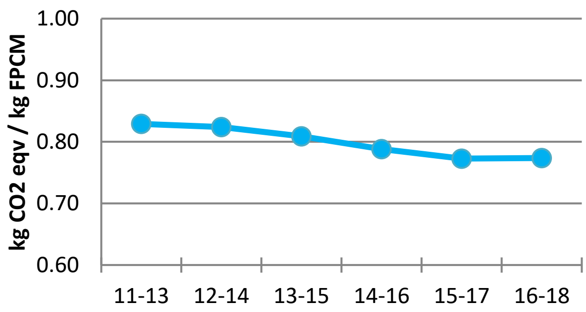
	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018
Dairy	70%	69%	69%	71%	74%	77%
Cattle	34%	33%	34%	33%	36%	44%
Sheep	42%	42%	40%	39%	39%	50%
Tillage	59%	61%	61%	62%	62%	62%
All Farms	45%	44%	44%	43%	45%	52%

6.4 Environmental Emissions Intensity Trends

The following section examines the trends in environmental efficiency of production for the main products produced on livestock farms (milk, beef, sheep meat). Results are again reported on the basis of a three year rolling average (e.g. the 2011-2013 results are the average of 2011, 2012 and 2013 results). Results for individual years are reported in the appendices on a farm system basis.

Results presented in Figure 131 show that, on a three year rolling average basis, the kg of CO_2 equivalent per kg of FPCM has generally followed a declining trend since 2011, before levelling off towards the end of the period examined.

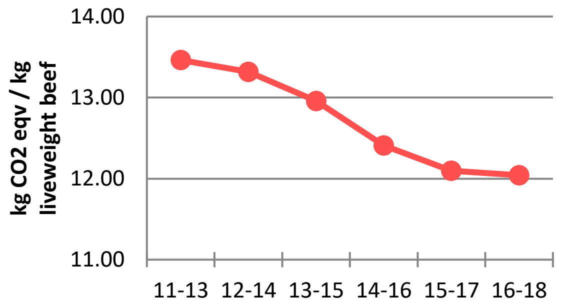
Figure 131: Ag. GHG Emissions per kg FPCM: 2013-2018 Dairy Farms*



Note: (IPCC approach) 3 year rolling average

Figure 132 indicates that kg of CO_2 equivalent per kg of live-weight beef produced on cattle farms also tended to follow a declining trends, before again levelling out towards the end of the study period.

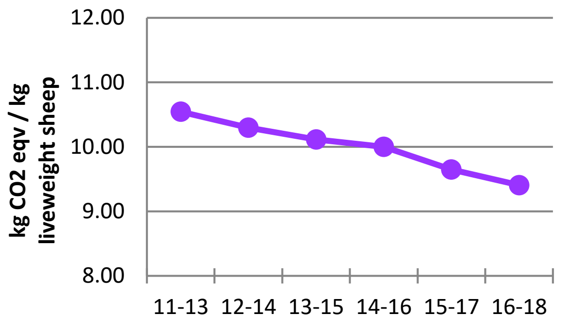
Figure 132: Ag. GHG Emissions per kg live-weight beef produced: 2013-2018 (Cattle Farms*



Note: (IPCC approach) 3 year rolling average

Figure 133 indicates, on three year rolling average basis, a steady declining trend in terms of kg of CO_2 emitted per kg of live-weight sheep produced between 2013 and 2018.

Figure 133: Ag. GHG Emissions per kg live-weight sheep produced: 2013-2018 Sheep Farms*

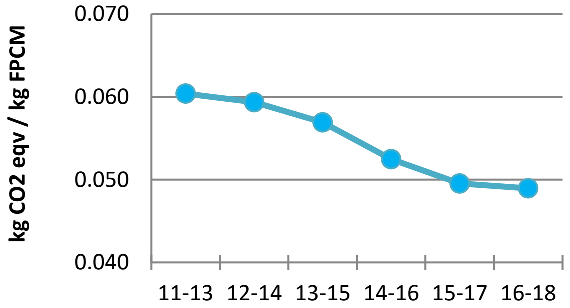


Note: (IPCC approach) 3 year rolling average

Energy based GHG emissions may be affected by the weather in any given year (e.g. wet conditions may require extra movement of farm livestock herds). Results presented in Figure 134 indicate a gradual decline in GHG emissions derived from electricity and fuel associated with milk production at the start and middle of the study period with a levelling off towards the end.

*Methodological update from previous report, numbers have been amended.

Figure 134: Energy use related GHG emissions per kg FPCM: 2013-2018 Dairy Farms

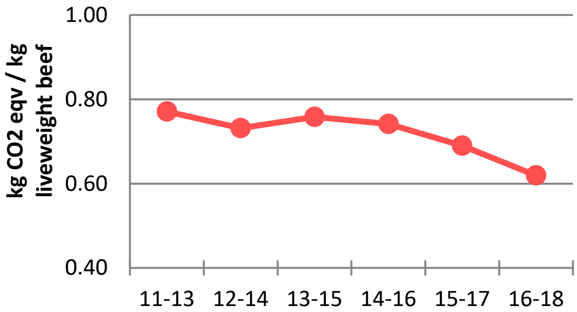


Note: (IPCC approach) 3 year rolling average

Energy based CO_2 emissions related to the production of live-weight beef on cattle farms were relatively static over the study, with a slight decline toward the end of the study period as illustrated in Figure 135.

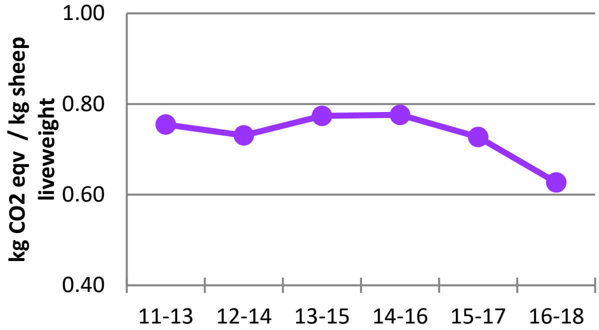
Energy based GHG emission from the production of live-weight sheep was also relatively static over the 2013-18 period except for a slight increase in the mid-study period, followed by a return to previous levels as illustrated in Figure 136.

Figure 135: Energy use related GHG emissions per kg live-weight beef produced: 2013-2018 Cattle Farms*



Note: (IPCC approach) 3 year rolling average

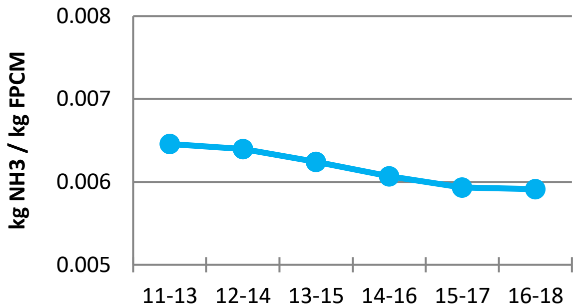
Figure 136: Energy use related GHG emissions per kg live-weight sheep produced: 2013-2018 Sheep Farms*



Note: (IPCC approach) 3 year rolling average

Similar to GHG emissions, on a three year rolling average basis, the NH_3 emissions intensity of milk production tended to follow a declining trend towards the start and middle of the study period, before levelling off towards the end as outlined in Figure 137.

Figure 137: Ammonia emissions per kg FPCM: 2013-2018 3 year rolling average Dairy Farms

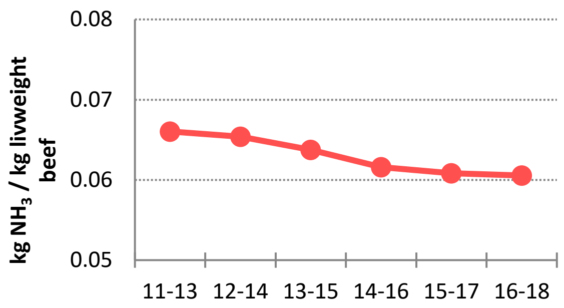


Note: 3 year rolling average

On a three year rolling average basis, NH_3 emissions per kg of live-weight beef produced on cattle farms were relatively static over most of the period presented, before a slight decline was seen more recently, as shown in Figure 138.

**Methodological update from previous report, numbers have been amended.*

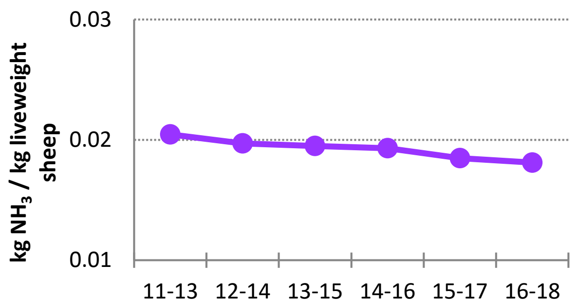
Figure 138: Ammonia emissions per kg live-weight beef produced: 2013-2018 Cattle Farms*



Note: 3 year rolling average

This pattern was repeated for NH_3 emissions per kg of live-weight sheep meat produced on sheep farms, as illustrated in Figure 139.

Figure 139: Ammonia emissions per kg live-weight sheep produced: 2013-2018 Sheep Farms*

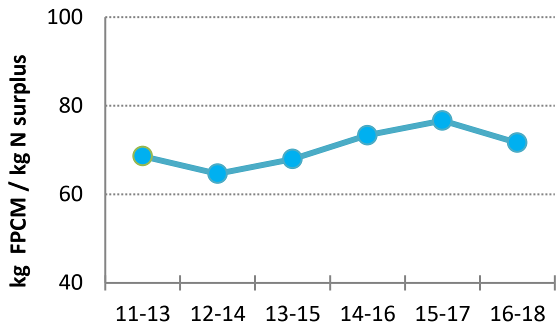


Note: 3 year rolling average

Figure 140 illustrates the trend on dairy farms in terms of kg of FPCM produced per kg of N surplus (excess of N input over outputs), on a three year rolling average basis. The graph shows an increase in FPCM produced per kg of N surplus followed by a decline at the end of the period.

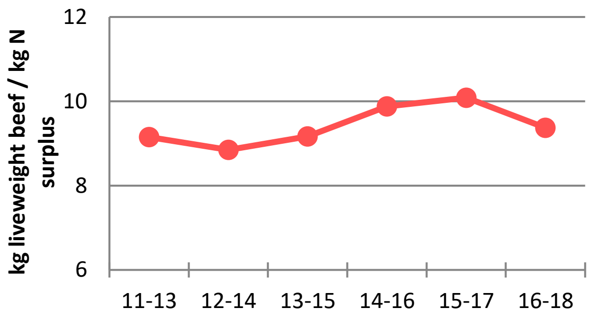
Figure 141 shows the trend per kg of live-weight beef produced per kg of N surplus. Based on a three year rolling average, results indicate a relatively static trend at the start of the study period followed by a slight increase mid study period, before a decline at the end.

Figure 140: kg of FPCM produced per kg of N surplus: 2013-2018 Dairy Farms



Note: 3 year rolling average

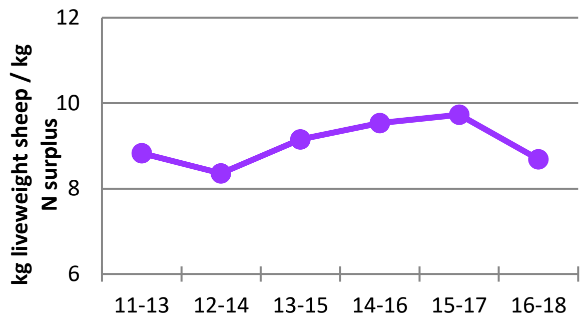
Figure 141: kg of live-weight beef produced per kg of N surplus: 2013-2018 Cattle Farms*



Note: 3 year rolling average

Results for kg of live-weight sheep meat produced per kg of N surplus on sheep farms are presented in Figure 142. Results suggest a declining trend at the start of the study period, followed by an upward trajectory mid study period before a decline at the end of the period studied.

Figure 142: kg of live-weight sheep produced per kg of N surplus: 2013-2018 Sheep Farms



Note: (IPCC approach) 3 year rolling average

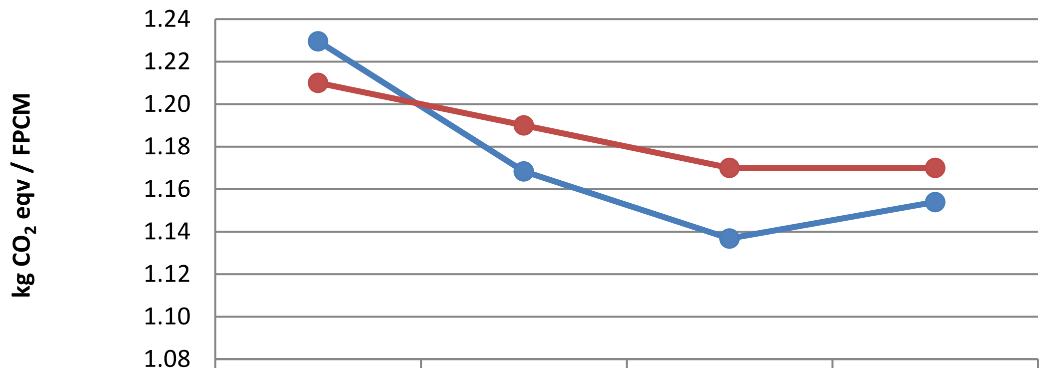
Methodological update from previous report, numbers have been amended.

7. National Cross Validation on Carbon Footprint of Milk Production

Using the more holistic LCA approach (including agricultural and energy based emissions) the Teagasc NFS data have been used in conjunction with the Moorepark LCA model (O'Brien et al., 2014) to produce LCA carbon footprint indicators using NFS data. Results from this LCA approach indicate that the carbon footprint of Irish milk production (CO_2 equivalent per kg of FPCM produced) declined between 2015 and 2017 on a rolling three year average basis, both on a weighted farm and national aggregate basis (results weighted by milk supply). However, this declining three year moving average trend was reverse at the end of the period examined. The increase in the LCA carbon foot print indicator for the three year period 2016-2018 can largely be attributed to adverse weather experienced in 2018. Drought conditions experienced in 2018 led to reduced grass growth rates which precipitated higher purchased feed inputs and fertiliser application rates, while output remained static.

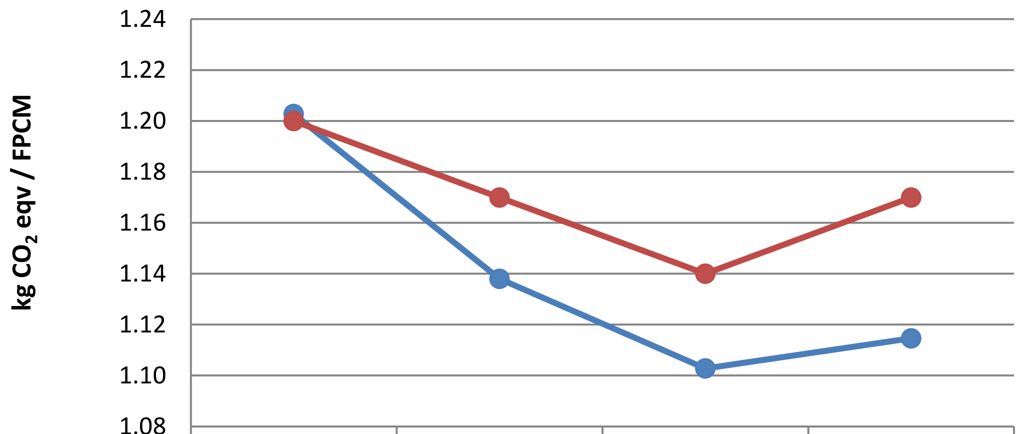
These results in terms of kg CO_2 equivalent per kg of FPCM are consistent with other nationally based results obtained using a similar LCA approach and farm level data collected and published as part of the Bord Bia Sustainable Dairy Assurance Scheme (SDAS) (Bord Bia, 2019; Muphy, 2020) as outlined below.

Figure 143: GHG per kg FPCM (LCA Approach) – 3 year rolling nationally weighted farm average



	2013-2015	2014-2016	2015-2017	2016-2018
Teagasc NFS	1.23	1.17	1.14	1.15
Bord Bia SDAS	1.21	1.19	1.17	1.17

Figure 144: GHG per kg FPCM (LCA Approach) – 3 year rolling average weighted by milk supply.



	2013-2015	2014-2016	2015-2017	2016-2018
Teagasc NFS	1.20	1.14	1.10	1.11
Bord Bia SDAS	1.20	1.17	1.14	1.17

8. Ongoing and Future Work

The Teagasc National Farm Survey sustainability indicator set is a powerful tool with which to assess the actual performance of Irish farms across a range of areas and allows detailed comparisons between and within farm systems. This report builds on the research reported in previously published sustainability reports (Hennessy et al., 2013; Lynch et al., 2016; Buckely et al., 2019) and shows the changes in relevant indicators through time.

The indicator set reported will continue to evolve (in terms of new indicators and the methodology used to calculate existing indicators) and will continue where possible to demonstrate changes in the multiple dimensions of sustainability across a nationally representative sample of farms in Ireland over time. The data required to ensure the continued refinement of such sustainability metrics is continually under review. To that end, work is ongoing to strengthen the social and environmental indicators in particular. As such, two important environmental aspects not yet included are currently in progress.

Life-Cycle Analysis Model for Beef Production

Measuring GHG emissions and carbon footprints for beef farms is more challenging than for dairy farms. The system of production on dairy farms is more homogeneous than on beef farms and the volume of the principal output (milk) can be more easily recorded. In addition, there are much more limited movements of animals onto and off of dairy farms. By contrast there are a range of different systems on beef farms and movements of animals onto and off of farms can be quite diverse depending on the specifics of the cattle system in operation. In addition, the output of the farm (live-weight gain) can be hard to capture as it is not directly observed and measured by the farmer. However, an updated LCA model for beef production is currently being developed by Teagasc colleagues in the Animal and Grassland Research and Innovation Programme (AGRIP) and the Teagasc NFS data collection schedule is being expanded to enable the application of a Beef LCA carbon footprint in Teagasc Sustainability Report indicator set.

Biodiversity

Farms produce food, but also produce/maintain a range of eco system services, including appropriate habitats for wildlife. The provision of habitats can in turn provide benefits on the farm itself through the provision of ecosystem services such as pollination as well as contributing to the wider set of environmental public goods produced by agriculture. Agricultural production is thus involved in the production of an environment that can be appreciated by local communities and tourists as well as having its own intrinsic value.

However, one of the global concerns associated with the intensification of agricultural production is that wildlife and native flora may be negatively impacted, resulting in irrevocable or difficult to reverse biodiversity loss. Biodiversity is therefore an important component of farm performance, but can usually only reliably be assessed by detailed on-farm surveys. Typically, such measurement is resource intensive and represents a long term commitment, which would ordinarily be beyond the current scope and resources of the Teagasc NFS.

However, competitive research funding has been obtained to investigate the potential of remote mapping and ground truthing methods of farmland habitat biodiversity measurement for a representative portion of NFS dairy farms. The inclusion of biodiversity metrics is becoming increasingly desirable in quantitative measurements of sustainability by key stakeholders, consumers, producers and policymakers. Consequently, with on-going ecological and farm data measurement research on biodiversity measurement, using remote sensing and ground truthing, indicators will be developed for biodiversity that will add to those already included in the indicator set of the Teagasc Sustainability Report. Sufficient resource provision could subsequently allow this biodiversity measurement to be replicated across all farm types within the Teagasc National Farm Survey.

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Glossary of Terms

CO_2 equivalent: For reporting purposes all non-carbon dioxide (CO_2) emissions are converted to CO_2 equivalents using appropriate global warming potentials for CH_4 and N_2O which are respectively 25 and 298 times greater than CO_2.

Direct Costs: Costs directly incurred in the production of a particular enterprise, e.g., fertilisers, seeds and feeding stuffs.

Fat and Protein Corrected Milk (FPCM): This is the functional unit used for carbon foot printing dairy output on farm. It adjusts kg/litres of milk to allow for the level of milk solids produced which is standardized to 4% fat and 3.3% true protein per kilogramme of milk.

Greenhouse Gases (GHG): The amount of greenhouse gas emissions (CO_2, N_2O, CH_4) associated with the production of a specific type of agricultural produce, expressed as kg CO_2 equivalent per kg of produce (e.g. per kg beef, milk).

Gross Output: Gross output for the farm is defined as total sales less purchases of livestock, plus value of farm produce used in the house, plus receipts for hire work, services, fees etc. It also includes net change in inventory, which in the case of cows, cattle and sheep is calculated as the change in numbers valued at closing inventory prices. All non-capital grants, subsidies, premiums, headage payments are included in gross output in this report.

Gross Margin: Gross output minus direct costs.

Labour Unit: One labour unit is defined as at least 1,800 hours worked on the farm by a person over 18 years of age. Persons under 18 years of age are given the following labour unit equivalents:

16-18 years: 0.75
14-16 years: 0.50

Please note: An individual cannot exceed one labour unit even if he/she works more than 1,800 hours on the farm.

Life Cycle Analysis: An alternative method to the IPCC approach to measuring carbon is the Life-Cycle Assessment approach which accounts for emissions through the entire food production supply chain.

Nitrogen balance: (per hectare farmed), is used as an indicator of the potential magnitude of nitrogen surplus which reflects the risk of nutrient losses to water bodies all other things being equal. It is calculated on the basis of N inputs less N outputs on a per hectare basis at the farm gate level.

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 at the farm gate level.

Phosphorus balance: (per hectare farmed), is used as an indicator of the potential magnitude of phosphorus surplus which may result in nutrient losses to water bodies all other things being equal. It is calculated on the basis of P inputs less P outputs on a per hectare basis at the farm level.

Phosphorus use efficiency: is used to highlight the proportion of P retained in the farm system (P outputs / P inputs). This is a generic measure allowing comparison across different farm types.

Appendix 1

Table 5: Sustainability Indicator results for Dairying Farms 2013-2018

Indicator	***2013***	***2014***	***2015***	***2016***	***2017***	***2018***
Economic Sustainability Metrics			€			
Economic return per hectare	3,436	3,404	3,283	3,021	3,720	3,637
Profitability per hectare	1,667	1,767	1,710	1,457	2,111	1,728
Productivity of labour	48,468	50,803	49,363	41,188	68,646	47,947
		percentage				
Market orientation	88	88	88	87	90	89
Viability	77	80	75	69	85	73
Social Sustainability Metrics						
Household vulnerable	10%	9%	13%	16%	8%	13%
Isolation	7%	8%	8%	8%	8%	7%
High age profile	12%	14%	6%	9%	12%	12%
Hours worked	2,395	2,354	2,329	2,370	2,341	2,397
Agricultural education	70%	67%	71%	74%	76%	81%
Environmental Sustainability Metrics						
		tonnes CO2 eqv per farm				
Total farm average Ag. GHG emissions*	471.8	473.3	492.3	515.8	533.0	536.5
of which dairy*	278.7	279.1	302.3	317.1	330.9	333.4
cattle*	189.8	191.4	187.1	196.1	199.7	200.8
sheep*	1.5	1.4	1.5	1.3	1.4	1.3
other*	1.6	1.2	1.1	1	0.9	1.0
energy use	24.3	24.9	24.6	22.8	22.9	23.7
		tonnes CO_2 eqv per ha				
Ag GHG Emissions*	8.6	8.6	8.8	8.9	9.2	9.2
Energy GHG Emissions	0.44	0.46	0.46	0.42	0.42	0.43
		kg CO_2 eqv				
GHG Emissions per kg milk*	0.83	0.81	0.78	0.79	0.78	0.78
GHG Emissions per kg FPCM*	0.84	0.81	0.77	0.78	0.77	0.77
GHG Emissions per € output*	2.9	2.9	3.1	3.5	2.9	3.0
Energy Emissions per kg milk	0.06	0.06	0.05	0.05	0.05	0.05
Energy Emissions eqv per kg FPCM	0.06	0.06	0.05	0.05	0.05	0.05
GHG Emissions per kg FPCM (LCA)	1.31	1.24	1.14	1.13	1.14	1.19
		tonnes NH_3 per farm				
Total farm average NH3 emissions	2.45	2.47	2.57	2.76	2.82	2.88
of which dairy	1.92	1.94	2.05	2.13	2.19	2.18
cattle	0.24	0.24	0.22	0.26	0.25	0.28
sheep	0.0	0.0	0.0	0.0	0.0	0.0
chemical fertiliser	0.29	0.29	0.30	0.38	0.37	0.42
kg NH_2						
NH_3 emissions per hectare	44.1	44.3	45.6	47.1	47.8	48.8
NH_3 emissions per Euro output	0.015	0.015	0.016	0.018	0.015	0.016
NH_3 emissions per kg milk	0.0063	0.0062	0.0059	0.0060	0.0059	0.0059
NH_3 emissions per kg FPCM	0.0065	0.0063	0.0059	0.0059	0.0059	0.0059

Indicator	***2013***	***2014***	***2015***	***2016***	***2017***	***2018***
		kg per ha				
N Balance per hectare	185.0	170.3	155.9	164.8	171.9	200.7
P Balance per hectare	10.6	10.4	9.0	9.0	11.4	15.6
		percentage				
N use efficiency	19.7	22.2	25.0	24.0	24.4	21.5
P use efficiency	53.6	56.8	63.8	62.4	58.4	48.7
		Per kg of N Surplus				
Kg FPCM	59.2	66.1	78.6	75.3	76.0	63.6

*** Methodological update from previous report, with historical numbers revised accordingly.**

Table 6: Sustainability Indicator results for Cattle Farms 2013-2018

Indicator	***2013***	***2014***	***2015***	***2016***	***2017***	***2018***
Economic Sustainability Metrics						
Economic return per hectare	1,269	1,154	1,189	1,312	1,336	1,312
Profitability per hectare	402	374	463	507	533	483
Productivity of labour	12,893	11,225	15,029	14,809	16,909	13,344
			percentage			
Market orientation	62%	61%	64%	64%	64%	62%
Viability	18%	15%	24%	23%	25%	18%
Social Sustainability Metrics						
Household vulnerable	42%	41%	38%	42%	39%	40%
Isolation	19%	22%	22%	24%	23%	24%
High age profile	27%	28%	25%	31%	32%	38%
Hours worked	1,682	1,646	1,474	1,566	1,508	1,513
Agricultural education	35%	31%	36%	33%	38%	41%
Environmental Sustainability Metrics						
			tonnes CO_2 eqv per farm			
Total farm average Ag. GHG emissions*	155.3	148.1	138.6	145.9	148.1	150.8
of which dairy*	0.0	0.0	0.0	0.0	0.0	0.0
cattle*	150.0	143.3	134.4	141.6	144.3	146.8
sheep*	4.8	4.4	3.9	4.0	3.5	3.7
other*	0.5	0.4	0.4	0.3	0.3	0.3
energy use	9.8	9.5	9.5	8.5	8.1	8.2
			tonnes CO_2 eqv per ha			
Ag GHG Emissions*	4.4	4.3	4.0	4.6	4.6	4.5
Energy GHG Emissions	0.28	0.29	0.30	0.28	0.26	0.26
			kg CO_2 eqv			
Ag. GHG Emissions per kg live-weight beef*	13.6	13.0	12.3	11.9	12.0	12.1
Ag. GHG Emissions per € output*	5.5	5.9	5.3	5.2	5.1	5.6
Energy Emissions per kg live-weight beef	0.70	0.74	0.77	0.59	0.48	0.60
			tonnes NH_3 per farm			
Total farm average NH3 emissions	0.75	0.71	0.68	0.73	0.74	0.75
of which dairy	0.0	0.0	0.0	0.0	0.0	0.0
cattle	0.70	0.67	0.64	0.68	0.69	0.69
sheep	0.01	0.01	0.00	0.00	0.00	0.00
chemical fertiliser	0.05	0.04	0.04	0.04	0.04	0.05
			kg NH_3			
NH_3 emissions per hectare	21.7	21.0	20.0	23.2	23.2	22.9
NH_3 emissions per Euro output	0.028	0.029	0.026	0.026	0.025	0.028
NH_3 emissions per kg live-weight beef*	0.0666	0.0637	0.0609	0.0601	0.0614	0.0602
			kg per ha			
N Balance per hectare	72.4	61.3	53.6	63	65.2	70.7
P Balance per hectare	5.7	5	5.4	5.6	6.2	6.0

Indicator	***2013***	***2014***	***2015***	***2016***	***2017***	***2018***
			percentage			
N use efficiency	19.5	22.4	22.4	23.1	24.2	20.8
P use efficiency	61.6	67.5	61.2	69.3	64.0	63.2
			Per kg of N Surplus			
kg Live weight beef*	8.0	8.7	10.8	10.2	9.3	8.7

*** Methodological update from previous report, with historical numbers revised accordingly.**

Table 7: Sustainability Indicator results for Sheep Farms 2013-2018

Indicator	***2013***	***2014***	***2015***	***2016***	***2017***	***2018***
Economic Sustainability Metrics						
Economic return per hectare	1,236	1,265	1,134	1,291	1,375	1,322
Profitability per hectare	361	475	417	435	545	400
Productivity of labour	10,951	13,289	14,122	14,266	17,043	12,316
			percentage			
Market orientation	56%	57%	57%	61%	60%	59%
Viability	15%	24%	24%	24%	27%	20%
Social Sustainability Metrics						
Household vulnerable	44%	46%	45%	42%	41%	44%
Isolation	14%	13%	11%	9%	12%	13%
High age profile	33%	37%	28%	33%	30%	38%
Hours worked	1,749	1,710	1,700	1,675	1,644	1,581
Agricultural education	44%	41%	36%	39%	42%	50%
Environmental Sustainability Metrics						
			tonnes CO_2 eqv per farm**			
Total farm average Ag. GHG emissions*	144.0	141.0	130.8	142.1	147.1	141.9
of which dairy*	0.9	0.8	1.2	0.0	1.7	0.0
cattle*	73.8	76.0	68.2	76.6	76.1	73.0
sheep*	68.8	63.8	61.1	65.0	68.8	68.3
other*	0.5	0.4	0.4	0.5	0.4	0.5
energy use	9.3	9.7	9.9	7.9	8.7	8.2
			tonnes CO_2 eqv per ha			
Ag GHG Emissions*	3.8	3.7	3.2	3.7	3.9	3.7
Energy GHG Emissions	0.25	0.25	0.27	0.22	0.26	0.23
			kg CO_2 eqv			
Ag. GHG Emissions per kg live-weight sheep produced*	10.0	10.0	9.9	9.5	9.0	9.2
Ag. GHG Emissions per € output*	5.1	4.6	4.6	4.6	4.5	4.5
Energy Emissions per kg live-weight sheep produced*	0.63	0.78	0.91	0.64	0.63	0.61
			tonnes NH_3 per farm			
Total farm average NH3 emissions	0.50	0.51	0.47	0.52	0.53	0.51
of which dairy	0.0	0.0	0.0	0.0	0.0	0.0
cattle	0.36	0.37	0.33	0.38	0.38	0.35
sheep	0.10	0.09	0.09	0.09	0.10	0.09
chemical fertiliser	0.04	0.05	0.04	0.05	0.05	0.07
			kg NH_3			
NH_3 emissions per hectare	13.0	12.9	11.2	13.5	13.5	12.8
NH_3 emissions per Euro output	0.017	0.015	0.015	0.016	0.015	0.016
NH_3 emissions per kg live-weight sheep*	0.019	0.019	0.020	0.018	0.017	0.019
			kg per ha			
N Balance per hectare	55.8	51.4	42.4	52.5	53.4	70.2
P Balance per hectare	5.3	5.8	5.9	5.6	6.5	8.0

Indicator	***2013***	***2014***	***2015***	***2016***	***2017***	***2018***
			percentage			
N use efficiency	24.7	27.7	32.1	29.3	31.5	24.7
P use efficiency	57.8	57.1	58.6	60.6	63.6	50.9
			Per kg of N Surplus			
kg Live weight sheep*	8.3	8.3	10.9	9.5	8.9	7.7

*** Methodological update from previous report, with historical numbers revised accordingly.**

Table 8: Sustainability Indicator results for Tillage Farms 2013-2018

Indicator	***2013***	***2014***	***2015***	***2016***	***2017***	***2018***
Economic Sustainability Metrics						
Economic return per hectare	1,684	1,638	1,784	1,671	1,734	1,852
Profitability per hectare	679	618	757	671	817	904
Productivity of labour	37,940	34,252	38,978	36,355	44,330	43,620
			percentage			
Market orientation	74%	73%	77%	73%	76%	78%
Viability	57%	61%	62%	60%	74%	62%
Social Sustainability Metrics						
Household vulnerable	21%	20%	20%	23%	11%	18%
Isolation	26%	22%	21%	21%	19%	16%
High age profile	22%	20%	15%	28%	27%	34%
Hours worked	1,570	1,544	1,540	1,525	1,462	1,504
Agricultural education	61%	60%	62%	62%	61%	62%
Environmental Sustainability Metrics						
			tonnes CO_2 eqv per farm			
Total farm average Ag. GHG emissions*	158.3	157.6	154.9	147.7	142.1	141.4
of which dairy*	0.0	0.0	0.0	0.0	0.0	0.0
cattle*	105.8	107.1	106.1	94.3	94.6	98.3
sheep*	12.8	9.8	9.4	8.0	7.7	8.4
other*	39.7	40.6	39.3	45.3	39.7	34.8
energy use	26.0	25.4	23.3	23.3	19.3	20.1
			tonnes CO_2 eqv per ha			
Ag GHG Emissions*	2.4	2.5	2.4	2.2	2.3	2.3
Energy GHG Emissions	0.4	0.4	0.3	0.4	0.3	0.3
			kg CO_2 eqv			
Ag. GHG Emissions per € output*	1.8	2.1	1.8	1.8	1.7	1.6
			tonnes NH_3 per farm			
Total farm average NH3 emissions	0.56	0.59	0.60	0.61	0.52	0.57
of which dairy	0.0	0.0	0.0	0.0	0.0	0.0
cattle	0.46	0.49	0.49	0.45	0.43	0.44
sheep	0.01	0.01	0.01	0.01	0.01	0.01
chemical fertiliser	0.08	0.10	0.10	0.15	0.08	0.12
			kg NH_3			
NH_3 emissions per hectare	7.91	8.82	8.87	8.50	7.82	8.84
NH_3 emissions per Euro output	0.0061	0.0076	0.0065	0.0068	0.0062	0.0061
			kg per ha			
N Balance per hectare	52.4	50.8	45.2	46.6	43.0	62.0
P Balance per hectare	6.9	7.4	4.3	5.0	4.7	9.6
			percentage			
N use efficiency	61.7	63.8	67.8	67.4	69.8	57.1
P use efficiency	84.2	84.0	92.9	89.7	90.6	73.3

*** Methodological update from previous report, with historical numbers revised accordingly.**

Table 9: Sustainability Indicator results for All Farms 2013-2018

Indicator	***2013***	***2014***	***2015***	***2016***	***2017***	***2018***
Economic Sustainability Metrics						
Economic return per hectare	1,706	1,627	1,605	1,638	1,793	1,766
Profitability per hectare	657	668	703	676	835	722
Productivity of labour	21,413	20,763	22,958	21,024	28,164	21,529
			percentage			
Market orientation	67%	66%	68%	68%	69%	68%
Viability	32%	32%	36%	34%	40%	31%
Social Sustainability Metrics						
Household vulnerable	34%	34%	33%	36%	32%	34%
Isolation	17%	18%	18%	19%	18%	19%
High age profile	25%	27%	21%	27%	28%	33%
Hours worked	1,819	1,779	1,670	1,724	1,674	1,681
Agricultural education	45%	42%	44%	43%	47%	49%
Environmental Sustainability Metrics						
			tonnes CO_2 eqv per farm			
Total farm average Ag. GHG emissions*	213.0	207.6	202.3	210.8	215.5	217.0
of which dairy*	52.3	51.6	54.6	56.1	58.8	59.0
cattle*	141.1	138.1	131.1	137.5	139.7	141.1
sheep*	15.2	13.9	13.0	13.4	13.7	13.8
other*	4.3	3.9	3.6	3.9	3.4	3.1
energy use	13.9	13.7	13.4	12.1	11.6	11.8
			tonnes CO_2 eqv per ha			
Ag GHG Emissions**	4.9	4.8	4.6	5.0	5.1	5.1
Energy GHG Emissions	0.3	0.3	0.3	0.3	0.3	0.3
			tonnes NH_3 per farm			
Total farm average NH3 emissions	1.01	0.99	0.98	1.05	1.06	1.08
of which dairy	0.36	0.36	0.37	0.38	0.39	0.39
cattle	0.54	0.52	0.50	0.54	0.54	0.55
sheep	0.02	0.02	0.02	0.02	0.02	0.02
chemical fertiliser	0.09	0.09	0.09	0.11	0.11	0.13
			kg NH_3			
NH_3 emissions per hectare	23.25	22.94	22.42	24.78	24.88	24.85
NH_3 emissions per Euro output	0.0216	0.0222	0.0208	0.0218	0.0204	0.0219
			kg per ha			
N Balance per hectare	89.5	80.1	71.0	79.1	81.7	93.6
P Balance per hectare	6.7	6.4	6.1	6.2	7.2	8.3
			percentage			
N use efficiency	23.6	25.9	27.7	27.1	28.1	24.1
P use efficiency	61.1	64.9	63.5	68	64.5	59.0

*** Methodological update from previous report, with historical numbers revised accordingly.**