Teagasc National Farm Survey 2019 Sustainability Report

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03rd November, 2020

ISBN: 978-1-84170-668-9

Acknowledgements

The authors wish to thank all who contributed to the National Farm Survey 2019 – to the farmers who participate voluntarily and the Central Statistics Office (CSO) for sample selection and provision of national population weights. Grateful acknowledgement is also due to the Teagasc research staff involved in the collection and validation of the farm level data: J. Colgan, A Curley, L. Deane, L. Delaney, P. Harnett, P. Healy, P. Madden, J. McConnon, E. McGrath, K. McNamara, M. Nicholson, J. Robinson, J. Teehan and to M. Moloney for the administration of the survey.

The authors would like to thank Teagasc colleagues, past and present, Emma Dillon, Brian Moran, Kevin Hanrahan, Mary Ryan, Thia Hennessy and John Lynch who were involved in developing previous iteration of this report.

Any errors or omissions remain the responsibility of the authors.

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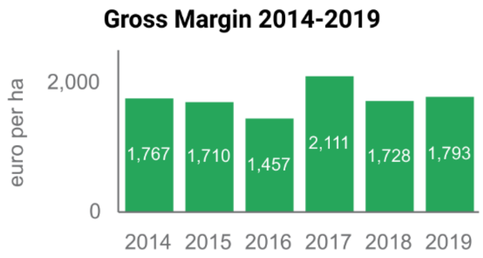
Abbreviations

CH_4	Methane
CO_2	Carbon dioxide
CO_2 e	Carbon dioxide equivalent
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

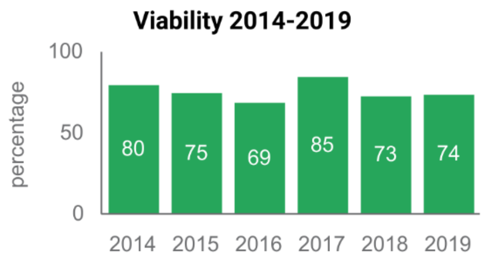
Gross Margin per ha 2019

€1,793



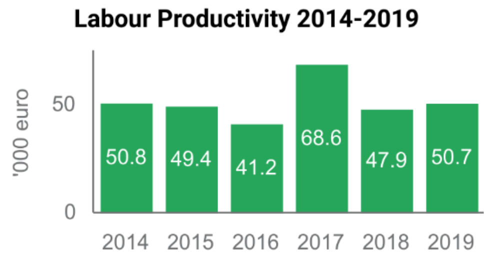
Viability 2019

74%



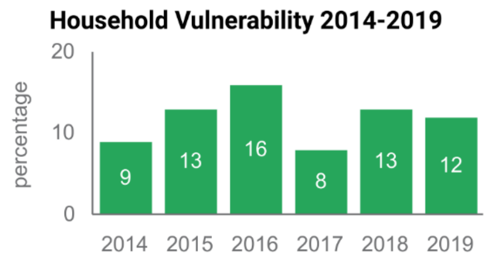
Productivity of Labour Unit 2019

€50,683



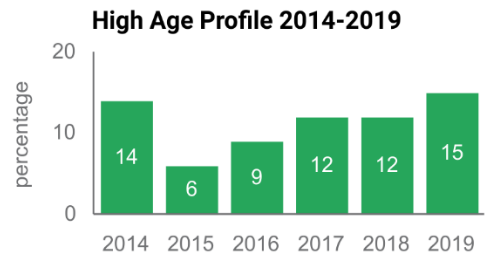
Household Vulnerability 2019

12%



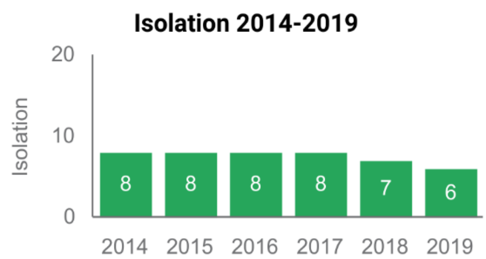
High Age Profile 2019

15%



Isolation 2019

6%

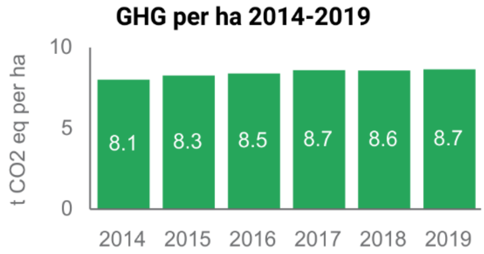


Source: Teagasc National Farm Survey

Dairy: Environmental Sustainability

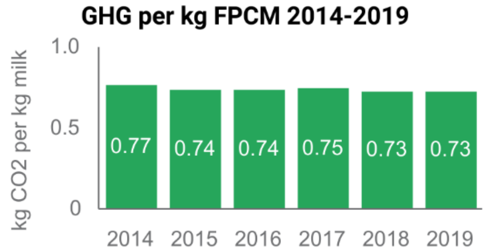
CO2 eq per ha 2019

8.7



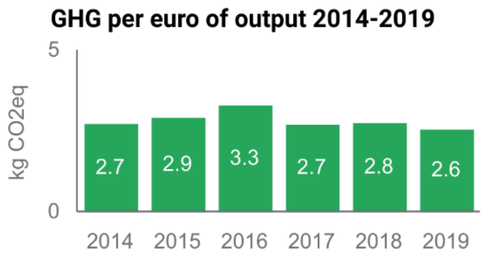
CO2 Eq per kg FPCM 2019

0.73



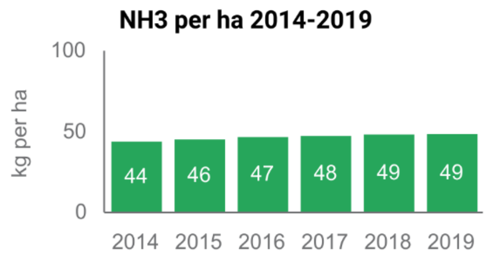
CO2 Eq per euro of output 2019

2.6



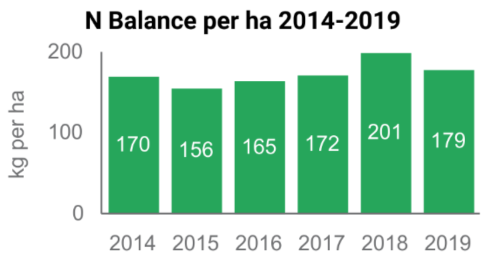
NH3 kg per ha 2019

49



N Balance kg per ha 2019

179

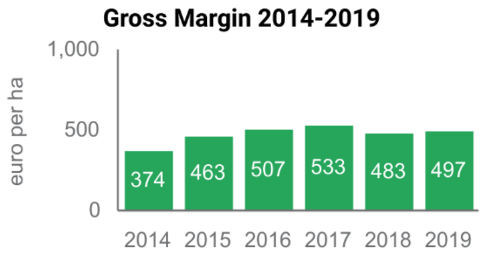


Source: Teagasc National Farm Survey

Cattle: Economic and Social Sustainability

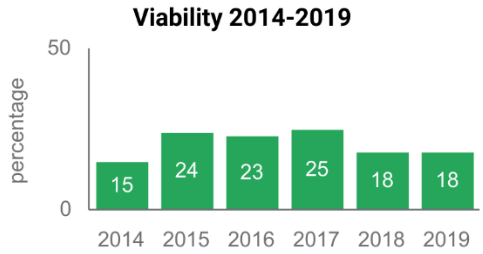
Gross Margin per ha 2019

€497



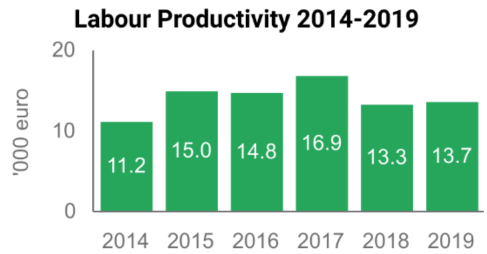
Viability 2019

18%



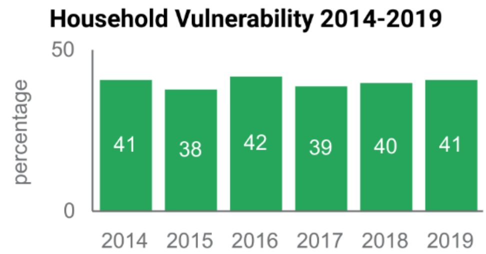
Productivity of Labour Unit 2019

€13,688



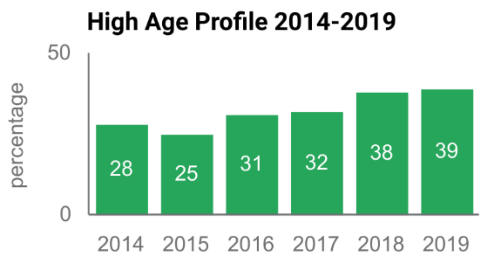
Household Vulnerability 2019

41%



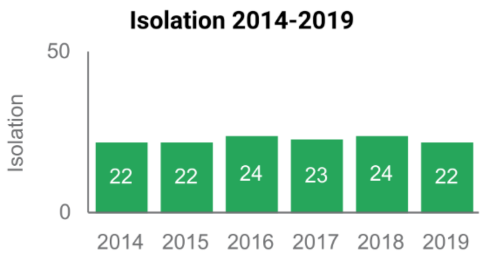
High Age Profile 2019

39%



Isolation 2019

22%

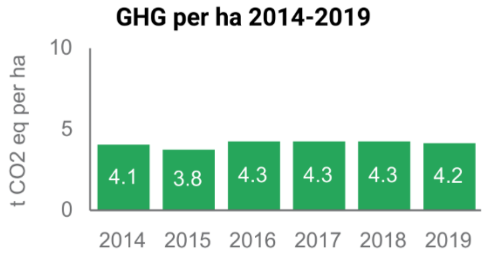


Source: Teagasc National Farm Survey

Cattle: Environmental Sustainability

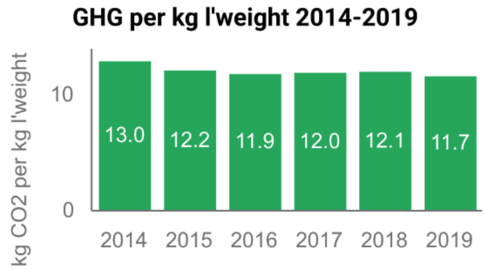
CO2 eq per ha 2019

4.2



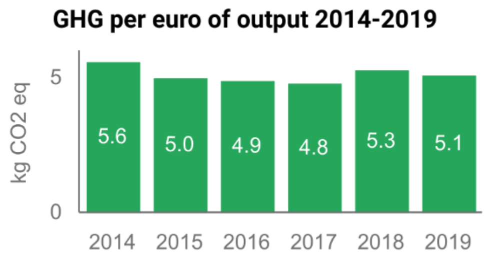
CO2 eq per kg of liveweight 2019

11.7



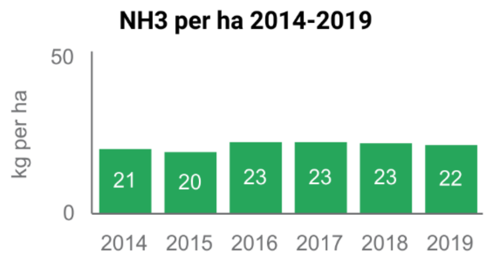
CO2 per euro of output 2019

5.1



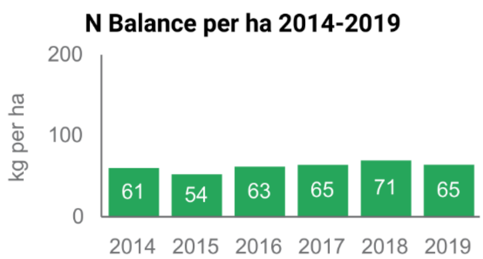
NH3 kg per ha 2019

22



N Balance kg per ha 2019

65

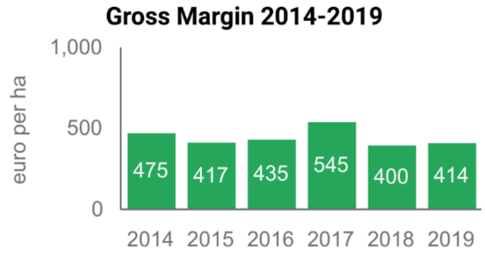


Source: Teagasc National Farm Survey

Sheep: Economic and Social Sustainability

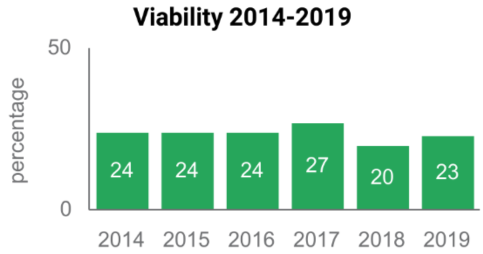
Gross Margin per ha 2019

€414



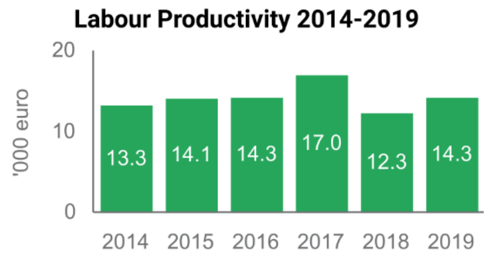
Viability 2019

23%



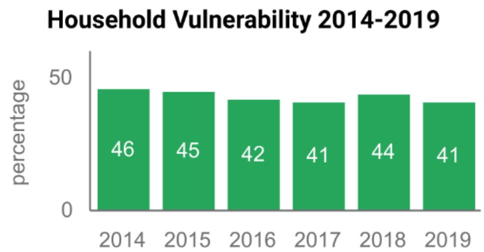
Productivity of Labour 2019

€14,259



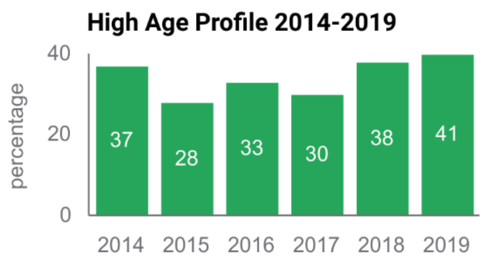
Household Vulnerability 2019

41%



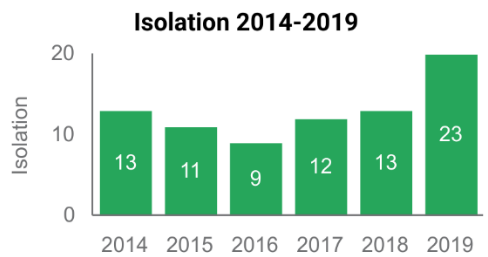
High Age Profile 2019

41%



Isolation 2019

23%

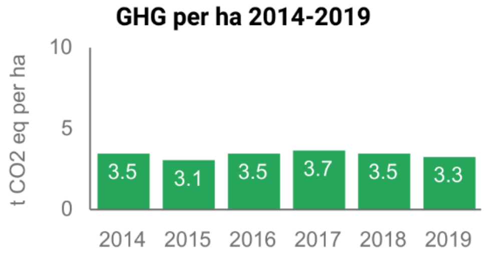


Source: Teagasc National Farm Survey

Sheep: Environmental Sustainability

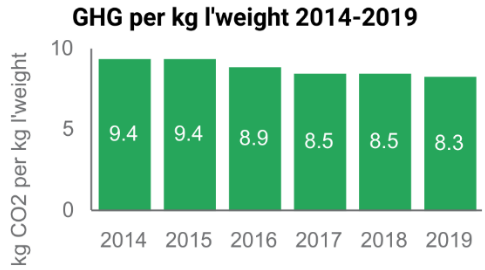
CO2 eq per ha 2019

3.3



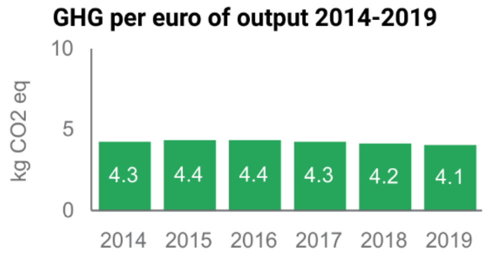
CO2 per kg liveweight 2019

8.3



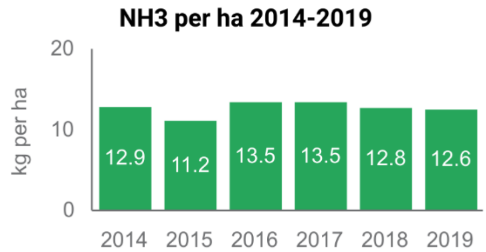
CO2 per euro of output 2019

4.1



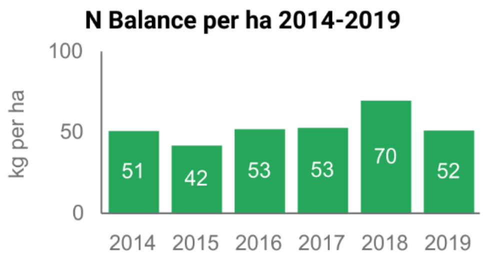
NH3 kg per ha 2019

12.6



N Balance kg per ha 2019

52

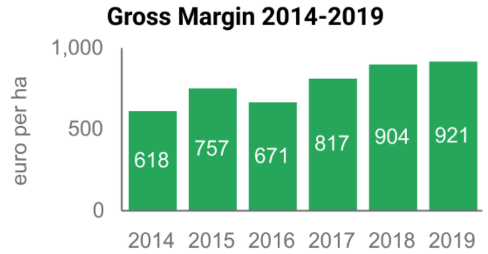


Source: Teagasc National Farm Survey

Tillage: Economic and Social Sustainability

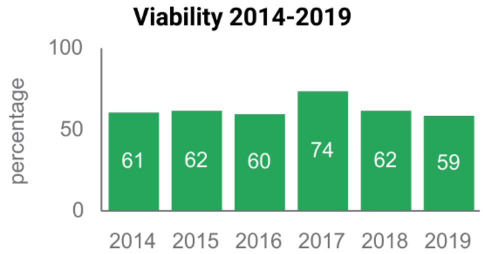
Gross Margin per ha 2019

€921



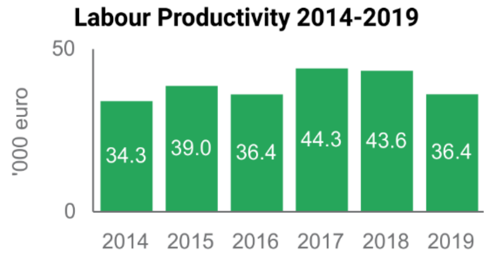
Viability 2019

59%



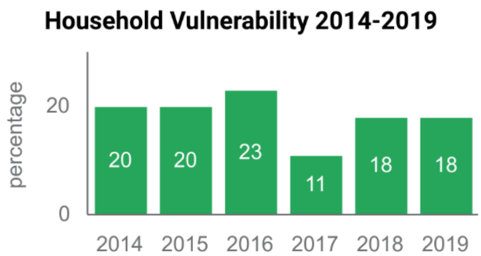
Productivity of Labour Unit 2019

€36,410



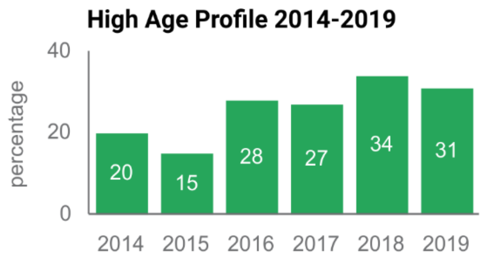
Household Vulnerability 2019

18%



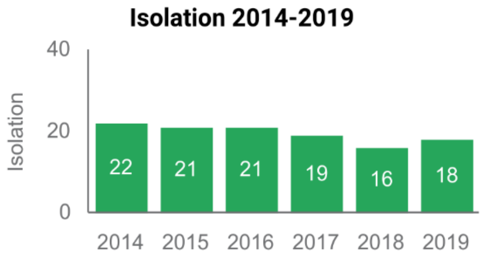
High Age Profile 2019

31%



Isolation 2019

18%

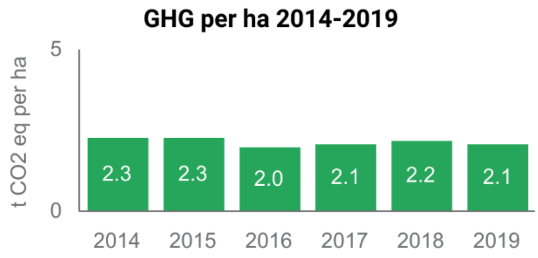


Source: Teagasc National Farm Survey

Tillage: Environmental Sustainability

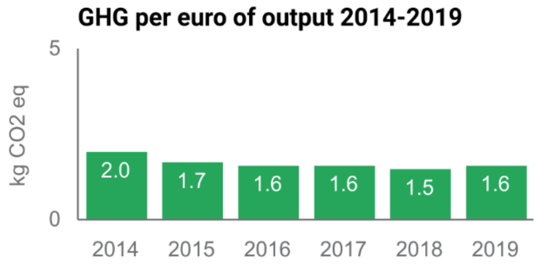
CO2 eq per ha 2019

2.1



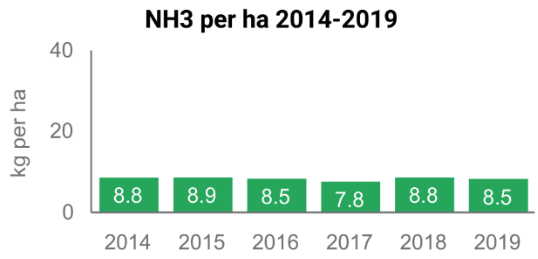
CO2 eq per euro of output 2019

1.6



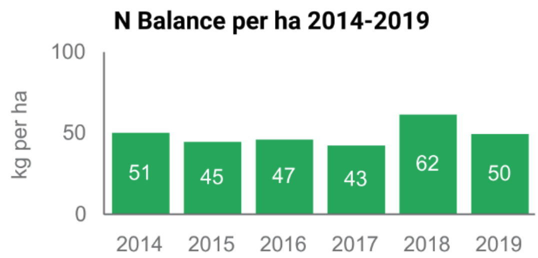
NH3 kg per ha 2019

8.5



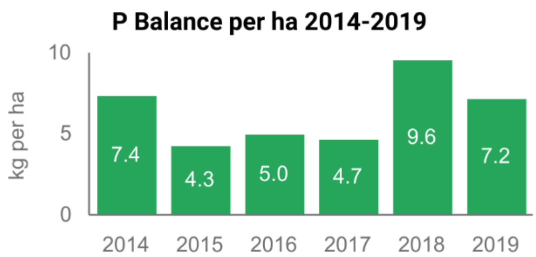
N Balance kg per ha 2019

50



P Balance kg per ha 2019

7.2



Source: Teagasc National Farm Survey

1. Introduction - Agricultural Sustainability

Globally, we face the grand challenge of trying to feed a growing human population, while minimising 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 influencing 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 nationally 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 (91,367 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 European 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 91,367 farms are represented in this study for 2019. 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 Donnellan et al., 2020). 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.in both a scientific and policy context), the sustainability indicator set will continue to evolve to maximise its 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. Indeed, the EU Farm to Fork strategy (EU Commission, 2020). proposes to develop the EU FADN into a Farm Sustainability Data Network, with a view to collecting data on sustainability indicators and reporting these in a common framework across the EU. The Teagasc National Farm Survey is leading the way on this as evidenced by this report.

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; Buckley & Donnellan, 2020). Updates presented here are based on methodological refinements, as well as additional data on agricultural activities on Irish farms collected and published by the Teagasc NFS. In particular, it should be noted that in this report for 2019 there have been methodological developments in the estimation of greenhouse gas emissions since the publication of the 2018 report. 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; Buckley & Donnellan, 2020). 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 therefore is consistent with international best practice.

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 compensated adequately 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 the European Commission 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 value of net changes 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 as set down in the under the National Minimum Wage Act, 2000 (as outlined by Government of Ireland, 2020a) 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.

f) Family Farm Income

Family Farm Income (FFI) is the return from farming for farm family labour, land and capital. It is a function of gross output plus subsidies less total net expenses.

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	%
Family Farm Income	Family Farm Income per hectare	€ / hectare

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.

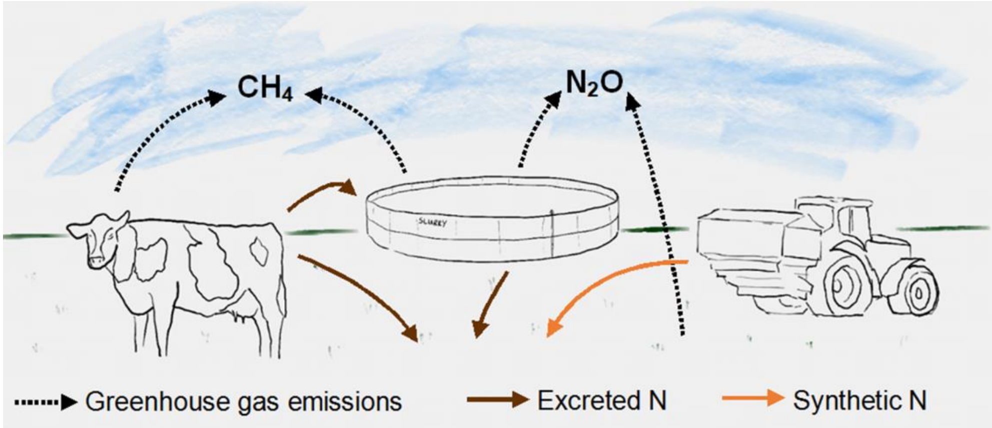
1. Greenhouse gas emissions

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 required 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). The Climate Action and Low Carbon Development (Amendment) Bill 2020 (Government of Ireland, 2020b) proposes a net-zero greenhouse gas emissions by 2050 for the state. 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, liming and urea application are also included in the analysis presented in this report.

A complicating factor inherent in a farm based approach to emissions measurement, (as opposed to a national emissions inventory approach), 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 a particular 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, 2020; SEAI, 2020)) 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 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

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 nitrogen based fertilisers applied (e.g. CAN, urea, protected 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 when it leaves the farm. 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 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 this 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 Dairy LCA model operational using NFS data. The additional data includes 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 ammonia 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 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
NH_3 emissions per farm	NH_3 emissions	Tonnes NH_3 equivalent / farm
NH_3 emissions per hectare	NH_3 emissions per hectare	Tonnes NH_3 equivalent / hectare
NH_3 emissions per kg of output	NH_3 emissions efficiency	kg NH_3 equivalent / kg output *AND* kg NH_3 / € output
N balance	N transfer risk	kg N surplus / ha^{-1}
N use efficiency	N retention efficiency	% N outputs / N inputs
N surplus per kg of output	N emissions efficiency	kg N surplus / kg output
P balance	P transfer risk	kg P surplus / ha^{-1}
P use efficiency	P retention efficiency	% P outputs / P inputs

3.3 Social Indicators

A farm will only be sustainable if employment in agriculture 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 entrants to farming with fewer younger people 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 a viable farming sector 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) Hours worked

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
Hours worked	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 newly developed management techniques. Hence, it is important to measure uptake of such innovations to ensure that evolving 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, and also reflect 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 where a specific technology or practice is used or where 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 farmers have with farm extension services and their peers.
- ***Spring slurry spreading*** (spreading at least 50% of total slurry between January and April) was identified as an important practice to minimise nutrient 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.
- ***Protected urea fertiliser use*** is associated with lower greenhouse gas emissions compared to Calcium Ammonium Nitrate (CAN). Protected urea is also associated with lower ammonia emissions compared to conventional straight urea fertiliser formulations and greater nitrogen recovery for agronomic purposes.
- ***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.
- ***Protected urea fertiliser use*** is associated with lower greenhouse gas emissions compared to Calcium Ammonium Nitrate (CAN). It is also associated with lower ammonia emissions compared to straight urea fertiliser formulations and greater nitrogen recovery for agronomic purposes.
- ***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.
- ***Protected urea fertiliser use*** is associated with lower greenhouse gas emissions compared to Calcium Ammonium Nitrate (CAN). It is also associated with lower ammonia emissions compared to straight urea fertiliser formulations and greater nitrogen recovery for agronomic purposes.
- ***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
Protected urea use	Protected urea use	Protected urea use	Protected urea use
Reseeding	Reseeding	Reseeding	Break crop
Low emission slurry spreading	Low emission slurry spreading		
Milk Recording			

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

4. Sustainability Indicator Results 2019

The main diagrams used to represent 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 hypothetical 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

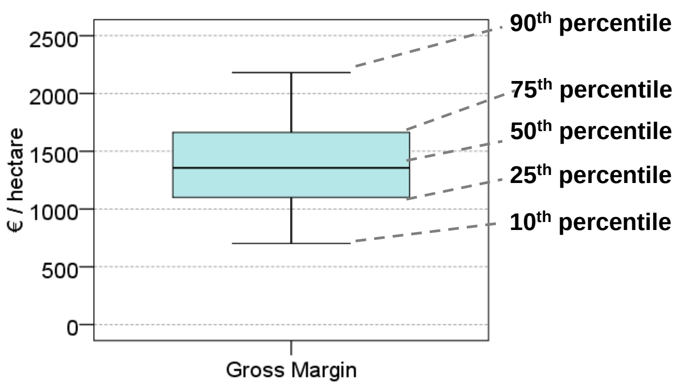
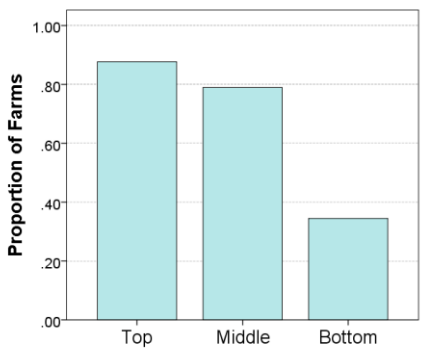


Figure 4: Example Bar Chart Proportion of farms

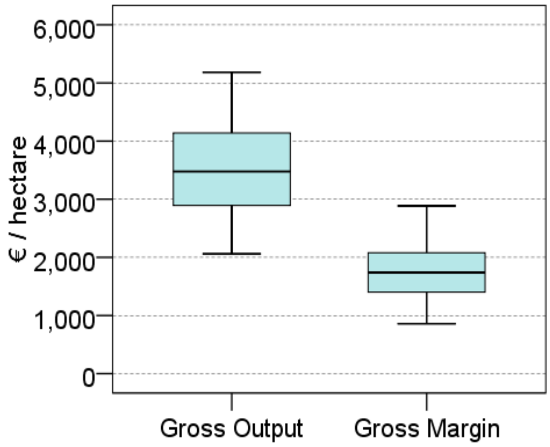


4.1 Dairy Farms

Economic Sustainability Indicators

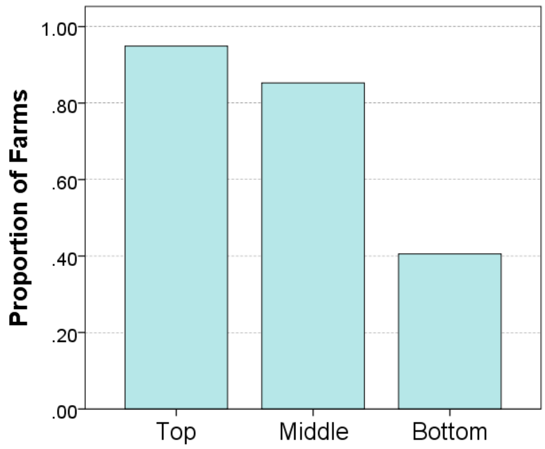
In 2019, the average dairy farm output per hectare was €3,605, and the average market gross margin per hectare was €1,793. Median values were slightly lower as shown in Figure 5.

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



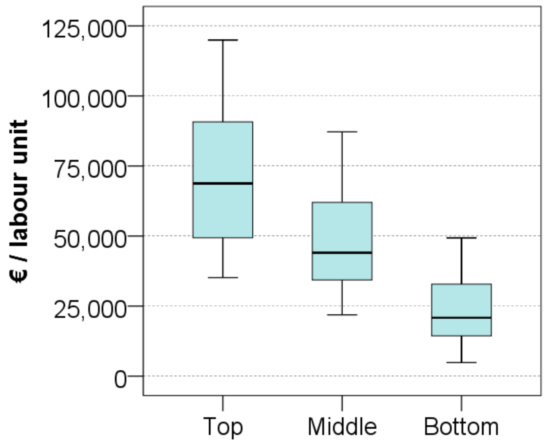
Overall 74% of dairy farms were economically viable in 2019. This ranged from 95% for the top third of economic performing dairy farms to 41% for the bottom third as shown in Figure 6.

Figure 6: Economic Viability: Dairy Farms



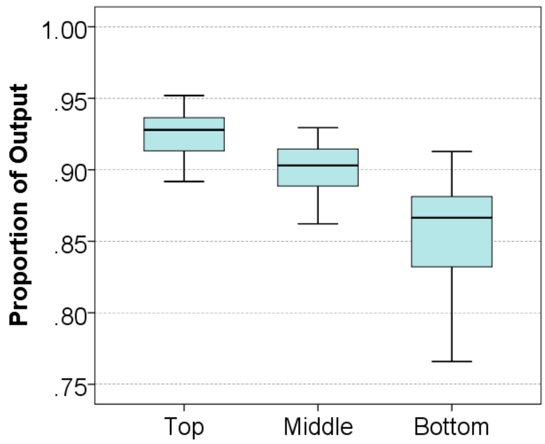
Average income per labour unit (unpaid family labour) for dairy farms in 2019 was €50,682. Average incomes per labour unit were €77,073, €48,858 and €25,115 for the top, middle and bottom performing farm groupings respectively. However, there was a large range in the return to labour for dairy farms, especially for the higher performing farms, as shown in Figure 7.

Figure 7: Productivity of Labour: Dairy Farms



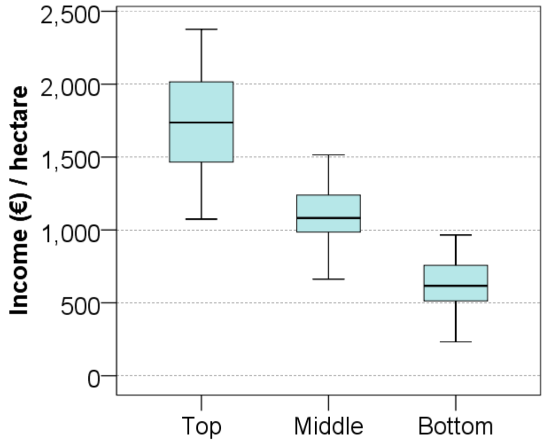
On average, dairy farms derived 88% of gross output directly from the market in 2019. The degree of market orientation was highest for the top third of dairy farms and the range was largest among the bottom third, as illustrated in Figure 8.

Figure 8: Market Orientation: Dairy Farms



The average family farm income per hectare on dairy farms was €1,123 in 2019. Within subcategories, the average income ranged from €1,720 from the top performing cohort to €559 for the bottom performers in economic terms. For the full dairy farm population, there was a large range of income per hectare across all three groups as seen in Figure 9.

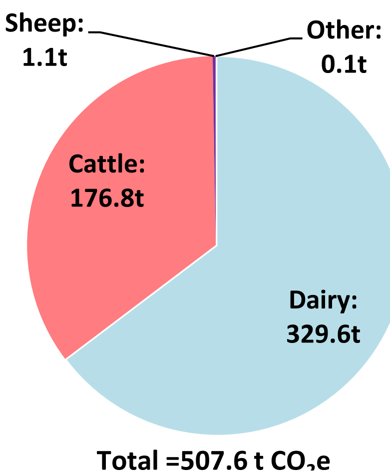
Figure 9: Family Farm Income per hectare: Dairy Farms



Environmental Sustainability Indicators

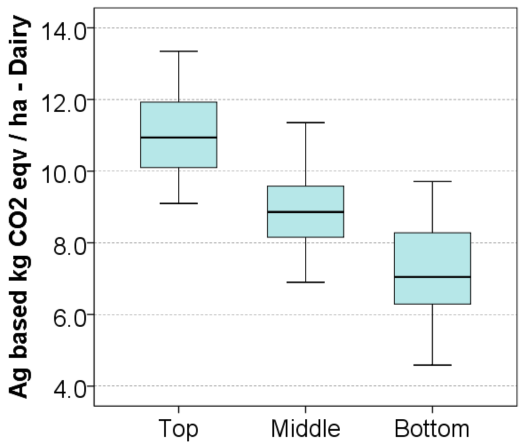
Figure 10 indicates that the average dairy farm produced 507.6 tonnes of agricultural GHG emissions (in CO_2 equivalent) in 2019. It should be noted that this measure is based on the IPCC definition of agricultural emissions. The majority of dairy farm emissions, 64.9%, were from milk based output, with 34.8% allocated to beef production on these farms (this would include emissions from cull cows and calf sales and transfers). The remaining emissions, less than 1%, were associated with sheep and crop production on dairy farms.

Figure 10: Agricultural GHG Emissions for the average Dairy Farm



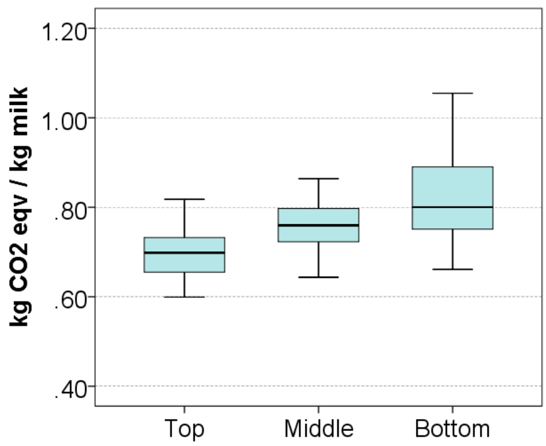
The average dairy farm emitted 8.69 tonnes of CO_2 equivalent per hectare. The better performing dairy farms in an economic sense tended to operate at higher intensities and this is reflected in their higher emissions of GHG per hectare as shown in Figure 11.

Figure 11: Agricultural GHG Emissions per hectare: Dairy Farms



When emissions allocated to dairy output are expressed per kilogramme of milk output, the average dairy farm emitted 0.74 kg CO_2 equivalent per kg of milk produced.[2] Figure 12 shows that those farms with a better economic performance also have the lowest emissions intensity per kg of milk produced.

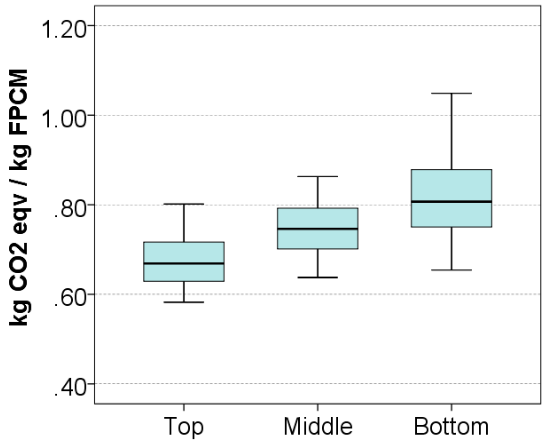
Figure 12: Agricultural GHG Emissions per kg of milk: Dairy Farms



[2] Convert kg to litre by multiplying by 1.03

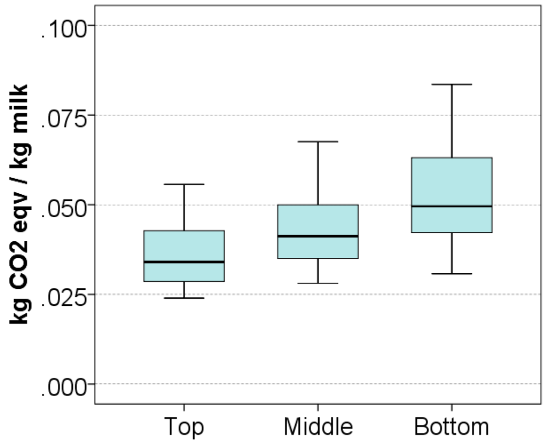
Emissions allocated to dairy output are also expressed per kg of fat and protein corrected milk (FPCM), which is standardized to 4% fat and 3.3% true protein per kg of milk. The average farm emitted 0.73 kg CO_2 equivalent per kg of FPCM produced. Figure 13 also shows that farms with the best economic performance also have the lowest emissions intensity per kg of FPCM produced.

Figure 13: Agricultural GHG Emissions per kg of FPCM: Dairy Farms



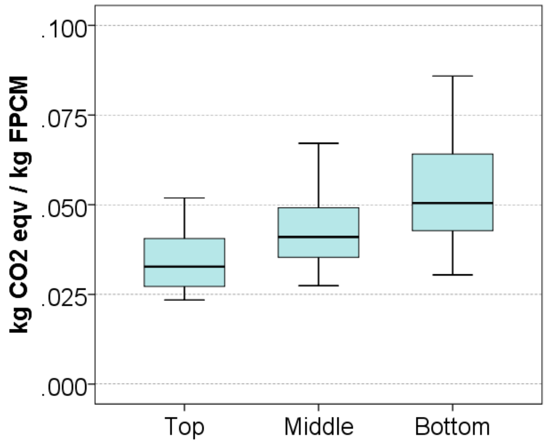
The average electricity and fuel based GHG dairy farm emissions were 0.0478 kg CO_2 equivalent per kg of milk in 2019. Figure 14 indicates that similar to agricultural based GHG emissions intensity per kg of milk, lower energy usage related GHG emissions per kg of milk produced is evident among farms with better economic performance.

Figure 14: Energy use related GHG Emissions per kg of Milk: Dairy Farms



The average electricity and fuel based GHG emissions were 0.0472 kg CO2 equivalent per kg of FPCM produced as shown in Figure 15. This indicator again shows that the top economic performers were more efficient in terms of FPCM produced per kg of energy related CO2 emissions generated.

Figure 15: 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 1.14 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 16 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 16: Total LCA based GHG emissions (Agriculture & Energy) per kg of FPCM: Dairy Farms

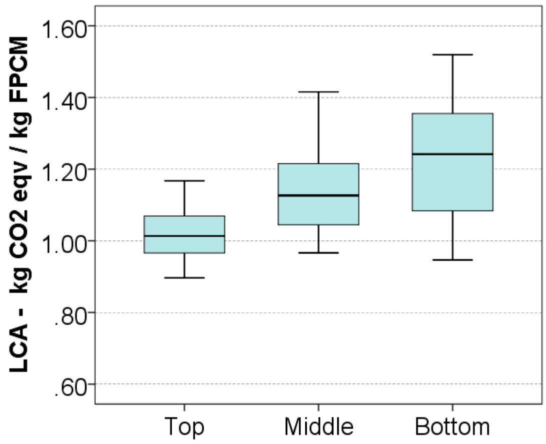
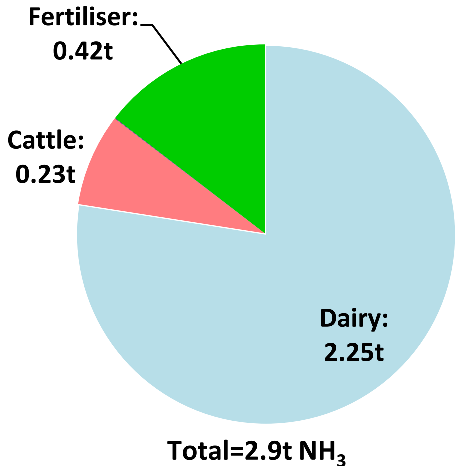


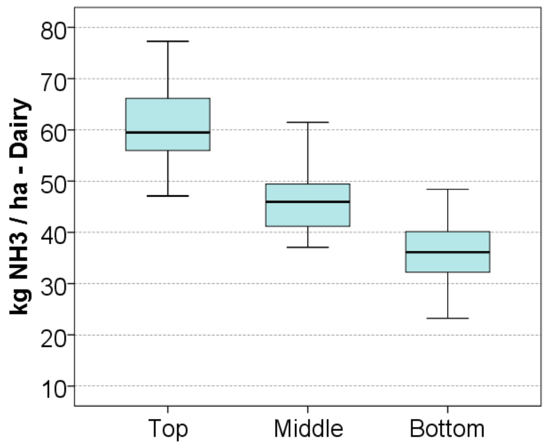
Figure 17 indicates that the average dairy farm produced approximately 2.9 tonnes of ammonia (NH_3) emissions in 2019. This calculation is based on an approach consistent with the EPA national inventory methodology. The majority of dairy emissions, 77%, were from milk based output, with 8% allocated to beef output (includes cull cows and calf sales / transfers mainly). The remaining emissions are those associated with chemical N fertiliser applications.

Figure 17: Total Ammonia Emissions for the average Dairy Farm



The average dairy farm emitted 49 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 in higher emission of ammonia per hectare, as shown in Figure 18.

Figure 18: Ammonia Emissions kg per hectare: Dairy Farms



The average dairy farm emitted 0.0057 kg of NH_3 per kg of FPCM produced. Figure 19 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 20. However, NH_3 per kg of milk was slightly higher at 0.0058.

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

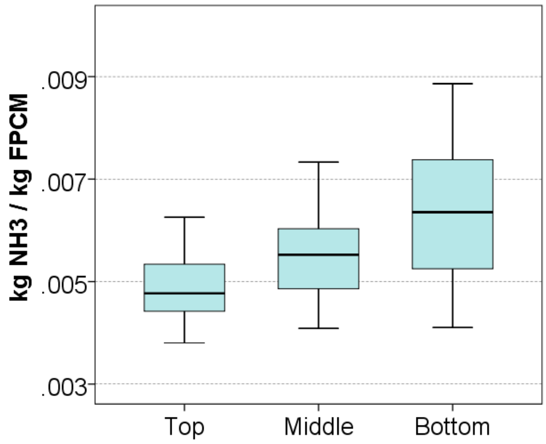
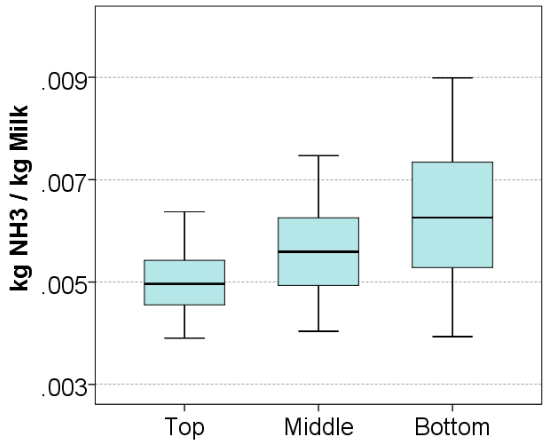
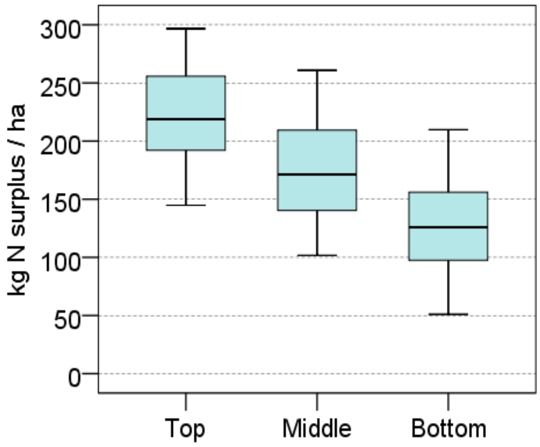


Figure 20: Ammonia Emissions per kg of Milk: Dairy Farms



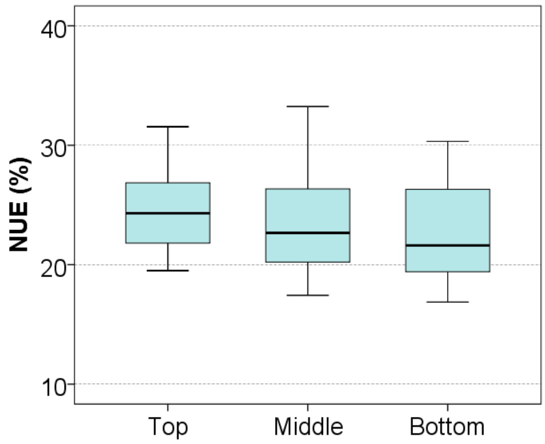
Nitrogen balance (excess of N inputs over outputs) averaged 178.7 kg N surplus per hectare across all dairy farms in 2019. Figure 21 indicates that higher N surpluses per hectare are associated with superior economic performance. This is due to the greater production intensity on economically better performing farms.

Figure 21: N Balance per ha: Dairy Farms



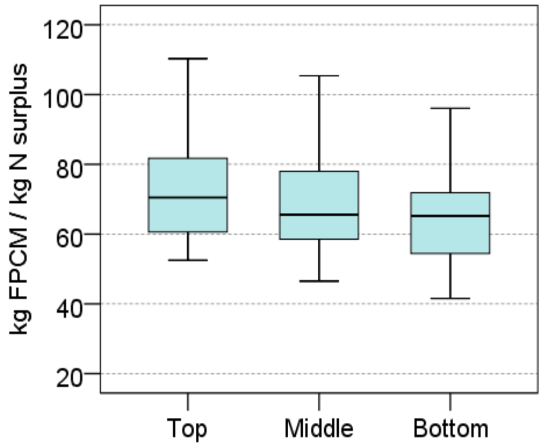
The average dairy farm had a NUE of 24.4%. Figure 22 demonstrates the slightly higher N use efficiency was evident among the better economic performing farmers, with the largest range prevalent among the middle and bottom cohorts.

Figure 22: N Use Efficiency: Dairy Farms



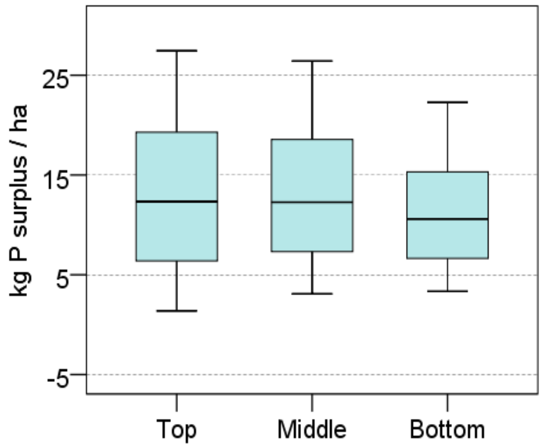
On average dairy farms produced 73.7 kg of FPCM per kg of surplus nitrogen. Figure 23 shows that higher NUE of milk production was linked with higher economic performance, with the top and middle cohorts producing more kg of FPCM per kg of surplus nitrogen.

Figure 23: NUE of Milk Production



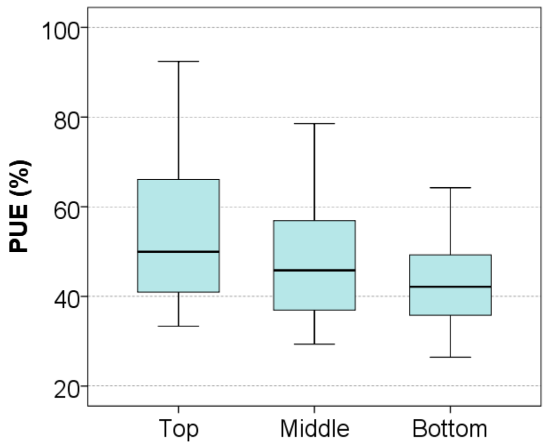
Phosphorus balance (excess of inputs over outputs) averaged 13.3 kg P surplus per hectare across all dairy farms in 2019. Figure 24 shows that there was a larger range of results, especially for the top performing cohort.

Figure 24: P Balance per ha: Dairy Farms



The average dairy farm had a P use efficiency of 53.5%. Figure 25 indicates higher P use efficiency was again more prevalent among the better economic performing farmers.

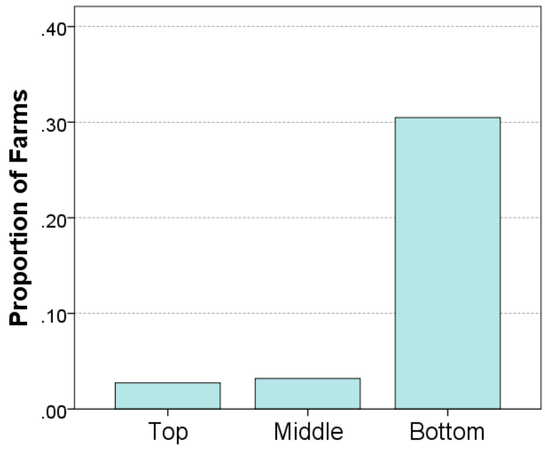
Figure 25: P Use Efficiency: Dairy Farms



Social Sustainability Indicators

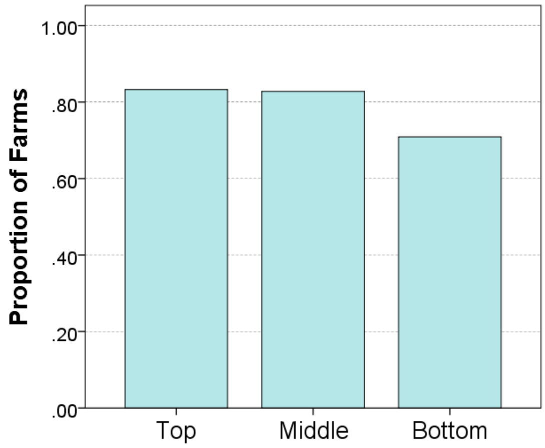
A minority of all dairy farm households, 12%, fell into the vulnerable category (non-viable and no off-farm employment). Figure 26 shows that there was a considerably larger proportion of households at risk among those farms with the lowest gross margin per hectare (30% among bottom third).

Figure 26: Household Vulnerability: Dairy



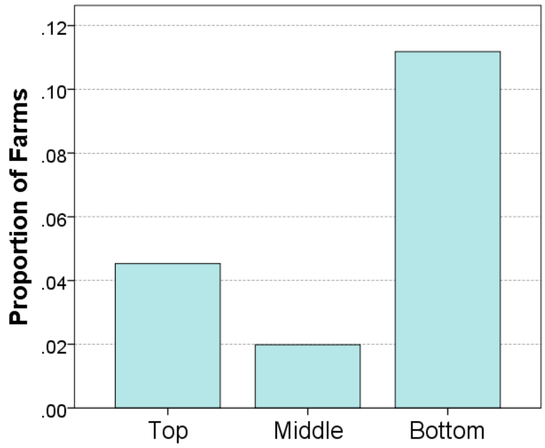
Overall, 79% of dairy farmers had received formal agricultural education of some description. Figure 27 shows that agricultural training rates were slightly higher across the middle and top performing cohorts.

Figure 27: Agricultural Education: Dairy



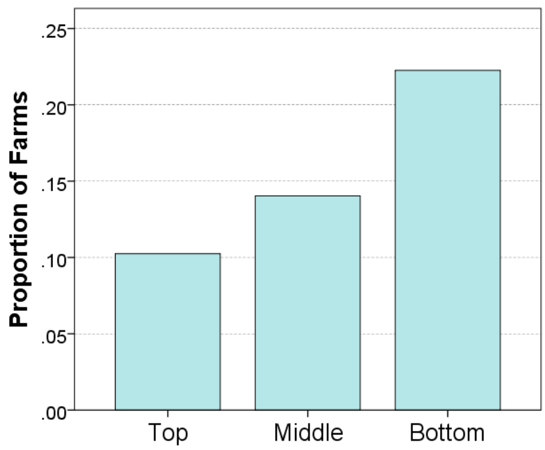
Only 6% of dairy farmers were living alone and were thus classified as being at risk of isolation. Figure 28 indicates that the risk was lowest for the middle preforming cohort.

Figure 28: Isolation Risk: Dairy Farms



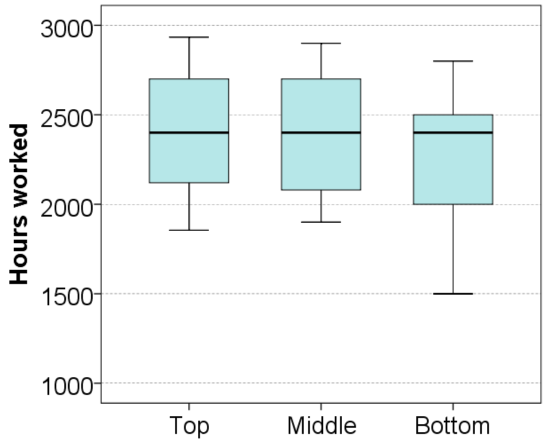
Across all dairy farms, 15% were identified as having a high age profile. Figure 29 shows that this was largest for the weaker economically performing dairy farms.

Figure 29: High Age Profile: Dairy Farms



On average, dairy farmers worked 2,365 hours per year on-farm (approximately 45.5 hours per week). Figure 30 shows that hours worked was highest for top and middle performing cohorts by economic performance. However, this figure does not take into consideration off-farm employment, or the share of hours worked by hired staff or other family members.

Figure 30: Hours Worked: Dairy Farm Operator

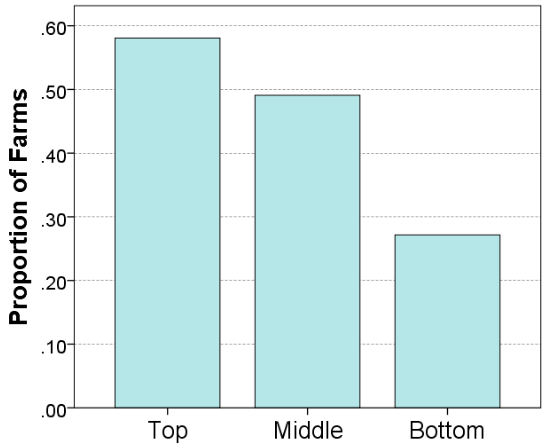


Dairy Innovation Indicators

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, application of protected urea fertiliser, as well as liming & grassland reseeding rates.

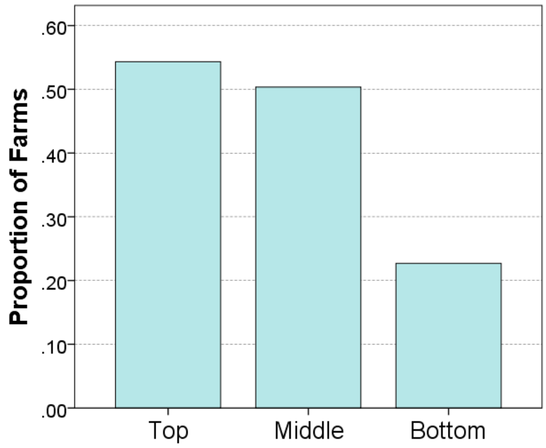
Figure 31 shows that those farms with better economic performance were more likely to use milk recording. Over 58% of the dairy farmers in the top group were milk recording, compared to 27% in the bottom group.

Figure 31: Milk Recording: Dairy Farms



Better economic performance was more prevalent among discussion group members. Membership rates were higher across the top and middle group, at over 50%, compared to 23% in the bottom cohort, as shown in Figure 32.

Figure 32: Discussion Group: Dairy Farms



The application of the majority of slurry in early spring was slightly higher across the top performing cohorts, as shown in Figure 33. However, all cohorts spread over 50% of slurry in springtime in 2019.

Figure 33: Spring Slurry: Dairy Farms

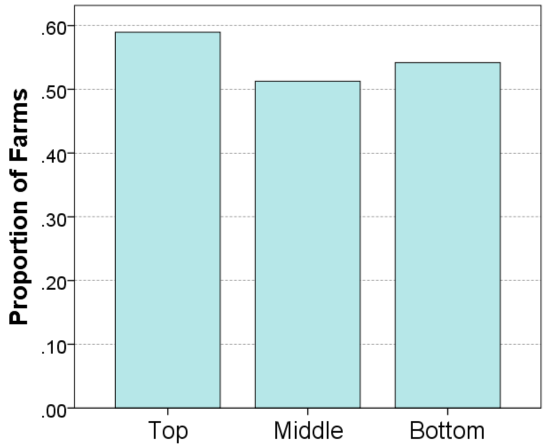


Figure 34 illustrates that greater use of low emissions slurry spreading equipment was associated with better economic performance. On average, nearly 53% of farmers in the top performing cohort used this technology, compared to circa 40% in the middle and bottom performing cohort.

Figure 34: Low emissions slurry spreading: Dairy Farms

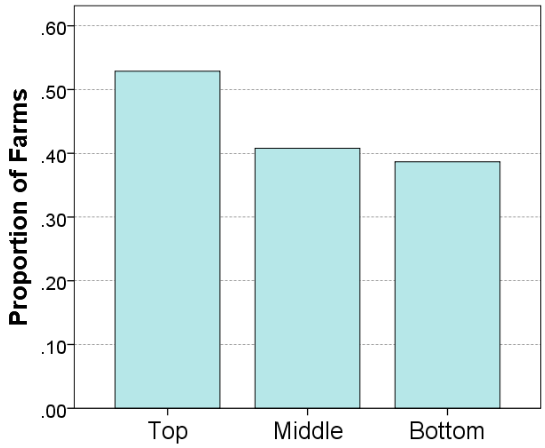


Figure 35 indicated that the use of protected urea fertiliser was more common across the higher economic performing farms. On average 21% of the top performing cohort used this fertiliser formulation compared to 6.5% of the bottom group.

Figure 35: Protected Urea Use: Dairy Farms

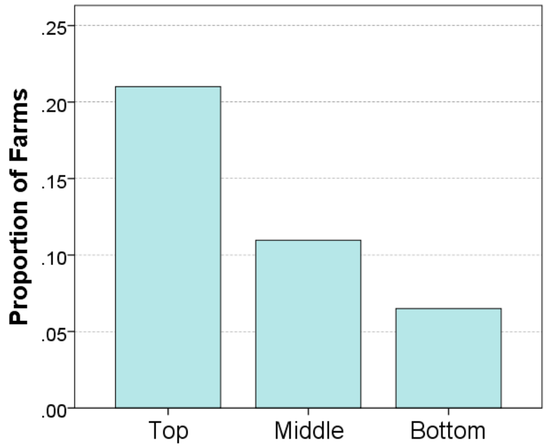


Figure 36 shows that liming was more prevalent among the better economic performers, with 42-44% of the top and the middle performing group engaging in this practice in 2019, compared to 23% for the bottom group.

Figure 36: Liming: Dairy Farms

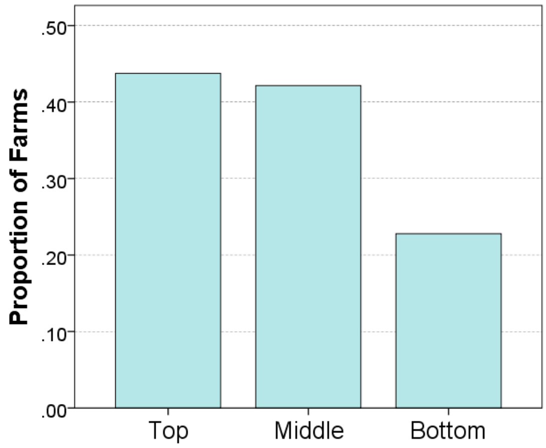
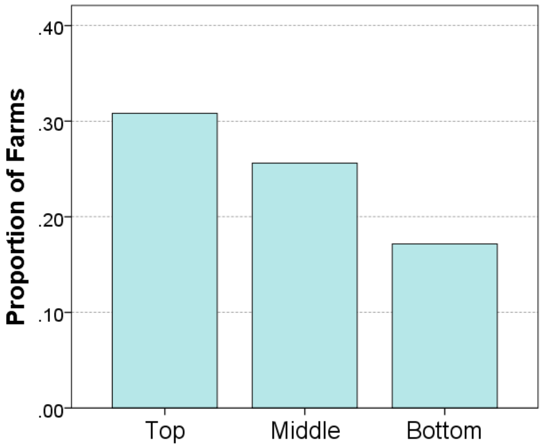


Figure 37 shows that reseeding was also more common among the better economic performing farms. A higher percentage of farmers in the top group (31%) engaged in reseeding of grassland compared to the bottom group (17%) in 2019.

Figure 37: Reseeding: Dairy Farms



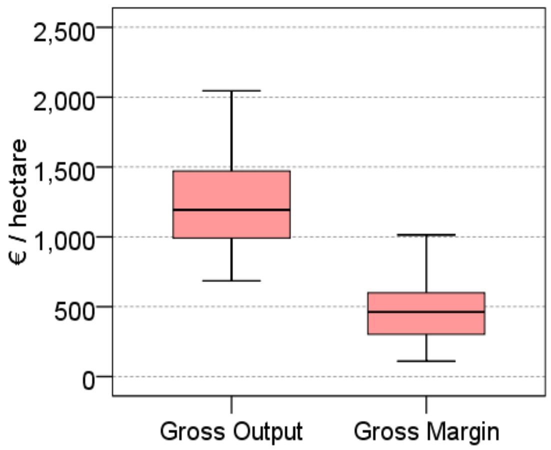
4.2 Cattle Farms

Cattle farms include both cattle rearing (mainly suckler based) and cattle finishing systems. Results for sustainability indicators in 2019 are presented below.

Economic Sustainability Indicators

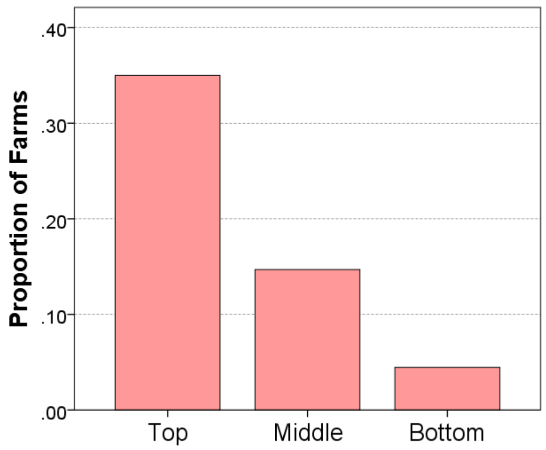
The average output per hectare for cattle farms was €1,306, and the average gross margin per hectare was €496 in 2019. There was a large range in farm economic performance, as shown in Figure 38.

Figure 38: Economic Return and Profitability of Land: Cattle Farms



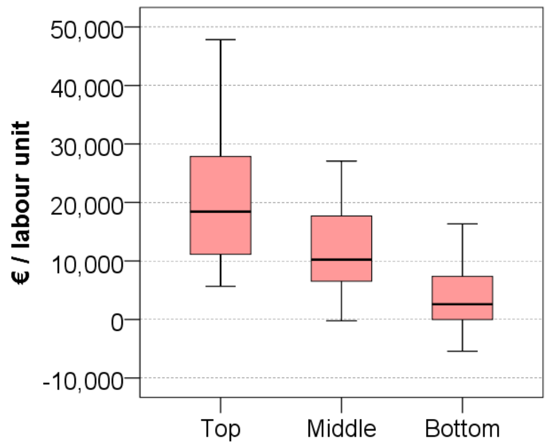
Only 18% of all cattle farms in the Teagasc NFS were defined as economically viable. As shown in Figure 39 the proportions deemed viable were 35%, 15% and 5% respectively, for the top, middle and bottom cohorts of farms by economic performance respectively.

Figure 39: Economic Viability: Cattle Farms



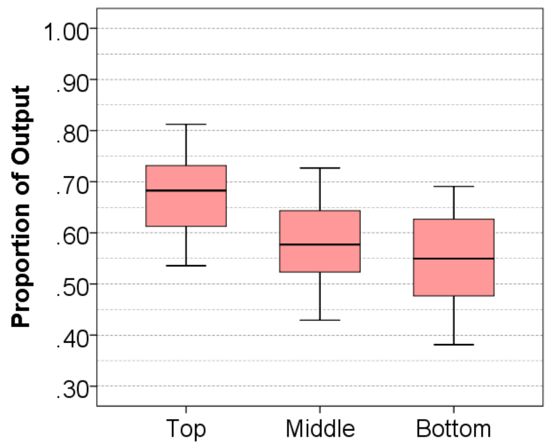
Across all cattle farms, the average income per labour unit was €13,688 in 2019. Figure 40 shows that this distribution was skewed by the top third of farms, which included a large number of relatively higher earners, with a mean income per labour unit of €23,664, compared with €12,955 and €4,112 for the middle and bottom cohorts of cattle farms respectively.

Figure 40: Productivity of Labour: Cattle



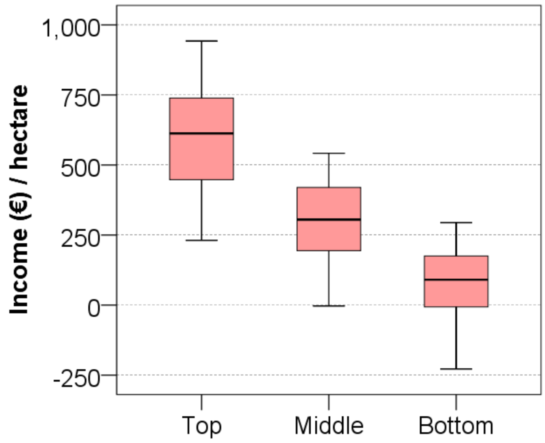
Market based output accounted for 60% of gross output across all cattle farms, with the remaining 40% accounted for by direct payment receipts. Figure 41 shows greater market orientation was exhibited across farms with better economic performance.

Figure 41: Market Orientation: Cattle Farms



The average family farm income per hectare on cattle farms was €311 in 2019. Across the subgroups, the average ranged from €603 for the top performing cohort to €49 for the bottom performers economically. Figure 42 shows significant ranges in income per hectare across the 3 groups, with negative income per hectare returned by a section of the bottom performing cohort.

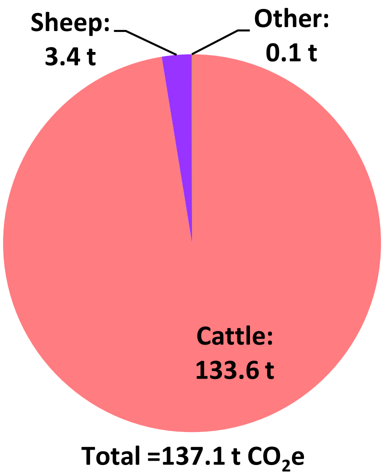
Figure 42: Family Farm Income per hectare: Cattle Farms



Environmental Sustainability Indicators

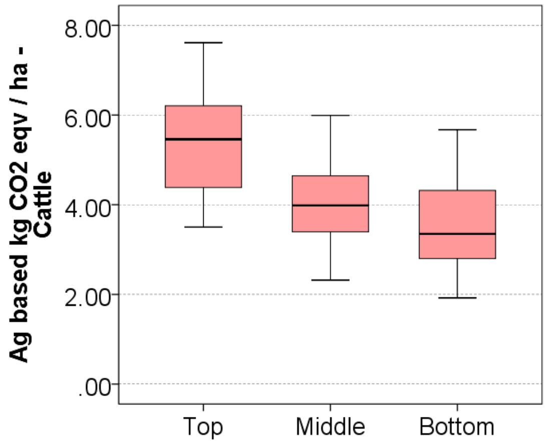
The average cattle farm produced 137.1 tonnes CO_2 equivalent of agricultural GHG emissions in 2019. Figure 43 shows that beef production was the principal source, generating 97.5% of these emissions. Sheep production was responsible for approximately 2.5% of total emissions on Irish cattle farms, and a very small proportion (less than 0.04%) was derived from other enterprises on these farms.

Figure 43: Agricultural GHG Emissions for the average Cattle Farm



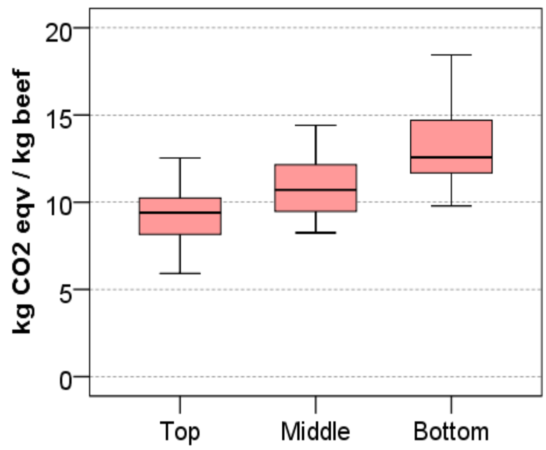
The average cattle farm emitted 4.2 tonnes of CO_2 equivalent of agriculturally generated GHG emissions per hectare in 2019. Emissions per hectare were higher for the more profitable cattle farms, which tended to be stocked at a higher intensity.

Figure 44: Agricultural GHG Emissions per hectare: Cattle Farms



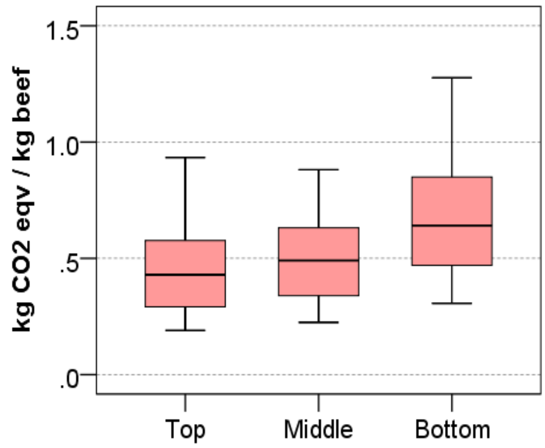
The emissions generated by cattle can be expressed in terms of their live-weight output (estimated using CSO price data). Figure 45 illustrates that there is a large range of emissions per kg of beef live-weight output. A positive association exists between emissions efficiency and economic performance. The top performing third of farms emitted, on average, 9.4 kg CO_2 equivalent per kg of live-weight beef produced, compared with 14.7 kg for the bottom performing third of cattle farms. The average level of GHG emissions across all farms was 11.7 kg CO_2 equivalent per kg beef of live-weight produced.

Figure 45: Agricultural GHG Emissions per kg live-weight beef produced: Cattle Farms



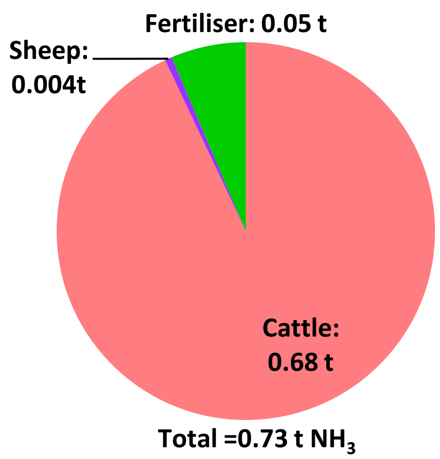
On average, electricity and fuel based GHG emissions across all cattle farms was 0.58 kg of CO_2 equivalent per kg beef live-weight produced. Figure 46 illustrates that energy based GHG emissions per unit of product were also lower on farms with better economic performance. The top third produced an average of 0.49 kg CO_2 energy-based emissions per kg of live-weight beef produced, while for the bottom performing third this figure was 0.71 kg.

Figure 46: Energy use related GHG Emissions per kg live-weight beef: Cattle Farms



The average cattle farm emitted 0.73 tonnes of ammonia (NH_3). Over 93% of total NH_3 emissions were linked with beef production, 6% were associated with chemical N fertiliser use and the remainder reflected emissions from the sheep enterprise on cattle farms, as shown by Figure 47.

Figure 47: Total Ammonia Emissions for the average Cattle Farm



On average, cattle farms emitted 22.3 kg of NH_3 per hectare in 2019. This ranged from 28.9 kg per hectare for the top performing cohort, to 17.3 per hectare for the bottom third, as shown by Figure 48. Emissions per hectare were higher for the more profitable cattle farms, which also tend to be stocked at a higher intensity.

Figure 48: Ammonia Emissions per hectare: Cattle Farms

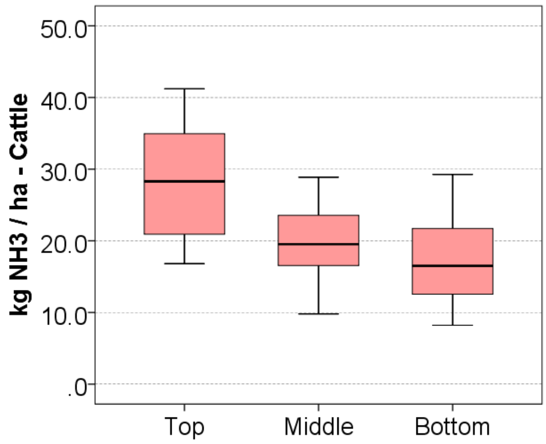


Figure 49 illustrates that, in terms of live-weight of beef produced, the more profitable cattle farmers have a lower level of ammonia emissions. There was a large range of results, especially for the bottom performing cohort of cattle farmers. On average, a kg of live-weight beef was produced at an intensity of 0.0598 kg of NH_3.

Figure 49: Ammonia Emissions per kg live-weight beef produced: Cattle Farms

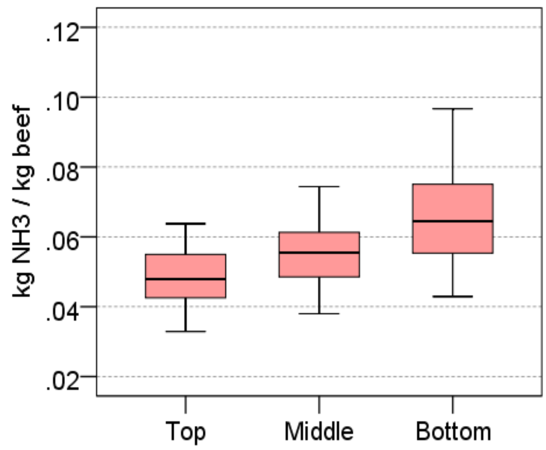
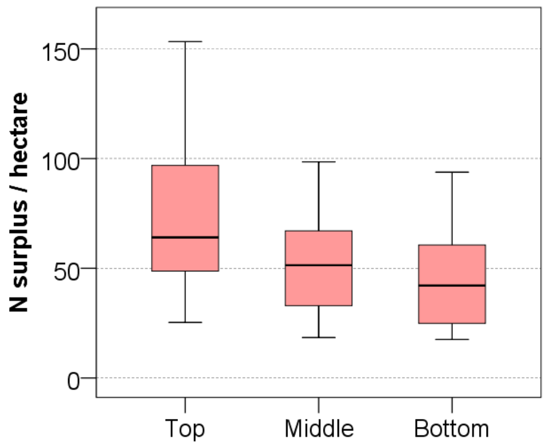


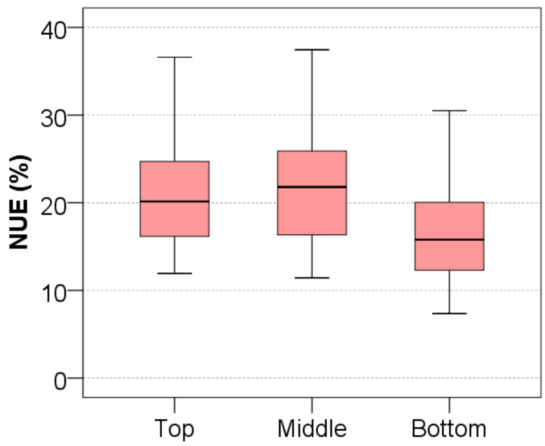
Figure 50 indicates that the nitrogen surplus per hectare tended to be higher on cattle farms that also performed better economically. In general, these farms are operated more intensively. The top performing third of cattle farms had an average nitrogen surplus of 79.3 kg N per hectare, compared to 47.9 kg N per hectare for the bottom third of farms.

Figure 50: N Balance per ha: Cattle Farms



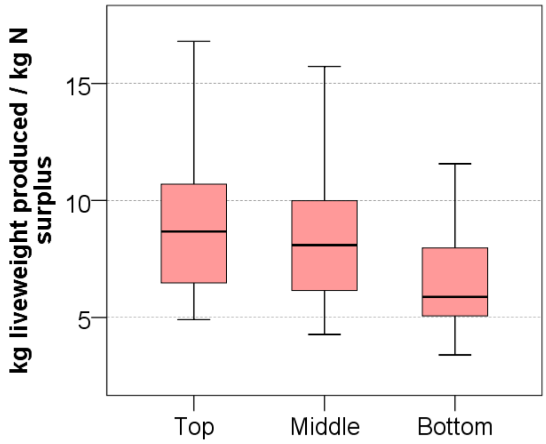
The average NUE across all cattle farms was 22.3%, but the range in NUE across the sample of cattle farms was significant, as shown in Figure 51. Despite the higher application rates, NUE tended to be higher on across the middle and top economic performing cohorts.

Figure 51: N Use Efficiency: Cattle Farms



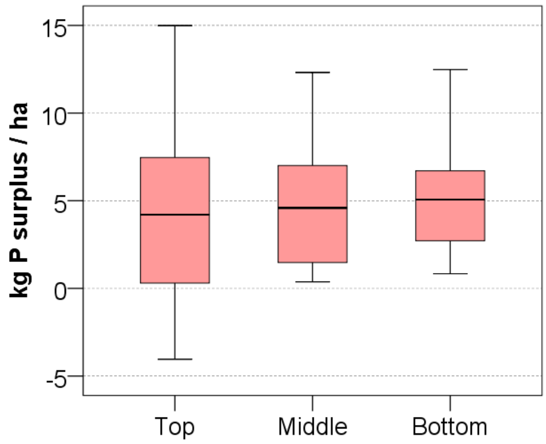
On average, cattle farms produced 9.7 kg of live-weight output per kg of N surplus. Higher NUE of beef production was prevalent on the better economic performing farms, with these top performers producing more beef live-weight per kg of surplus nitrogen, as illustrated in Figure 52.

Figure 52: NUE of beef production



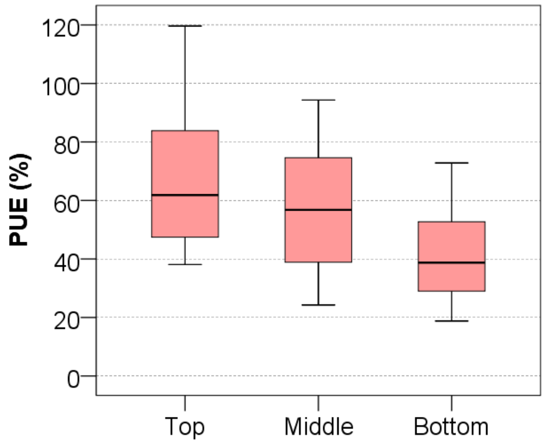
At the farm gate boundary, the P surplus across all cattle farms averaged 6.1 kg per hectare. There was a large range in P surpluses, especially across the better performing farms economically as shown in Figure 53.

Figure 53: P Balance per ha: Cattle Farms



At the farm gate boundary, the average farm PUE across all cattle farms was 65.4%. Figure 54 shows that higher PUE was again more prevalent on farms that performed best in economic terms. Average PUE ranged from 88% for the top third to 46% for the bottom third of cattle farmers.

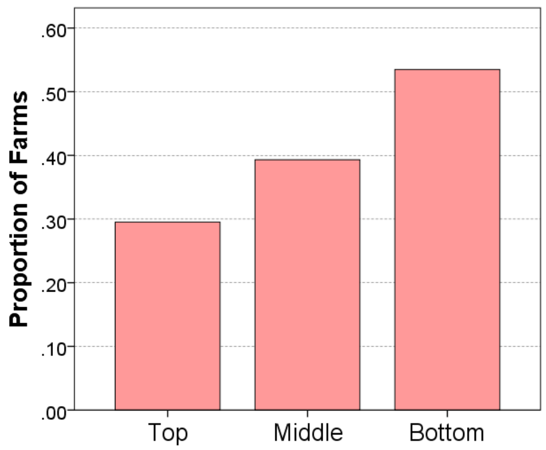
Figure 54: P Use Efficiency: Cattle Farms



Social Sustainability Indicators

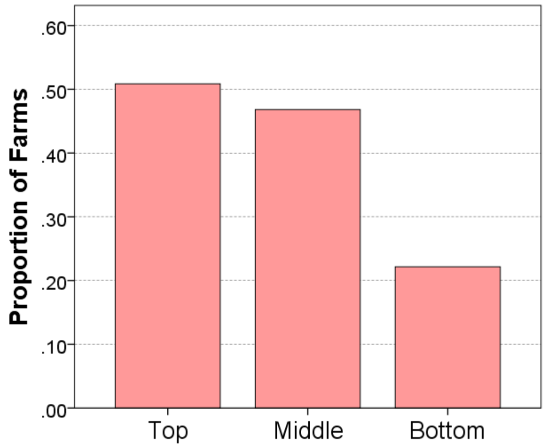
Overall, 41% of all cattle farms were considered vulnerable (a non-viable farm business with no off-farm employment). Figure 55 confirms that this vulnerability was associated with weaker economic performance, with 40% and 54% of the middle and bottom third of farms deemed vulnerable, compared to 30% of the top third.

Figure 55: Household Vulnerability: Cattle



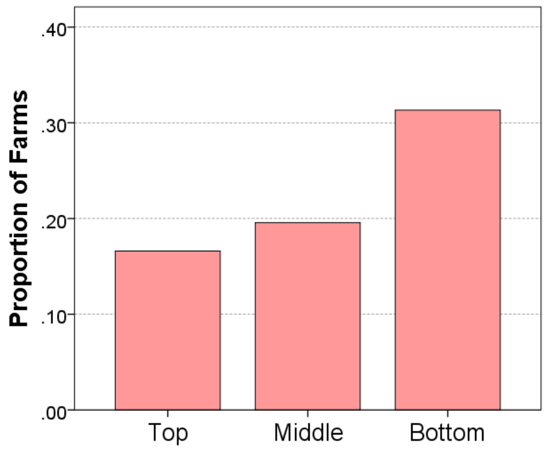
A total of 40% of cattle farmers had some level of agricultural education. Figure 56 indicates that educational attainment was positively associated with the better economic performing farms.

Figure 56: Agricultural Education: Cattle Farms



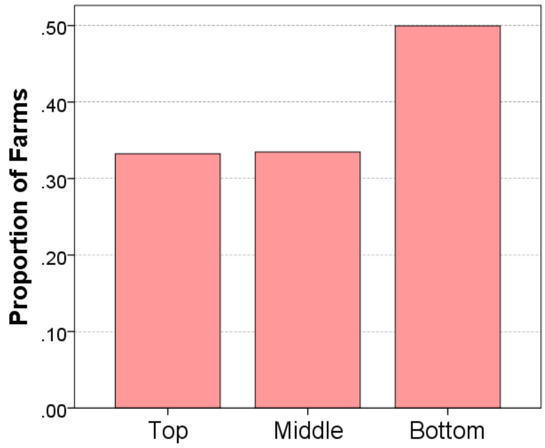
Overall, 22% of cattle farm operators were classified as being at risk of isolation; i.e. where the farmer lives alone. This was especially prevalent among farms with lower profitability, where 31% of farmers in the bottom third live alone, as shown in Figure 57.

Figure 57: Isolation Risk: Cattle Farms



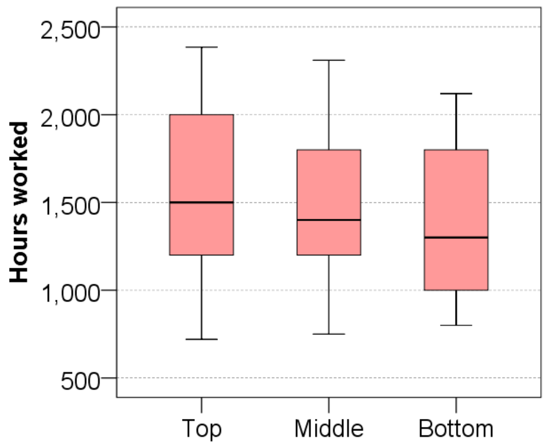
Additionally, 39% of cattle farms were classified as having a high age profile. As with other indicators of social sustainability, this was more prevalent among the weaker economic performing farms, as shown in Figure 58.

Figure 58: High Age Profile: Cattle Farms



The average cattle farm operator worked on farm for 1,470 hours over the year (an average of 28.2 hours per week). It should be noted that 40% of cattle farmers also work off-farm, so farm work hours are not alone necessarily indicative of overall work-life balance.

Figure 59: Hours Worked: Cattle Farms

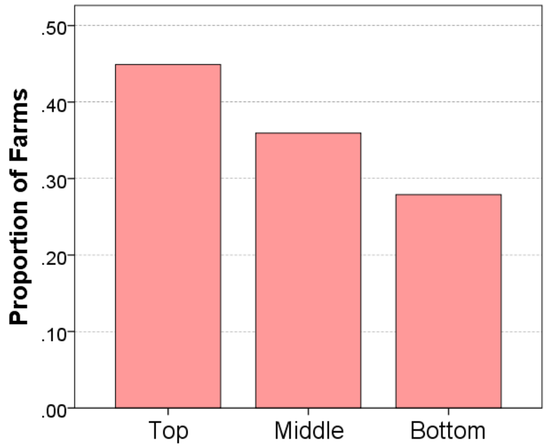


Cattle Farm Innovation Indicators

Six innovation indicators were examined for cattle farms: whether at least 50% of slurry was spread in the period January-April, use of low emission slurry spreading equipment was used, application of protected urea fertiliser, application of lime, grassland reseeding and whether the farmer was a member of a discussion group.

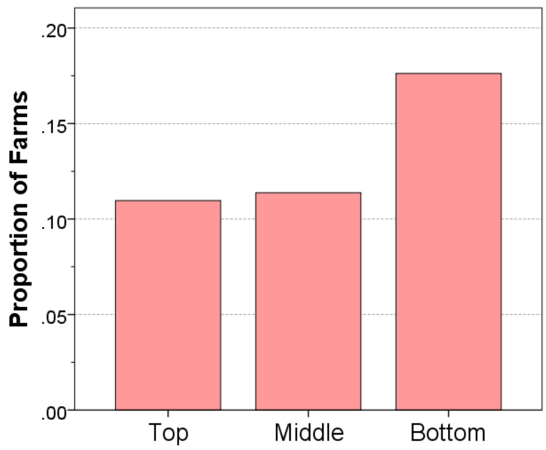
Figure 60 shows that those in the top and middle groups by economic performance had higher spring-time slurry application rates compared to the middle and bottom cohorts.

Figure 60: Spring Slurry: Cattle Farms



The level of overall use of low emission slurry spreading equipment on cattle farms is low, as shown by Figure 61. However, the bottom economic performing cattle farms tended to make greater use of this technology.

Figure 61: Low emission slurry spreading: Cattle Farms



The level of protected fertiliser use was low across all cattle farmers as seen by Figure 62. Between 1-3% of the top and middle cohort used this fertiliser formulation versus 0% for the bottom group.

Figure 62: Protected Urea use: Cattle Farms

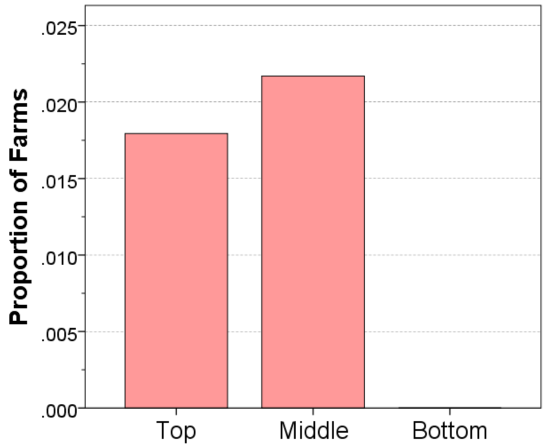


Figure 63 shows that liming rates were slightly higher on the top and middle performing cattle farm, at 12-13%, compared to 9% for the middle and bottom cohorts respectively.

Figure 63: Liming: Cattle Farms

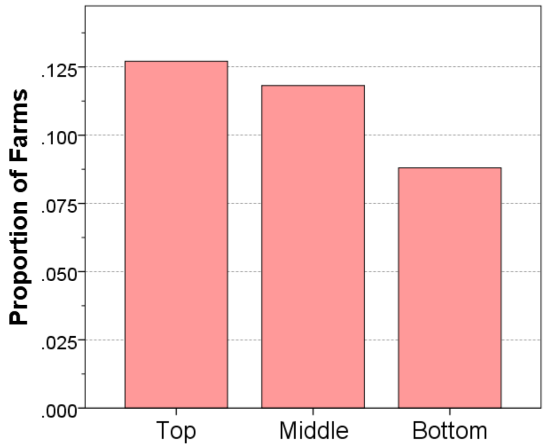
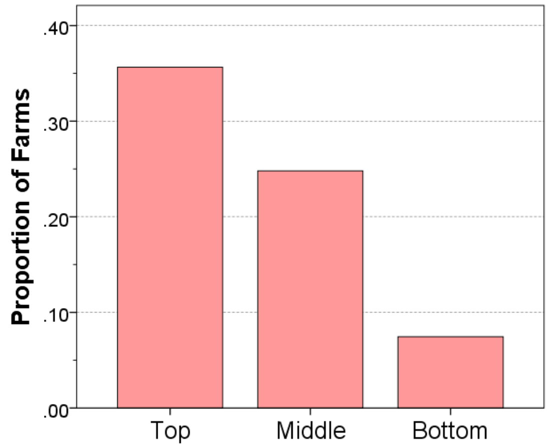


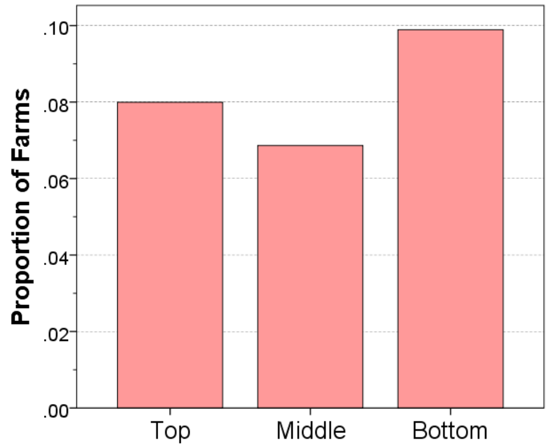
Figure 64 shows that 36% and 25% of the top and middle cohort were members of a discussion group compared to 7% in the bottom cohort.

Figure 64: Discussion Group: Cattle Farms



Reseeding levels were generally low across all groups, ranging from 7% to 10% as shown in Figure 65.

Figure 65: Reseeding: Cattle Farms

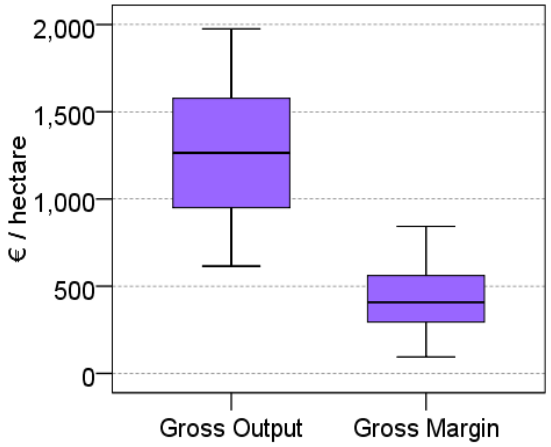


4.3 Sheep Farms

Economic Sustainability Indicators

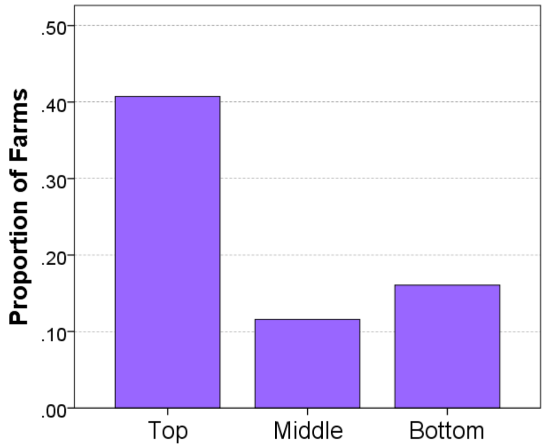
The average gross output per hectare for sheep farms was €1,246 in 2019, and the average gross margin was €414 per hectare.

Figure 66: Economic Return and Profitability of Land: Sheep Farms



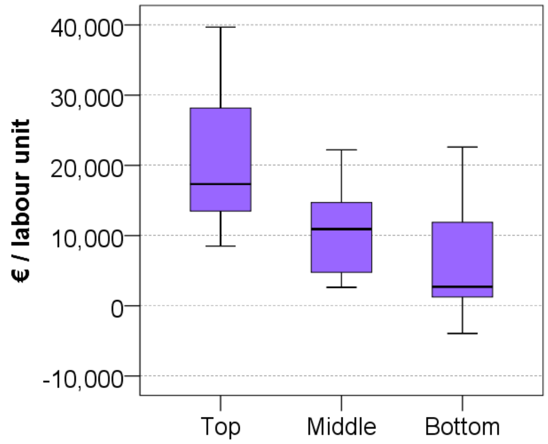
Across all sheep farms, only 23% were defined as economically viable. Figure 67 shows that, ranked by economic performance, the proportion of viable sheep farms ranged from 41% for the top third to 12-16% for the middle and bottom third of farms.

Figure 67: Economic Viability: Sheep Farms



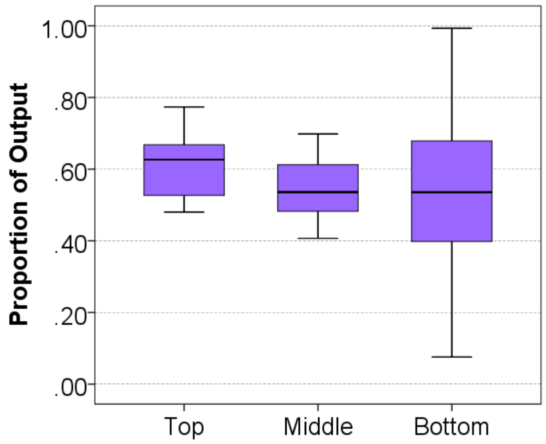
The average income per labour unit on sheep farms was €14,259. In common with cattle farms, there was a large range in economic performance, with the top third of sheep farms earning a mean income per labour unit of €23,186, compared with €7,323 for the bottom third, which also had a number of farms making net losses (see Figure 68). Median income for the 3 cohorts was €19,425, €10,915 and €2,705 respectively.

Figure 68: Productivity of Labour: Sheep Farms



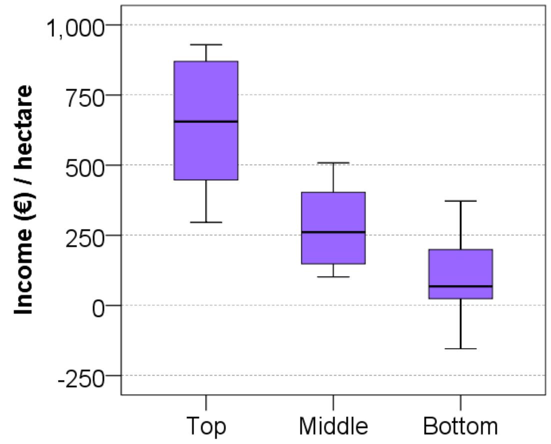
For the average sheep farm, approximately 55% of output was generated from the market, and 35% from direct payments. Figure 69 indicates that market orientation was positively associated with economic performance, with the top third of farms, based on economic performance, producing 63% of output from the market, compared with just 46% on average for bottom third. Figure 69 indicates a significant range across the bottom performing cohort in particular.

Figure 69: Market Orientation: Sheep Farms



The average family farm income per hectare on sheep farms was €326 in 2019. Across the subgroups, this average ranged from €652 for the top performing cohort to €37 for the bottom performers economically. Figure 70 shows significant ranges in income per hectare across the 3 groups with negative income per hectare returned by a section of the bottom performing cohort.

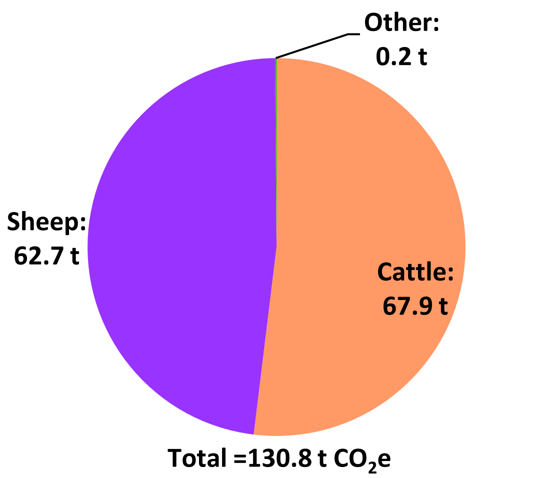
Figure 70: Family Farm Income per hectare: Sheep Farms



Environmental Sustainability Indicators

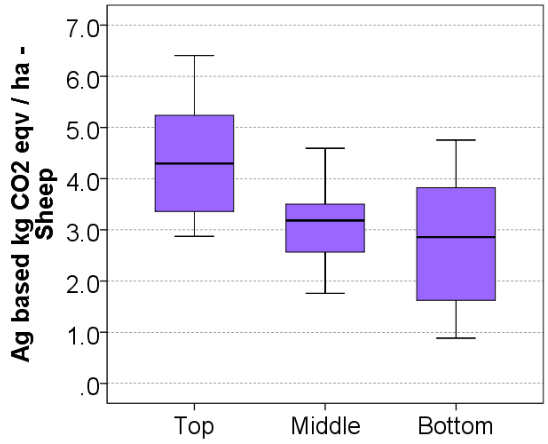
In 2019, the average sheep farm produced approximately 130.8 tonnes CO_2 equivalent of agricultural GHG emissions. Figure 71 indicates that just under half (47.9%) of these emissions were generated by the sheep enterprise, with over half (51.9%) generated by cattle enterprises present on specialist sheep farms, with the remainder coming from other sources, mainly crop fertilisation.

Figure 71: Agricultural GHG Emissions for the average Sheep Farms



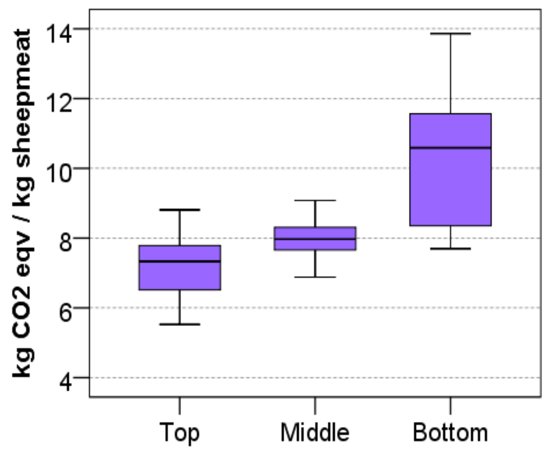
On average sheep farms emitted 3.3 tonnes of CO_2 equivalent per hectare. Higher emissions per hectare were associated with the more profitable sheep farms, as shown in Figure 72. However, there was a large range of results.

Figure 72: 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, 2020). Figure 73 shows that the emissions intensity per kg of live-weight produced were negatively associated with economic performance. The top third of farms generated 7.3 kg CO_2 equivalent per kg live weight produced, compared to 9.0 and 10.2 kg CO_2 equivalent for the middle and bottom cohorts respectively.

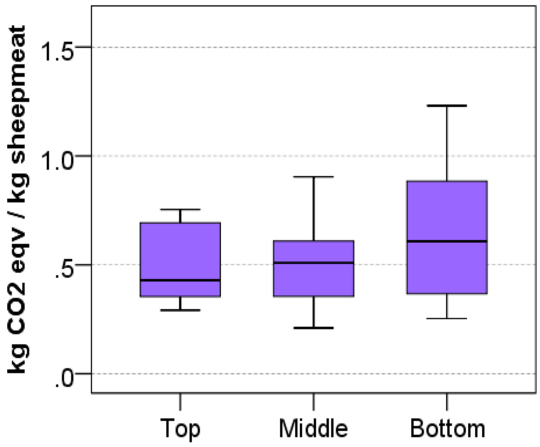
Figure 73: Agricultural GHG Emissions per kg live-weight produced: Sheep Farms



Better economic performance was also linked with lower electricity and fuel based GHG emissions per unit of output, as shown by Figure 74. The bottom third of farms in economic terms emitted 0.72 kg CO_2

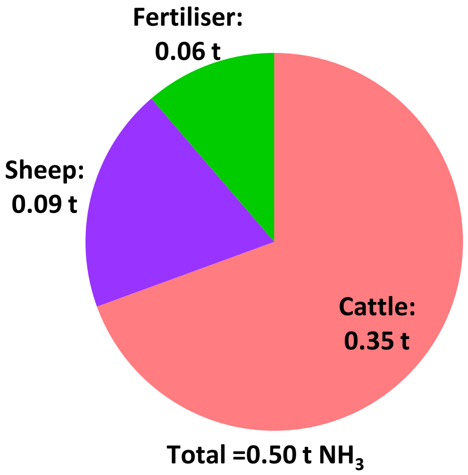
equivalent per kg live-weight sheep meat produced from energy based emissions, compared to 0.49 kg CO_2 for the top third of sheep farms.

Figure 74: Energy use related GHG Emissions per kg live-weight produced: Sheep Farms



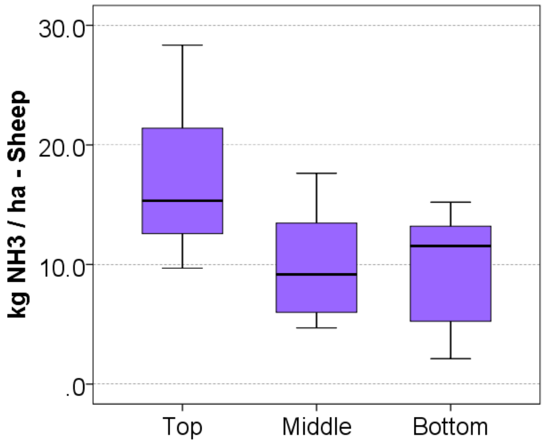
On average, specialist sheep farms emitted 0.50 tonnes of NH_3 in 2019. Even though the main output on these farms is sheep based, the majority of the NH_3 emissions related to cattle production (69%), with only 19% relating to sheep production. The remaining portion related to chemical fertilisers applied.

Figure 75: Total Ammonia Emissions for the average Sheep Farm



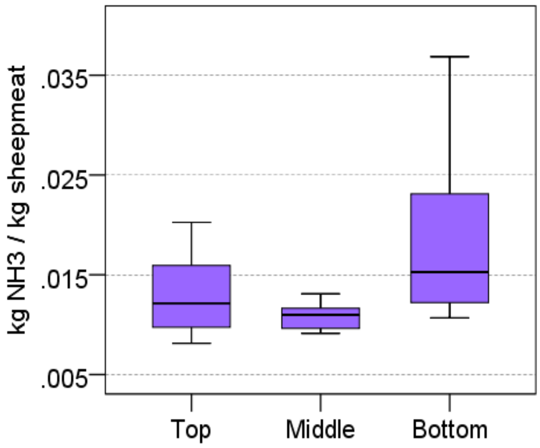
On average a specialist sheep farm emitted 12.6 kg of ammonia per hectare in 2019. Higher per hectare emissions were associated with economically better performing farms as shown in Figure 76, these farms tend to operate at a higher stocking intensity.

Figure 76: 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 and middle performing cohort in economic terms were found to produce a kg of live-weight sheep meat with a lower NH_3 emission intensity, as shown in Figure 77. On average sheep farmers produced 0.017 kg of NH_3 emissions per kg of live-weight sheep meat.

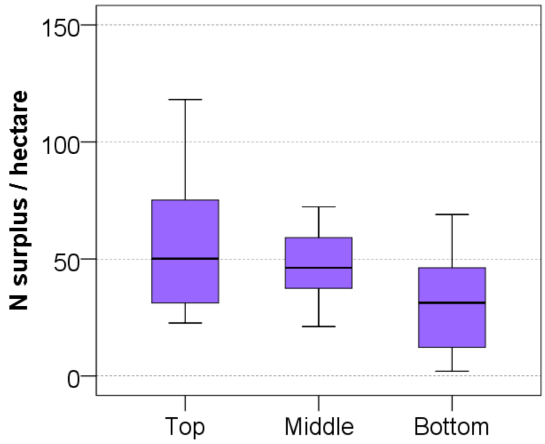
Figure 77: Ammonia Emissions per kg live-weight produced: Sheep Farms



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 78. The top third of farms, ranked by gross margin per hectare, had an average nitrogen surplus of

60.3 kg per hectare, compared with 48.9 and 44.9 kg per hectare for the middle and bottom cohorts respectively.

Figure 78: N Balance per ha: Sheep Farms



The average NUE across all sheep farms was 29.4%. Higher NUE was again associated with better economic performance as shown in (Figure 79).

Figure 79: N Use Efficiency: Sheep Farms

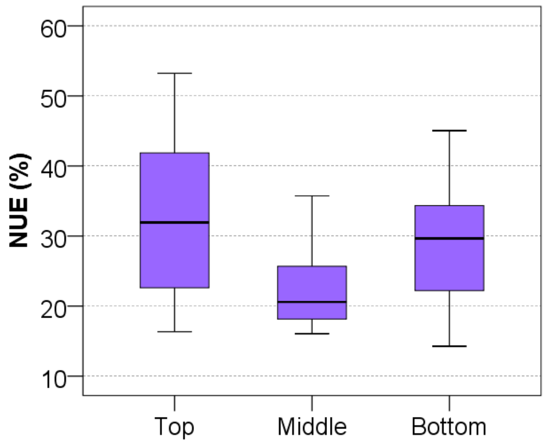
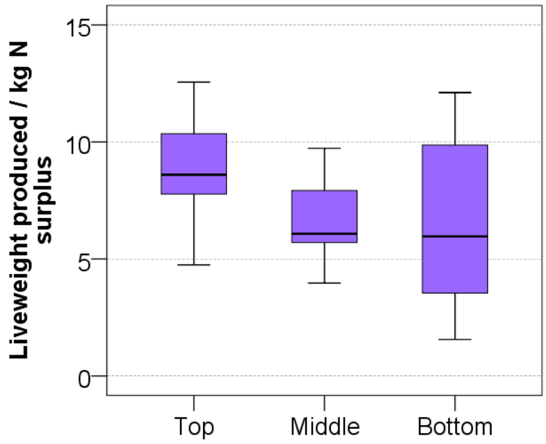


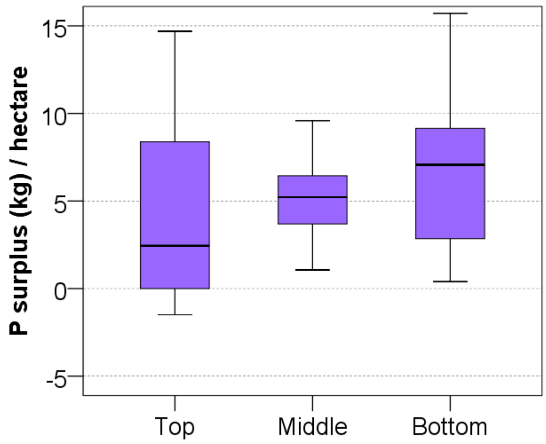
Figure 80 shows that the N surplus per kg of live-weight sheep meat produced tends to be positively associated with better economic performance, with the top third producing more live-weight output per kg of N surplus generated. The average across all sheep farms was 8.7 kg.

Figure 80: NUE by product of Sheep Farms



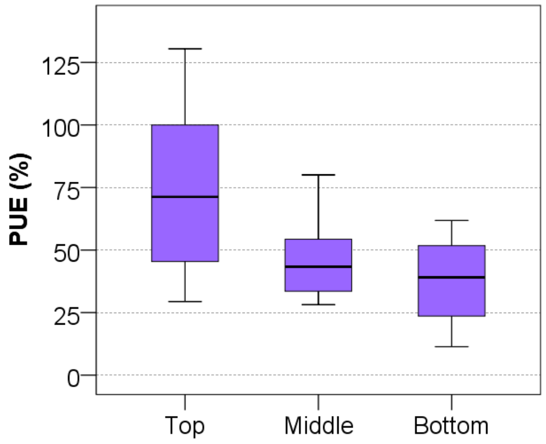
P balances across all specialist sheep farms were 4-8 kg per ha on average. There was a large range of results across the three cohorts, as shown by Figure 81.

Figure 81: P Balance per ha: Sheep Farms



Farm gate level PUE averaged 58.2% across all sheep farms. Figure 82 shows that higher PUE was associated with farms with better economic performance.

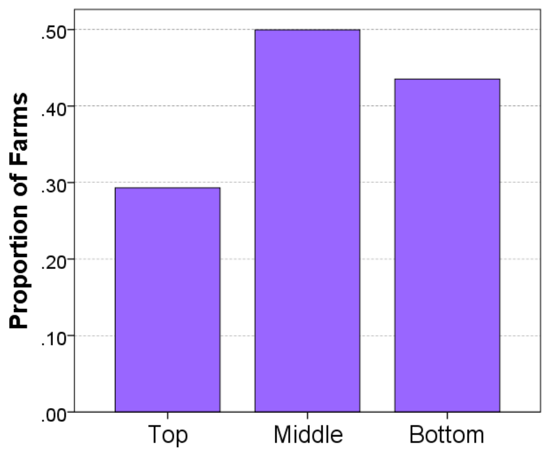
Figure 82: P use efficiency: Sheep Farms



Social Sustainability Indicators

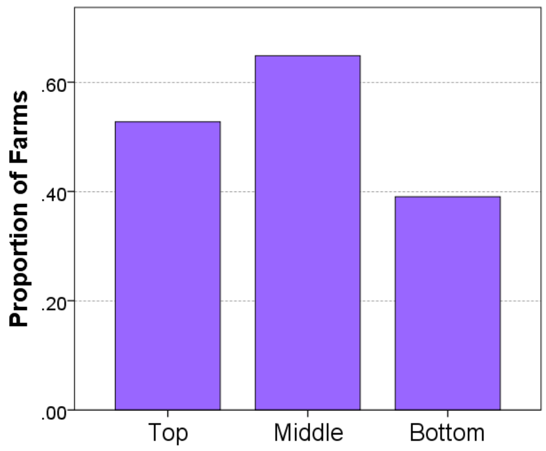
Over 41% of all sheep farms were considered vulnerable in 2019. Figure 83 shows that this ranged from 36% for the top performing sheep farms to 44% and 50% for the bottom and middle groups.

Figure 83: Household Vulnerability: Sheep Farms



Overall, 53% of sheep farmers had received formal agricultural education. Figure 84 shows that agricultural education was lowest among the bottom third of farms by economic performance.

Figure 84: Agricultural Education: Sheep Farms



On average, 23% of all specialist sheep farms were classified as being at risk of isolation. Figure 85 shows that this was significantly higher among the bottom performing cohort of sheep farms at 34%.

Figure 85: Isolation Risk: Sheep Farms

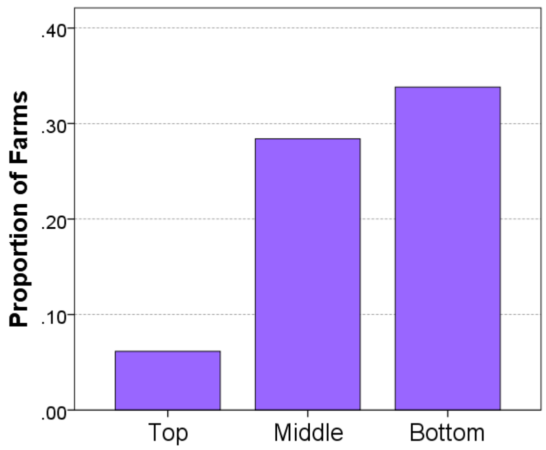
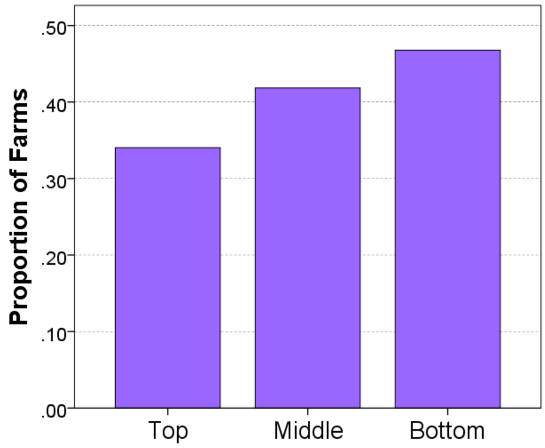


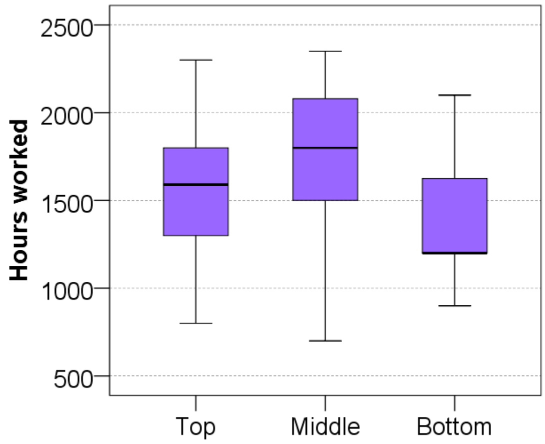
Figure 86 shows that the proportion of all specialist sheep farms with a high age profile averaged 41%. An inverse relationship was evident between high age profile and economic performance.

Figure 86: High Age Profile: Sheep Farms



Sheep farmers worked an average of 1,543 hours per year (or 29.7 hours a week). In common with cattle farms, it should be noted that this does not capture off-farm work, as 36% of sheep farmers are also engaged in off-farm employment (Figure 87).

Figure 87: Hours Worked: Sheep Farm Operators

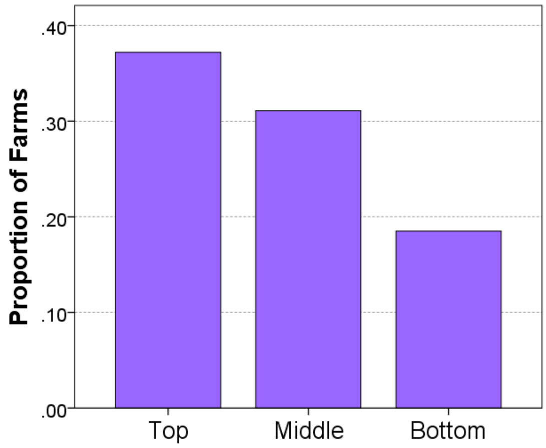


Sheep Farm Innovation Indicators

The five innovation indicators selected for sheep farms were whether at least 50% of slurry was spread in the period January-April, use of protected urea fertiliser, application of lime, grassland 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 and middle performing cohort at 37% and 31% respectively, compared to 19% for the middle and bottom groups. However, it should be noted that sheep farms tend to be more associated with farmyard manure (i.e solid) type storage systems, which might not lend themselves to early season application.

Figure 88: Spring Slurry: Sheep Farms



The use of protected urea fertiliser across sheep farmers was very limited. No sheep farmers in the middle and bottom cohorts used this fertiliser formulation and less than 2% of the top group applied it as seen by Figure 89.

Figure 89: Protected Urea use: Sheep Farms

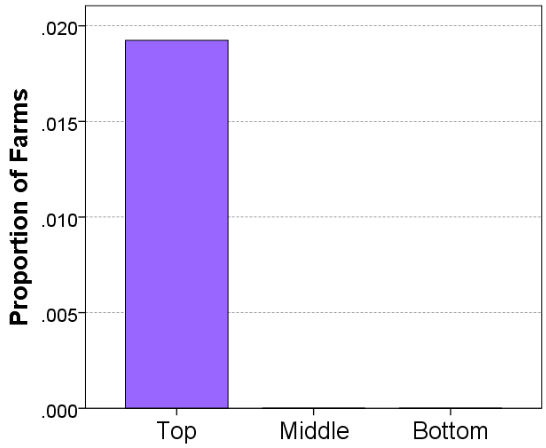


Figure 90 shows that liming activity was again more prevalent across the better economic performing farms, with 18% of the top performing cohort by economic performance engaged in liming, compared to 5% of the bottom group.

Figure 90: Liming: Sheep Farms

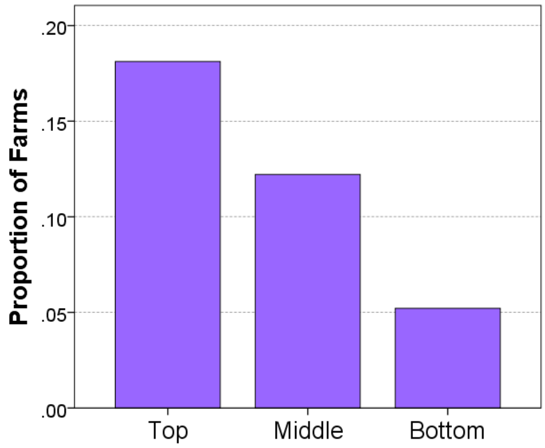


Figure 91 shows that higher levels of reseeding were associated with the sheep farms that performed better in economic terms.

Figure 91: Reseeding: Sheep Farms

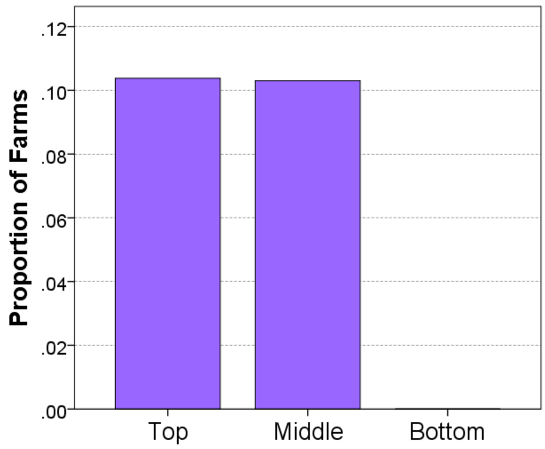
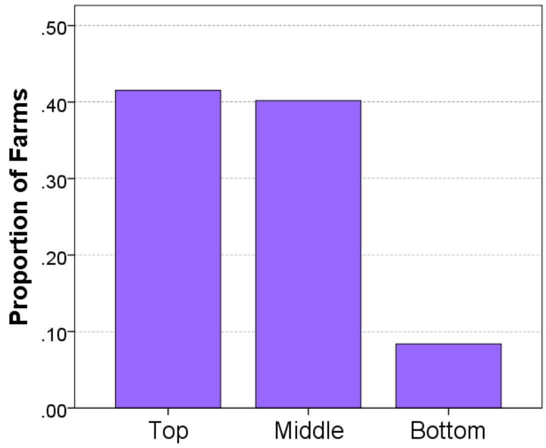


Figure 92 shows that membership of a discussion group was higher among the top and middle performing groups, at 42% and 40% respectively, compared to 8% for the bottom group.

Figure 92: Discussion Group: Sheep Farms

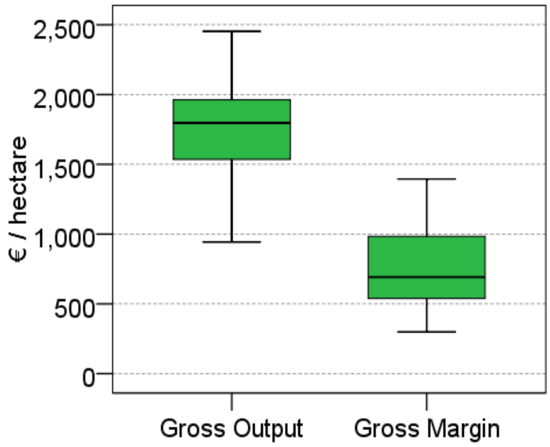


4.4 Tillage Farms

Economic Sustainability Indicators

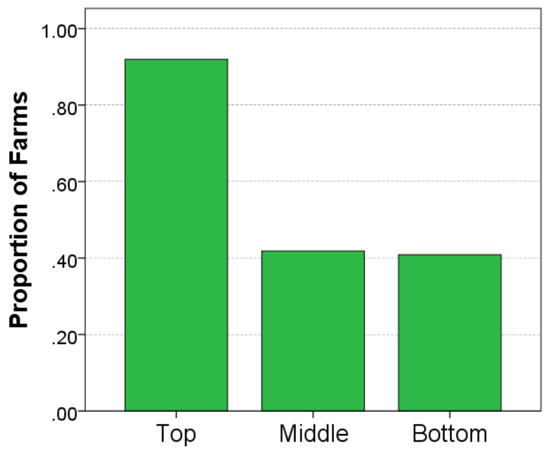
The average gross output per hectare for tillage farms was €2,038 and the average gross margin per hectare was €921 in 2019. But there was a large distribution around each as seen by Figure 93.

Figure 93: Economic Return and Profitability of Land: Tillage Farms



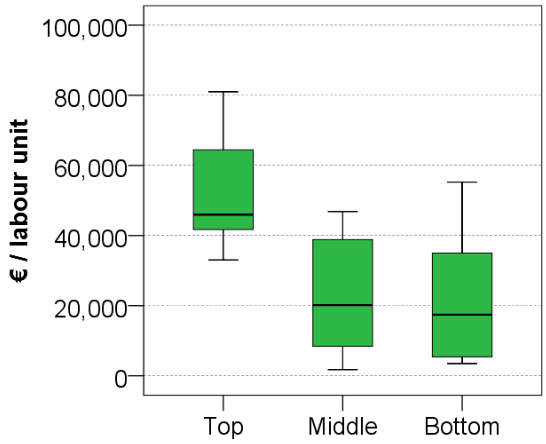
Overall, 59% of tillage farms were classified as economically viable. Figure 94 shows that the middle and bottom groups had lower levels of viability, at 41% and 42% compared to 92% for the top group.

Figure 94: Economic Viability: Tillage Farms



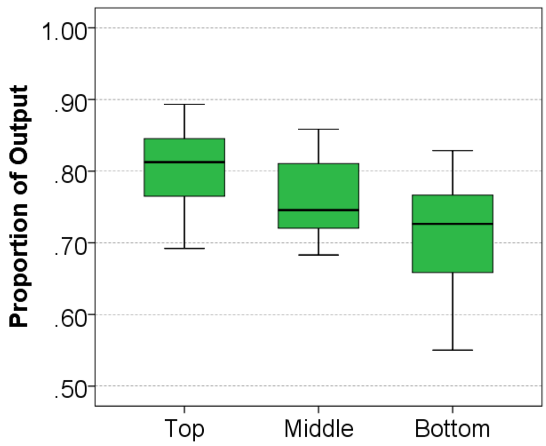
The average tillage income per labour unit (for unpaid family labour) was €36,410. Figure 95 shows that there is a large range in incomes on tillage farms, with the top one-third (ranked by gross margin per hectare) earning an average of €55,121 per labour unit, and the middle and bottom thirds earning similar revenue (circa €26,300) per labour unit provided. 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 95: Productivity of Labour: Tillage Farms



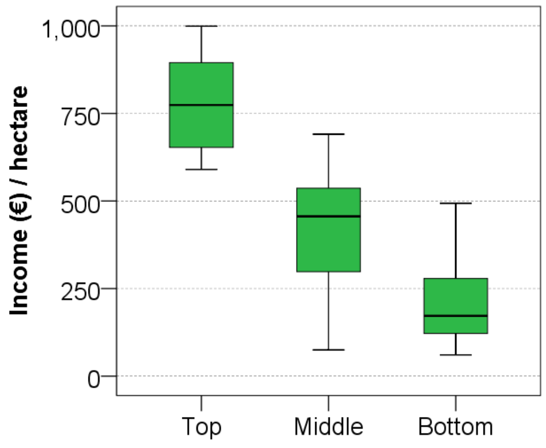
In 2019, tillage farms generated 75% of their output value from the market on average. Figure 96 shows that the top third of tillage farms derived 79% of farm output from the market, and the bottom third 70% on average.

Figure 96: Market Orientation: Tillage Farms



The average family farm income per hectare on tillage farms was €627 in 2019. Median income ranged from €851 from the top performing cohort to €202 for the bottom performers economically. Figure 97 shows significant ranges in income per hectare across the three groups.

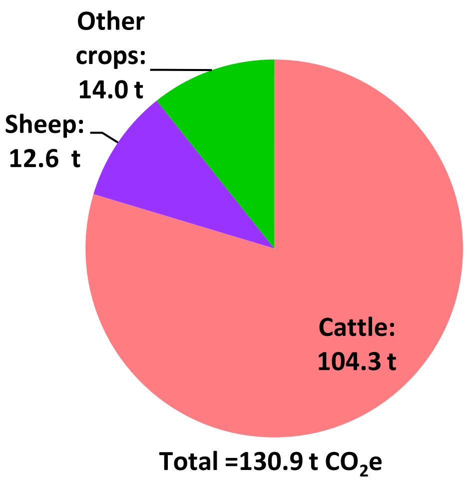
Figure 97: Family Farm Income per hectare: Tillage Farms



Environmental Sustainability Indicators

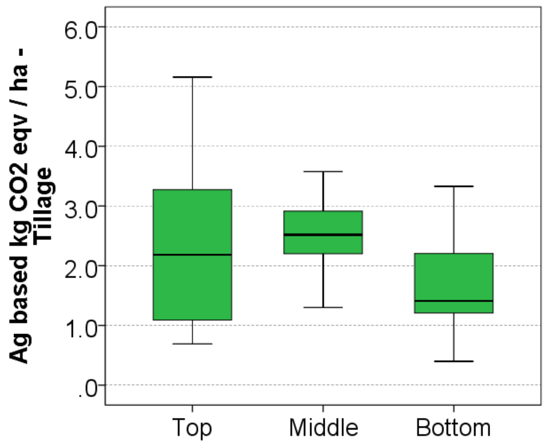
The average tillage farm produced 130.9 tonnes CO_2 equivalent of agricultural GHG emissions in 2019 as illustrated in Figure 98. However, only 10.7% of GHG emissions were generated from crop production. Despite being specialised in crop production, 79.6% of tillage farm emissions were from cattle present on these farms, with a further 9.7% from sheep.

Figure 98: Agricultural GHG Emissions for the average Tillage Farm



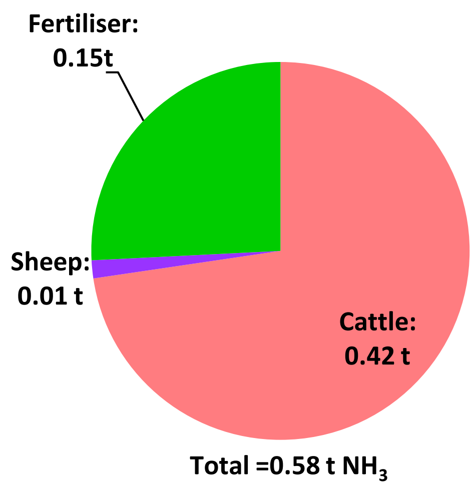
The average specialist tillage farm produced 2.1 tonnes CO_2 equivalent per hectare of agricultural GHG emissions in 2019. Higher emissions per hectare were again associated with higher economic performance.

Figure 99: Agricultural GHG Emissions per hectare: Tillage Farms



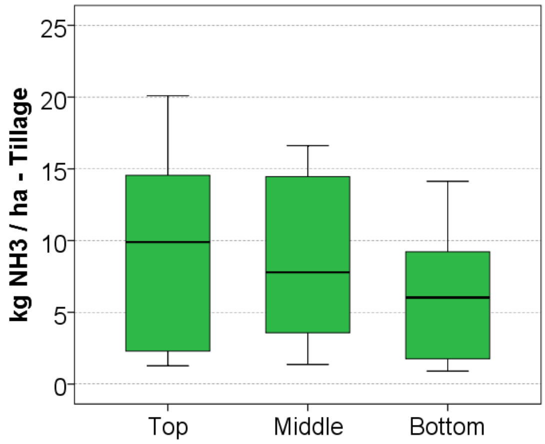
Tillage farms on average emitted 0.58 tonnes of NH_3 in 2019. Again, even though the main farm output is crop related, the bulk of emissions are associated with cattle rearing, at 73%. The remaining 26% of emissions were mostly associated with chemical fertiliser application.

Figure 100: Total Ammonia Emissions for the average Tillage Farm



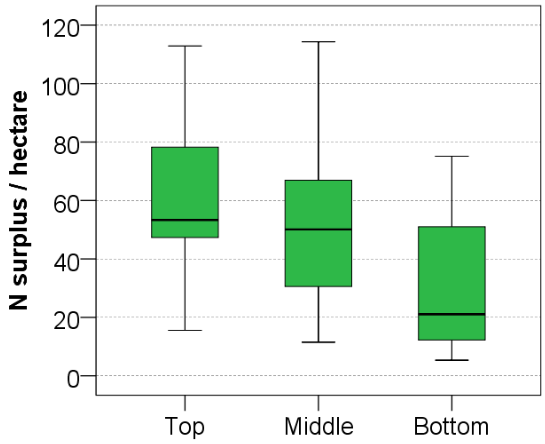
The average specialist tillage farm emitted 8.48 kg of NH_3 per hectare in 2019. Again, higher emissions per hectare were associated with higher economic performance. Economic performance tends to be positively associated with farm production intensity levels.

Figure 101: Total Ammonia Emissions per hectare: Tillage Farms



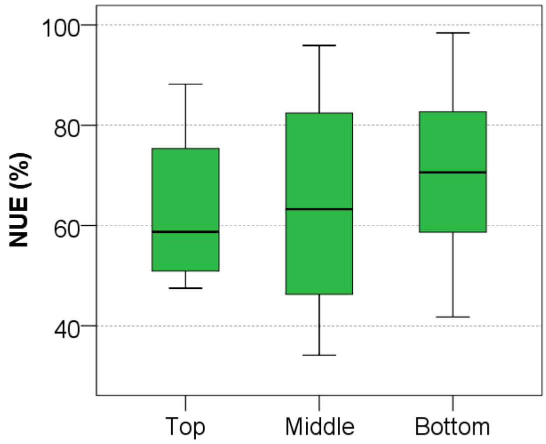
The average N surplus was 49.9 kg per hectare, but there was a large range in the farm results. Figure 102 shows higher N surpluses were aligned with higher economic performance. It should be noted that not all tillage farms from the Teagasc NFS are included here, as some tillage farms import manure, quantities of which are not currently recorded and these farm are thus excluded from analysis of environmental performance with respect to nitrogen and phosphorous.

Figure 102: N Balance per hectare: Tillage Farms



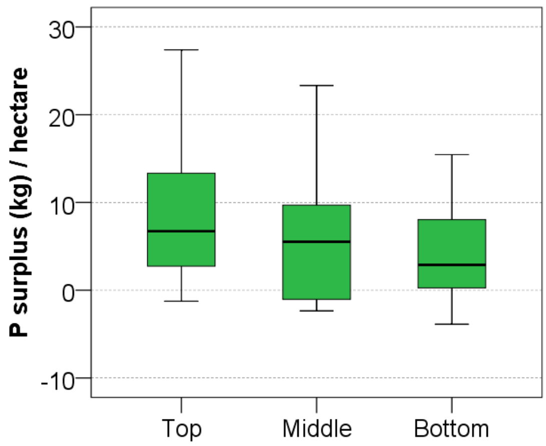
Across all tillage farms, the average NUE was circa 67.8%. There was a large distribution in NUE across the three groups as illustrated in Figure 103.

Figure 103: N Use Efficiency: Tillage Farms



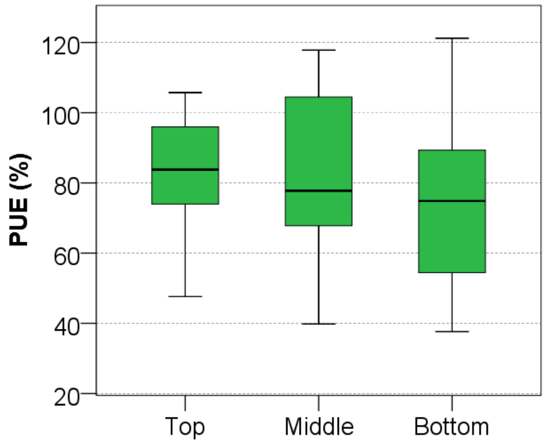
The average P balance across all tillage farms was 7.2 kg per hectare. However, as illustrated in Figure 104, there was again a large range of results around these group averages, but better farms, in economic terms, tended to have slightly higher P balances.

Figure 104: P Balance per hectare: Tillage Farms



PUE averaged circa 81.6% 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 105.

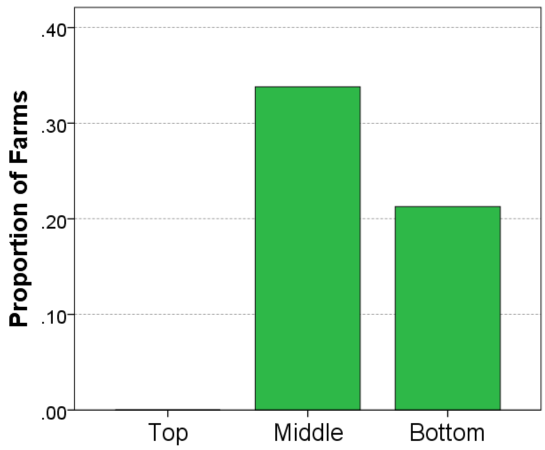
Figure 105: P Use Efficiency: Tillage Farms



Social Sustainability Indicators

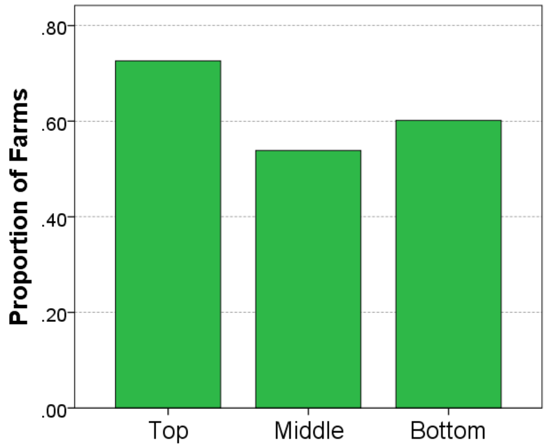
On average, a total of 18% of tillage farms are considered economically vulnerable. Figure 106 indicates that household vulnerability was highest across the middle cohort at 34%.

Figure 106: Household Vulnerability: Tillage



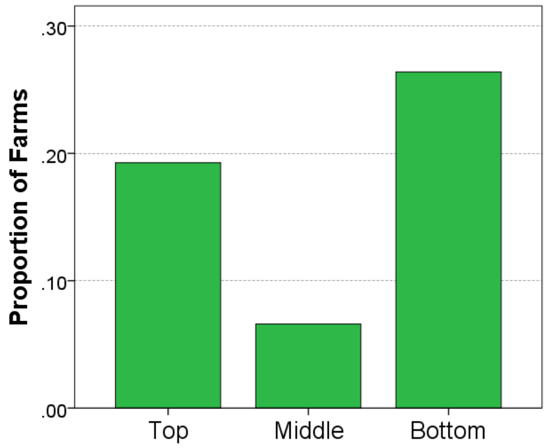
A total of 62% of tillage farmers had attained some level of agricultural education or training. Figure 107 shows that this rate was slightly lower for the middle performing third of tillage farms economically.

Figure 107: Agricultural Education: Tillage Farms



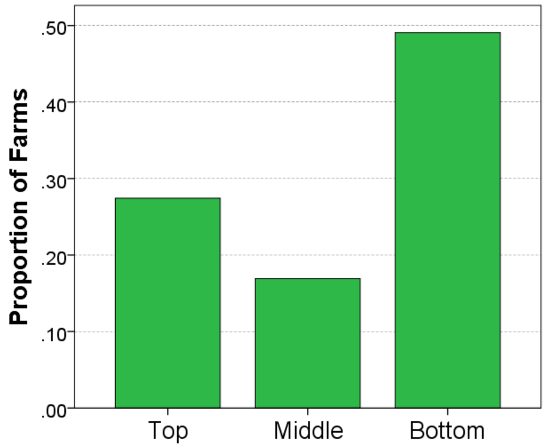
Overall, 18% of tillage farms were identified as being at risk of isolation (i.e. where the farm operator lived alone). At 26%, this rate was highest for the bottom performing cohort, followed by 19% for top performing cohort, as illustrated by Figure 108.

Figure 108: Isolation Risk: Tillage Farms



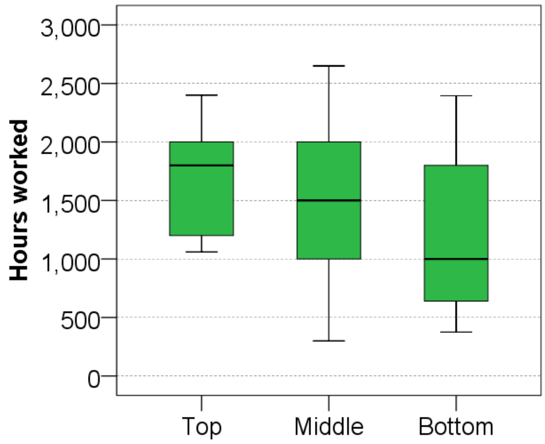
An average of 31% of tillage farms were identified as having a high age profile. Figure 109 shows that over 49% of farm households in the bottom group had a high age profile, compared to 17% and 27% for the middle and top performing cohorts respectively.

Figure 109: High Age Profile: Tillage Farms



The average tillage farmer worked 1,542 hours per year (29.7 hours per week). However, Figure 110 shows that the average was considerably lower for the bottom third of farms, ranked by gross margin per hectare. 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 110: Hours Worked: Tillage Farms



Tillage Innovation Indicators

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

Figure 111 shows that liming rates were higher for the middle performing cohorts (35%) compared to the top (25%) and bottom (21%) performing cohort.

Figure 111: Liming: Tillage Farms

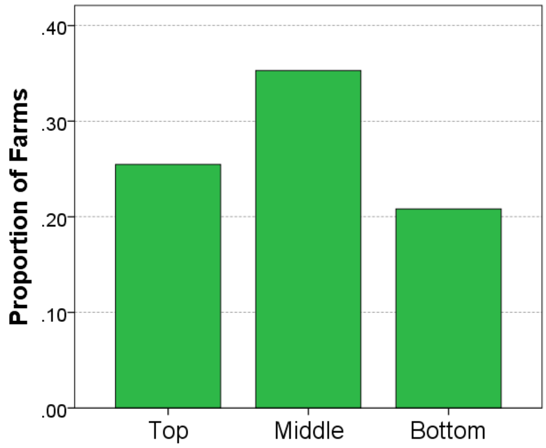


Figure 112 shows that the use of protected urea fertiliser was very low across all tillage farmers, only 3% and 5% of middle and bottom cohorts used this fertiliser.

Figure 112: Protected Urea use: Tillage Farms

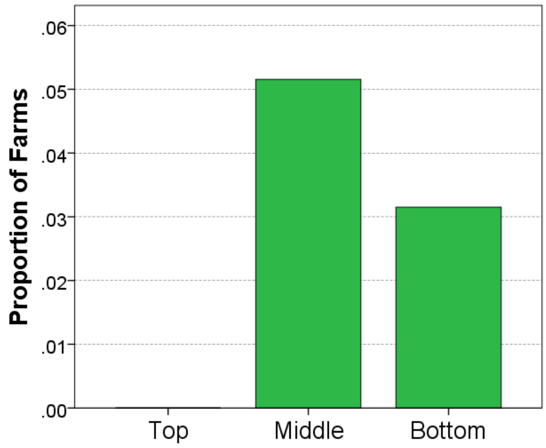


Figure 113 shows that the top performing cohorts were 2-4 times more likely to forward sell crops (16%), compared to the middle (9%) and bottom groups (4%).

Figure 113: Forward selling: Tillage Farms

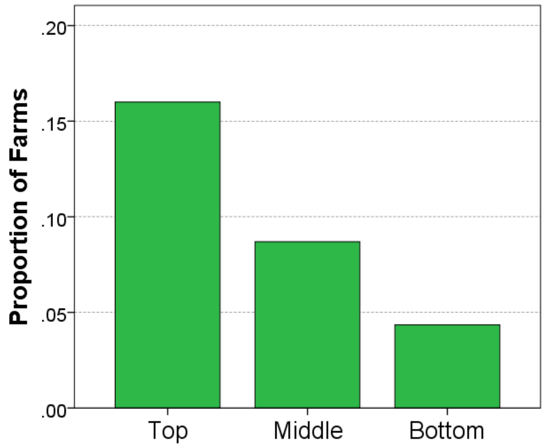


Figure 114 shows that farms where the operator was a member of a discussion group performed better economically. On average between 37% of farms in the top performing group were members of a discussion group. Those in the middle group at 16% had the lowest membership rates.

Figure 114: Discussion Group: Tillage Farms

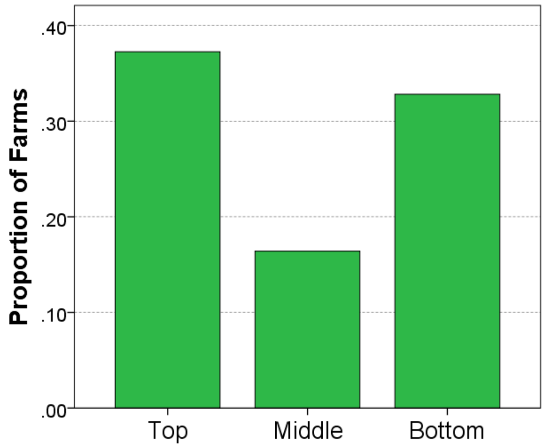
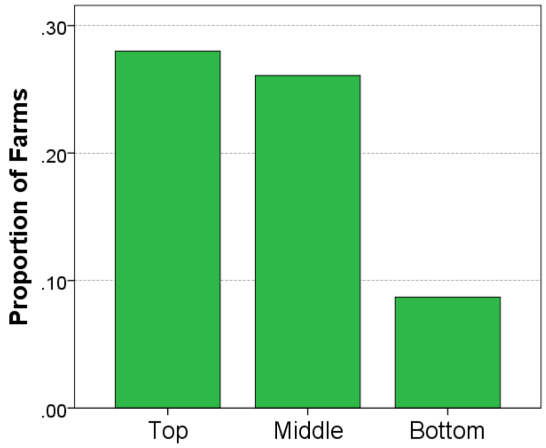


Figure 115 shows that, at 28% and 26% respectively the top and middle performing cohorts were nearly 3 times more likely to grow a break crop compared to bottom cohort (9%).

Figure 115: Break Crops: Tillage



5. Farm System Comparisons 2019

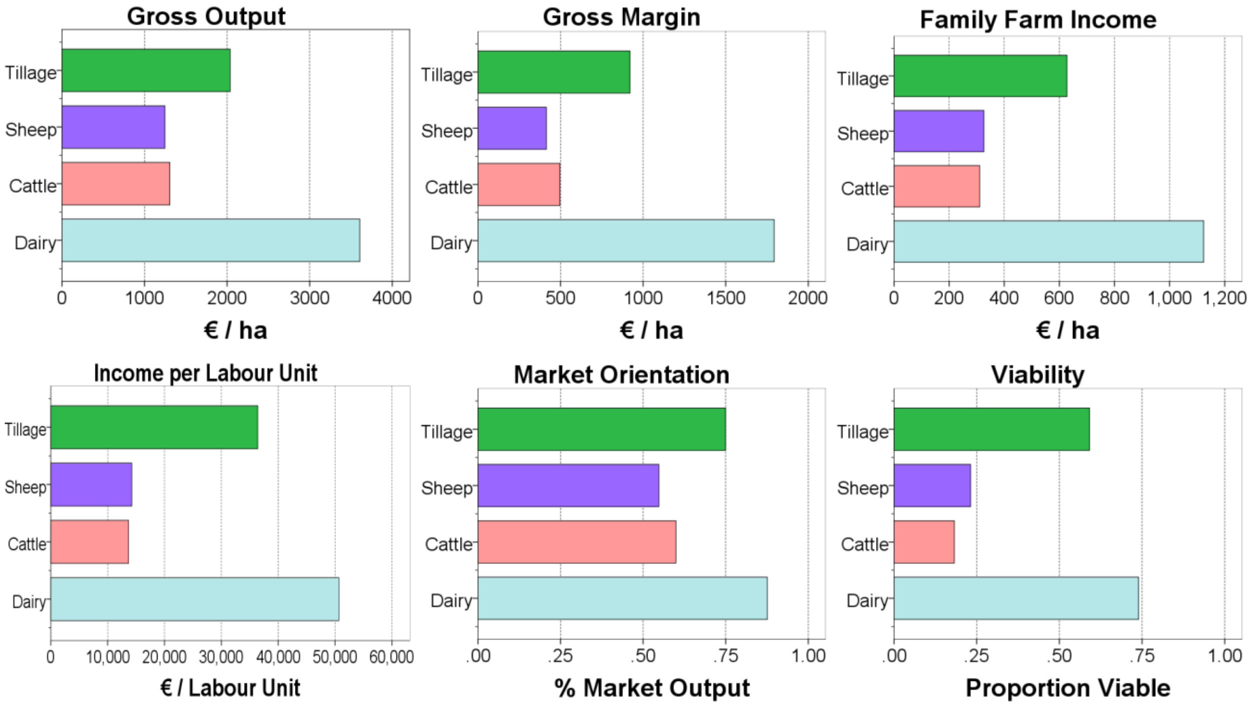
Economic Indicators: A comparison of economic sustainability across different farm types is shown in Figure 116 below. In general, dairy farms show the strongest economic performance, significantly ahead of all other systems in terms of gross output, gross margin and family farm income on a per hectare basis.

Tillage farms were ahead of both cattle and sheep farms (which were similar) in terms of gross output, gross margin and family farm income per hectare, but tillage farms were behind dairy farms in terms of income per labour unit. Cattle farms, and especially sheep farms, returned significantly lower income per labour unit in comparison to dairy farms and tillage farms in 2019.

The various 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 less than 25% of sheep farms and 20% of cattle farms classed as economically viable. Dairy farms were the most economically viable, followed by tillage systems.

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.

Figure 116: Economic Sustainability: Farm System Comparison 2019 (average per system)



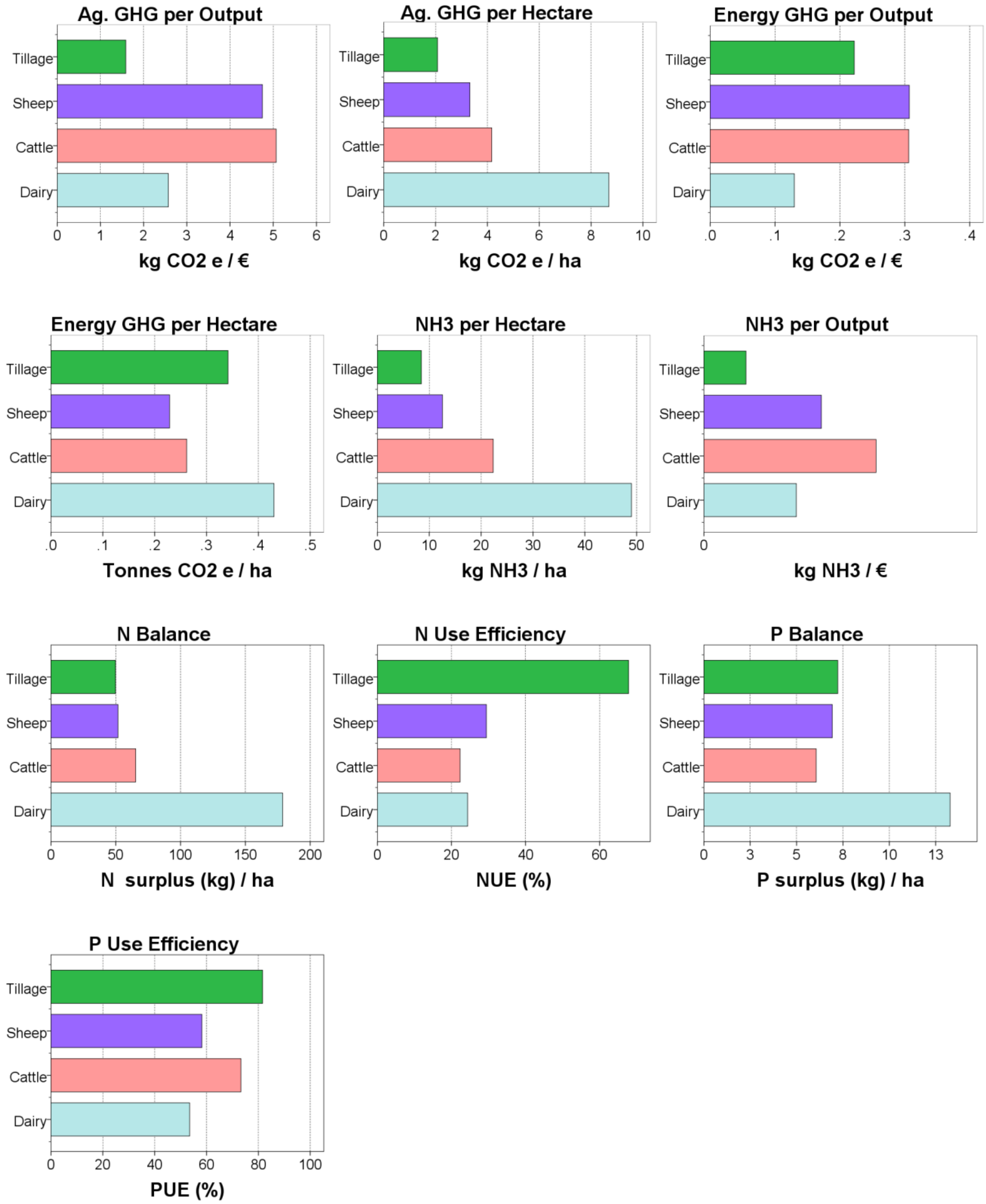
Environmental Indicators: The environmental sustainability of farms is more difficult to compare directly across different farm systems, as the indicators are more directly linked with the type of farming undertaken and the different outputs produced. More detail can be revealed by comparing within farm type variations (see previous section), but some shared environmental indicators across different farm types are presented in Figure 117.

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. Dairy farms show the highest emissions on a per hectare basis. 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 due to the lower value of output generated in beef and sheep compared to dairy systems.

In common with GHG emissions, ammonia emissions per hectare were significantly higher on dairy farms compared to all other systems. 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 exhibited the highest ammonia emissions intensity (due to the generally lower levels of output) followed 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 (due to data limitations) 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 for 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 unavailable for farms in the NFS (due to data limitations). PUE was highest on tillage farms, which was higher than that observed across all of the livestock systems.

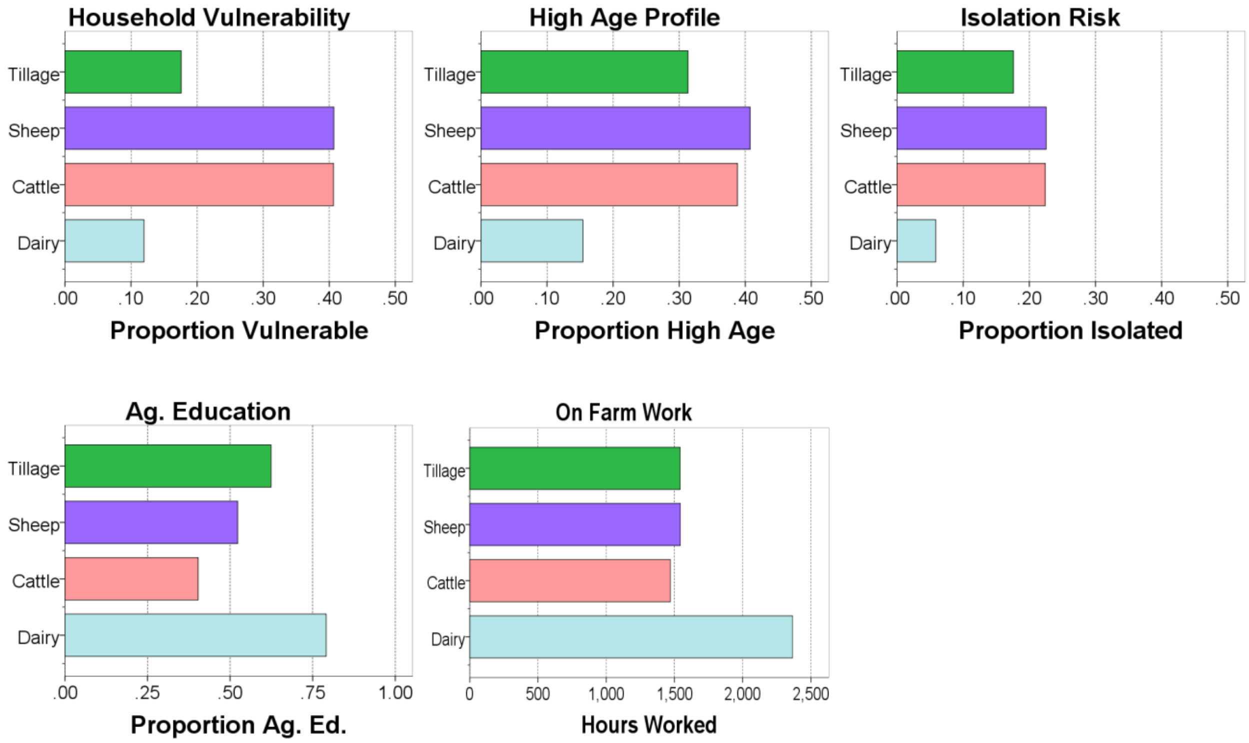
Figure 117: Environmental Sustainability: Farm System Comparison 2019 (average per system)



Social Indicators: Comparison of the social sustainability indicators of different farm types (in Figure 118) shows a similar overall trend to the economic performance indicators shown in Figure 116, 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 farm and non-farm work activities.

Given that there were lower levels of economic viability across cattle and sheep farms (see Figure 116) 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 sheep farms were more likely to be operated 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 118: Social Sustainability: Farm System Comparison 2019 (average per system)



6. Time Series Comparisons with a three year rolling average: 2014-2019

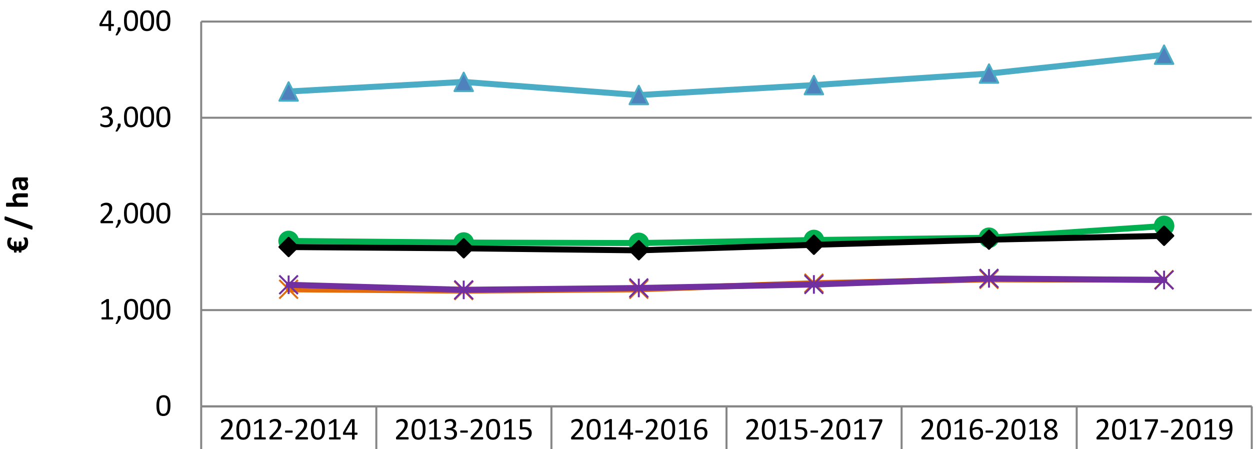
Building on research presented in previously published Teagasc Sustainability reports (Hennessy et al., 2013; Lynch et al., 2016, Buckley et al., 2019, Buckley et al., 2020), we can track the evolution of farm-level sustainability indicators over time. The figures presented below highlight changes in 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 2014 is based on the average of the years 2012 to 2014 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 119 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.

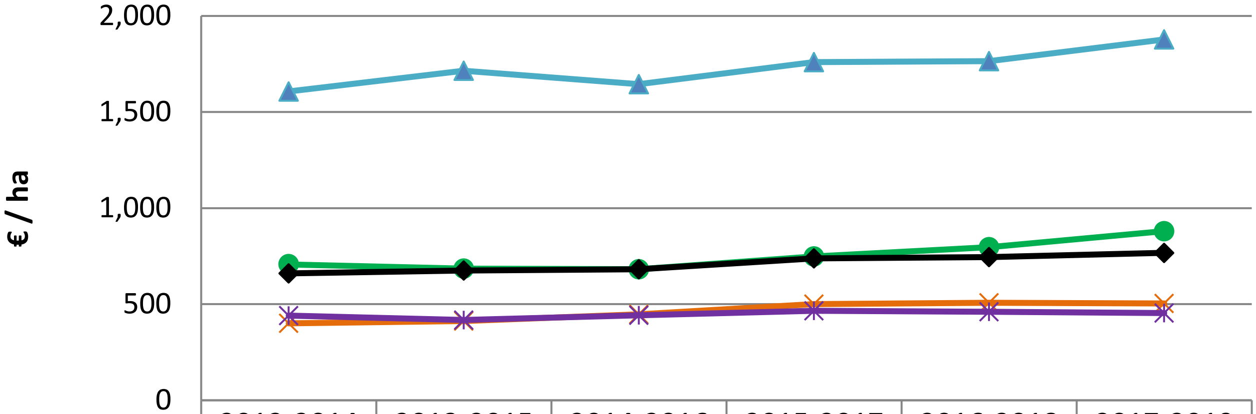
Figure 119: Economic Returns to Land: 3 year rolling average 2014-2019



	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
Dairy	3,274	3,374	3,236	3,341	3,459	3,654
Cattle	1,218	1,203	1,217	1,279	1,320	1,318
Sheep	1,263	1,212	1,230	1,267	1,329	1,314
Tillage	1,718	1,702	1,698	1,730	1,753	1,875
All Farms	1,655	1,644	1,622	1,679	1,732	1,772

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 120.

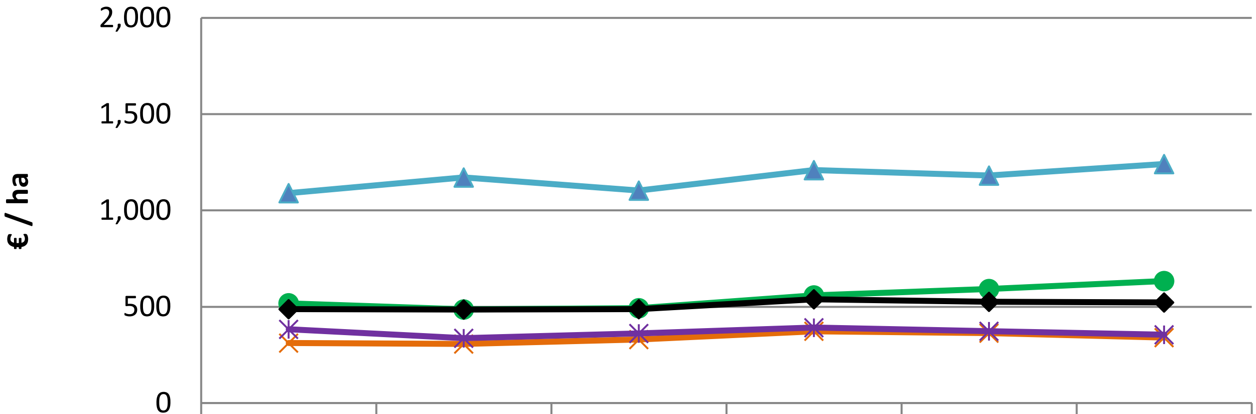
Figure 120: Profitability of Land: 3 year rolling average 2014-2019



	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
Dairy	1,607	1,715	1,645	1,759	1,766	1,878
Cattle	401	413	448	501	508	504
Sheep	440	418	442	466	460	453
Tillage	707	685	682	748	797	880
All Farms	660	676	682	738	744	767

Family farm income per hectare mirrored profitability of land in that dairying was again significantly higher than for all other systems and tended to increase over the years. Tillage farms again was second in the rank order. The lowest family farm income per hectare were returned by cattle and sheep farms, as illustrated by Figure 122.

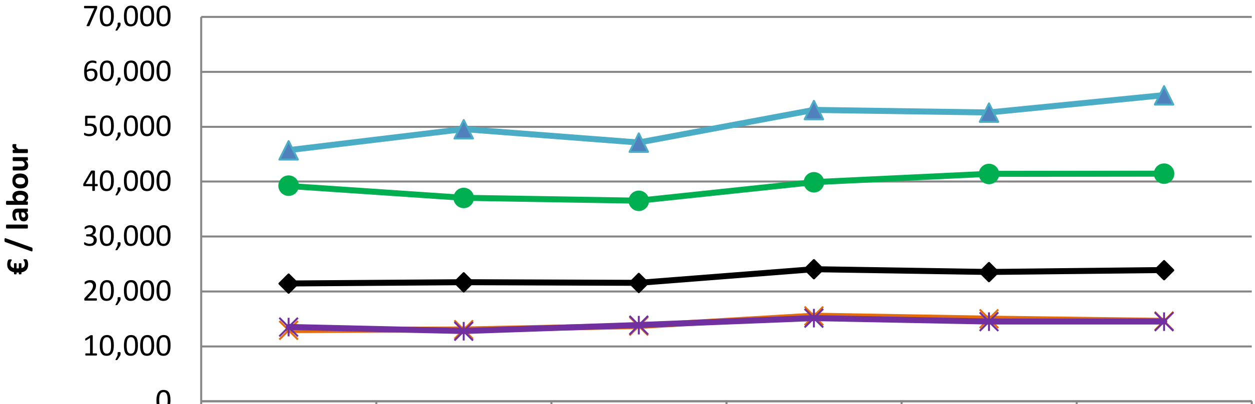
Figure 121: Family Farm income: 3 year rolling average 2014-2019



	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
Dairy	1,090	1,171	1,104	1,210	1,181	1,241
Cattle	312	307	330	373	363	339
Sheep	382	337	362	392	374	355
Tillage	517	487	493	559	592	634
All Farms	487	486	488	539	527	523

Figure 122 reveals that comparisons of farm income per labour unit follow broadly similar trends as the gross output, gross margin and family farm income 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, gross margin and family farm income, due to 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.

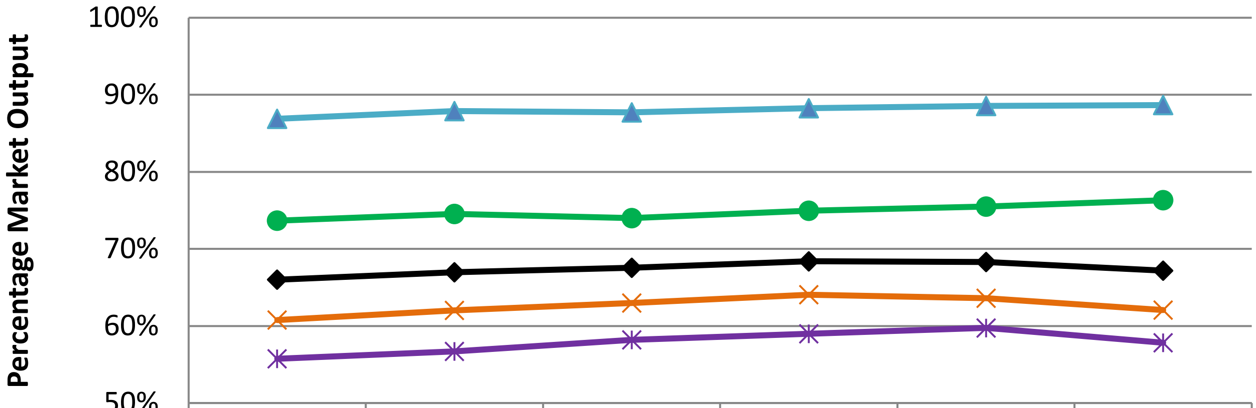
Figure 122: Productivity of Labour: 3 year rolling average 2014-2019



	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
Dairy	45,731	49,544	47,118	53,066	52,594	55,759
Cattle	12,968	13,049	13,688	15,582	15,021	14,647
Sheep	13,545	12,787	13,892	15,144	14,542	14,539
Tillage	39,227	37,057	36,528	39,888	41,435	41,453
All Farms	21,450	21,695	21,565	24,049	23,572	23,890

Figure 123 illustrates that the average share of output derived from the market generally tended to increase over the study period. This is because 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 and sheep systems was the lowest at between 56% and 64%.

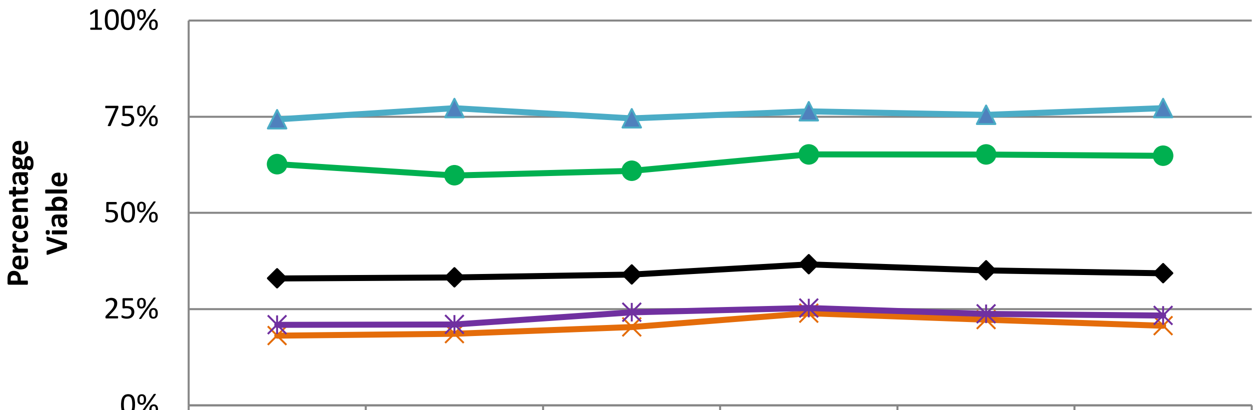
Figure 123: Percentage of Output Derived from Market: 3 year rolling average 2014-2019



	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
Dairy	87%	88%	88%	88%	89%	89%
Cattle	61%	62%	63%	64%	64%	62%
Sheep	56%	57%	58%	59%	60%	58%
Tillage	74%	75%	74%	75%	76%	76%
All Farm	66%	67%	68%	68%	68%	67%

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 77%), 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 124: Economic Viability: 3 year rolling average 2014-2019

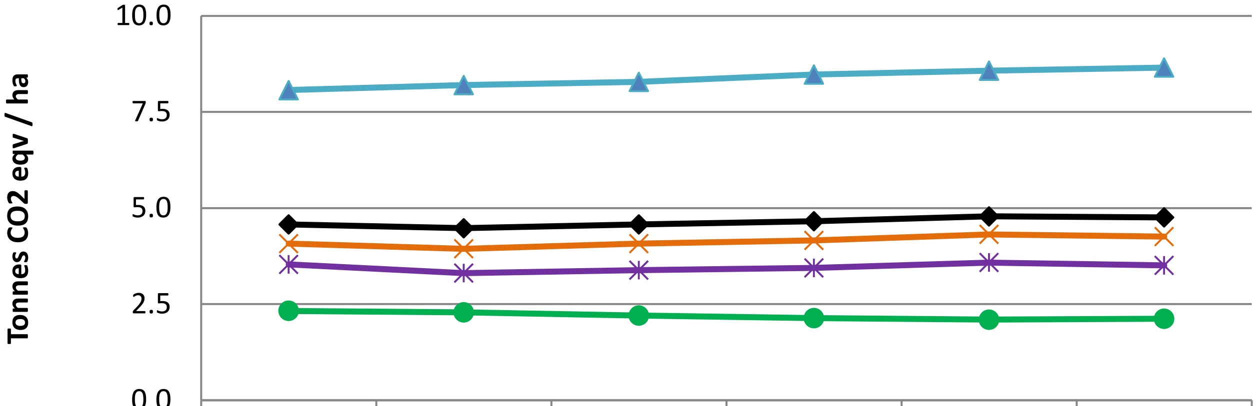


	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
Dairy	74%	77%	75%	76%	76%	77%
Cattle	18%	19%	20%	24%	22%	21%
Sheep	21%	21%	24%	25%	24%	23%
Tillage	63%	60%	61%	65%	65%	65%
All Farm	33%	33%	34%	37%	35%	34%

6.2 Environmental sustainability indicators

Figure 125 shows that agricultural GHG emissions per hectare have been increasing over the study period (4.6 to 4.8 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 2-4 times 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 GHG emissions is the driver for the increase in overall GHG emissions.

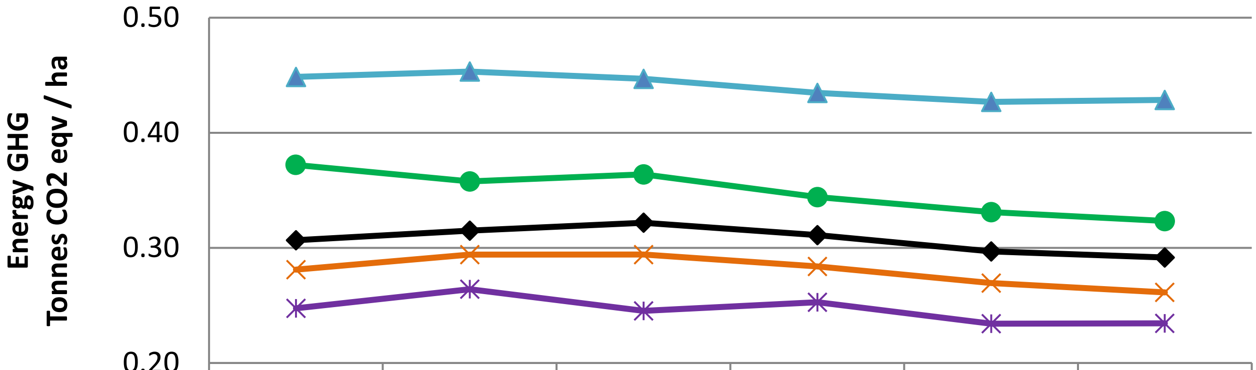
Figure 125: Ag. Greenhouse Gas Emissions per hectare: 3 year rolling average 2014-2019



	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
Dairy	8.1	8.2	8.3	8.5	8.6	8.7
Cattle	4.1	3.9	4.1	4.2	4.3	4.3
Sheep	3.5	3.3	3.4	3.4	3.6	3.5
Tillage	2.3	2.3	2.2	2.1	2.1	2.1
All Farms	4.6	4.5	4.6	4.7	4.8	4.8

Figure 125 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.

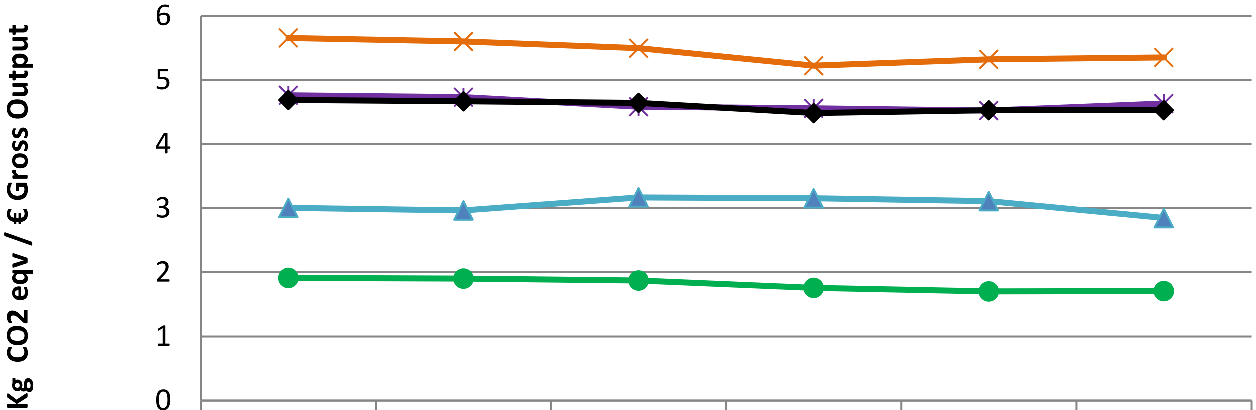
Figure 126: Energy Greenhouse Gas Emissions per hectare: 3 year rolling average 2014-2019



	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
Dairy	0.45	0.45	0.45	0.43	0.43	0.43
Cattle	0.28	0.29	0.29	0.28	0.27	0.26
Sheep	0.25	0.26	0.25	0.25	0.23	0.23
Tillage	0.37	0.36	0.36	0.34	0.33	0.32
All Farms	0.31	0.32	0.32	0.31	0.30	0.29

Figure 127 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 euro output.

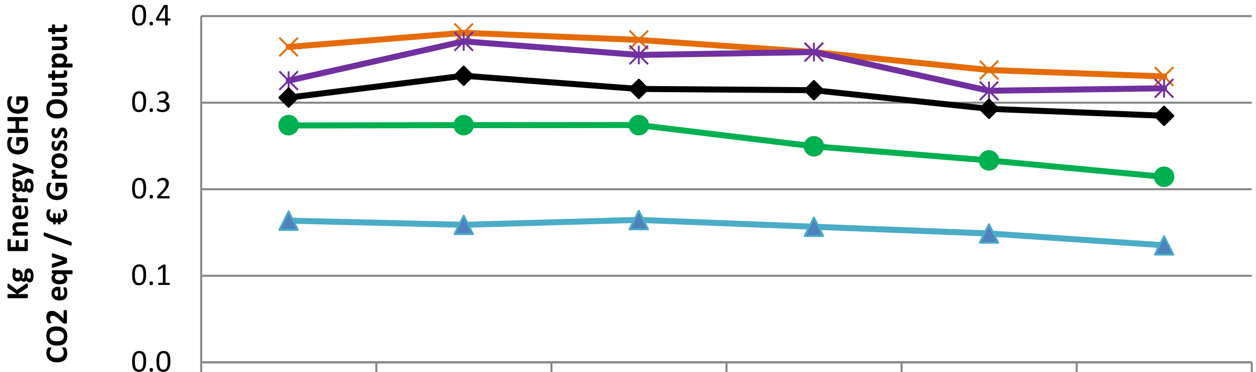
Figure 127: Ag. GHG Emissions per Euro output: 3 year rolling average 2014-2019



	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
Dairy	3.0	3.0	3.2	3.2	3.1	2.8
Cattle	5.7	5.6	5.5	5.2	5.3	5.4
Sheep	4.8	4.7	4.6	4.6	4.5	4.6
Tillage	1.9	1.9	1.9	1.8	1.7	1.7
All Farms	4.7	4.7	4.6	4.5	4.5	4.5

Figure 128 illustrates energy related 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.

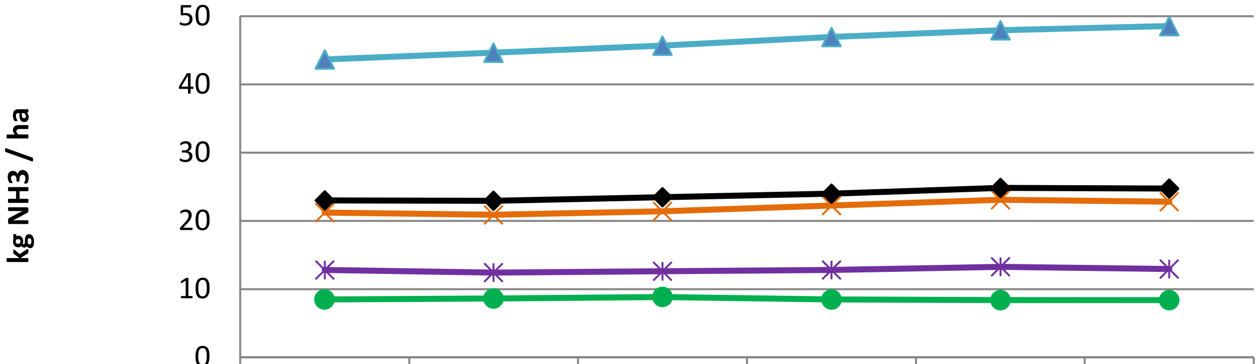
Figure 128: Energy related GHG Emissions per Euro output: 3 year rolling average 2014-2019



	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
Dairy	0.16	0.16	0.16	0.16	0.15	0.14
Cattle	0.36	0.38	0.37	0.36	0.34	0.33
Sheep	0.33	0.37	0.35	0.36	0.31	0.32
Tillage	0.27	0.27	0.27	0.25	0.23	0.21
All Farms	0.31	0.33	0.32	0.31	0.29	0.28

Figure 129 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 farm emissions per hectare towards the end of the study period.

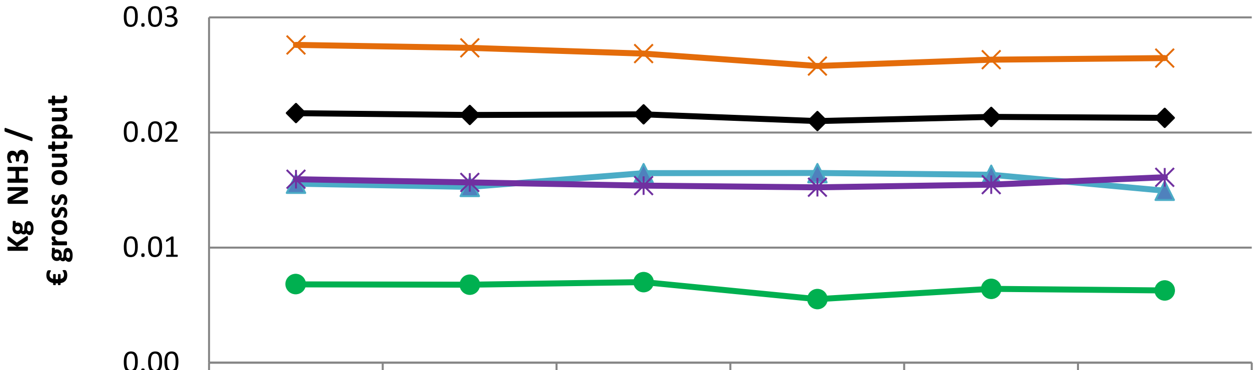
Figure 129: Kg of Ammonia Emissions per hectare: 3 year rolling average 2014-2019



	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
Dairy	43.7	44.7	45.7	46.9	47.9	48.6
Cattle	21.2	20.9	21.4	22.2	23.1	22.8
Sheep	12.8	12.4	12.6	12.8	13.3	12.9
Tillage	8.5	8.6	8.8	8.5	8.4	8.4
All Farms	23.0	22.9	23.4	24.0	24.8	24.7

Figure 130 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.

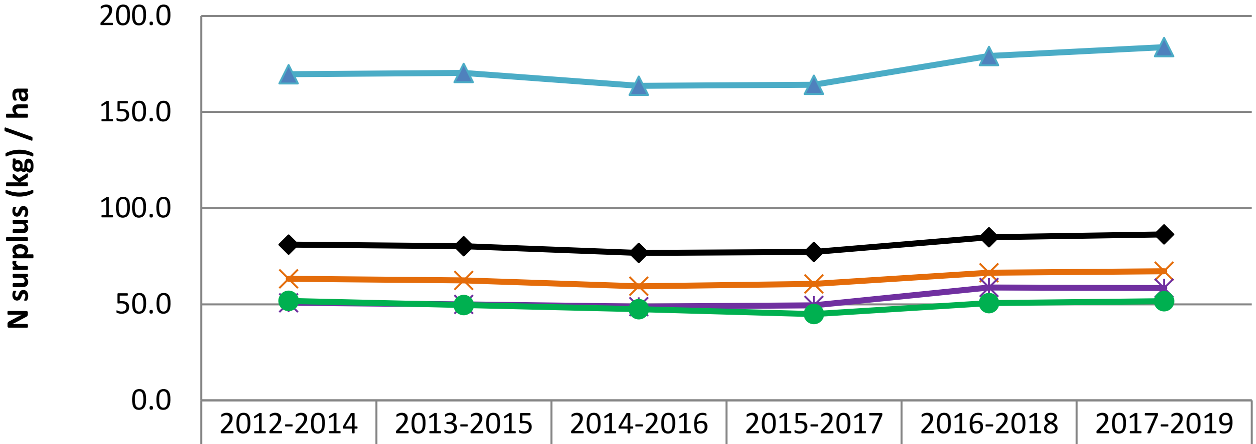
Figure 130: Ammonia (NH_3) Emissions per Euro Output: 3 year rolling average 2014-2019



	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
Dairy	0.016	0.015	0.016	0.016	0.016	0.015
Cattle	0.028	0.027	0.027	0.026	0.026	0.026
Sheep	0.016	0.016	0.015	0.015	0.015	0.016
Tillage	0.007	0.007	0.007	0.006	0.006	0.006
All Farms	0.022	0.022	0.022	0.021	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 associated with adverse annual weather conditions.

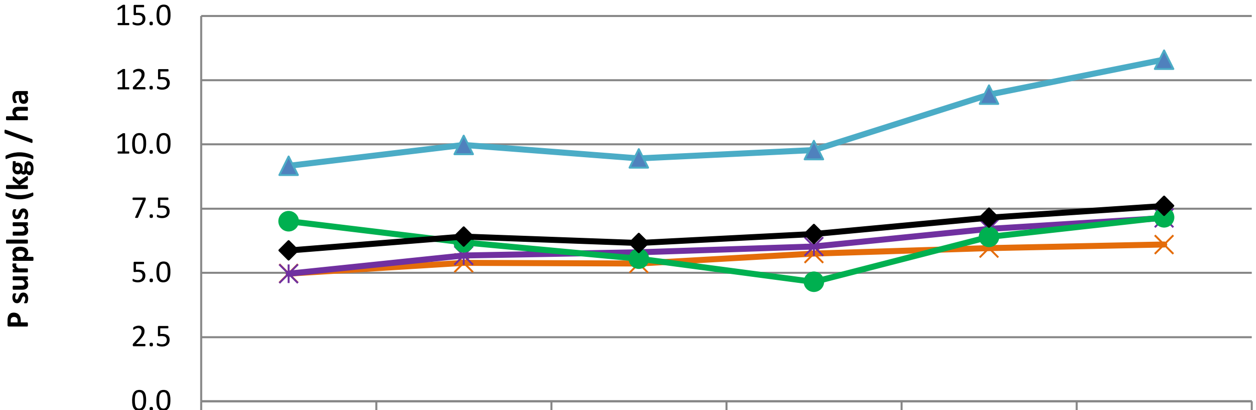
Figure 131: Nitrogen Balance per ha: 3 year rolling average 2014-2019



	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
Dairy	169.8	170.4	163.7	164.2	179.1	183.8
Cattle	63.2	62.5	59.3	60.6	66.4	67.2
Sheep	50.8	49.9	48.8	49.4	58.7	58.4
Tillage	51.7	49.5	47.5	44.9	50.5	51.6
All Farms	81.1	80.2	76.7	77.2	84.8	86.3

Figure 132 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 132: Phosphorus (P) Balance per ha: 3 year rolling average 2014-2019

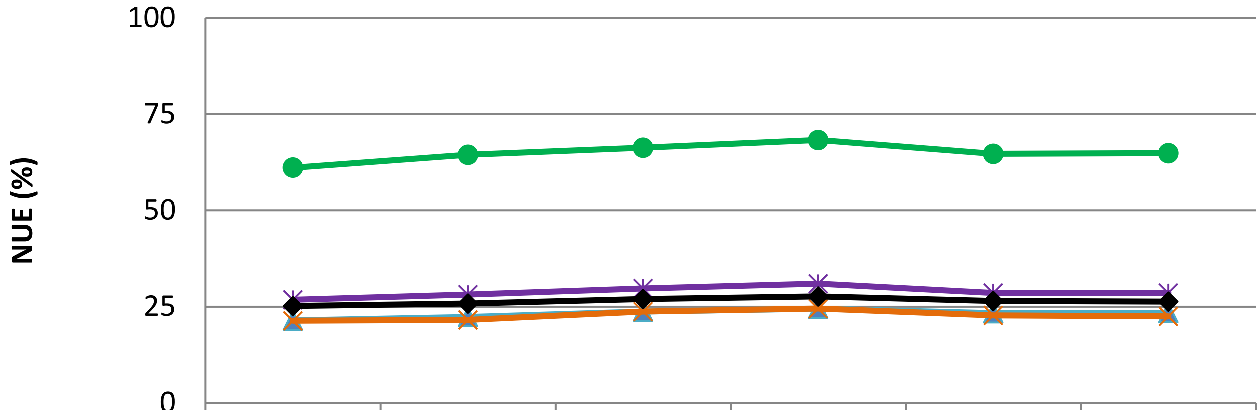


	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
Dairy	9.2	10.0	9.5	9.8	11.9	13.3
Cattle	5.0	5.4	5.4	5.8	6.0	6.1
Sheep	5.0	5.7	5.8	6.0	6.7	7.1
Tillage	7.0	6.2	5.6	4.6	6.4	7.2
All Farms	5.9	6.4	6.2	6.5	7.1	7.6

It should also be noted that 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 2019, Teagasc analysed a total of 45,157 soil samples from dairy, drystock and tillage enterprises (Teagasc, 2020). 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 133 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 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.

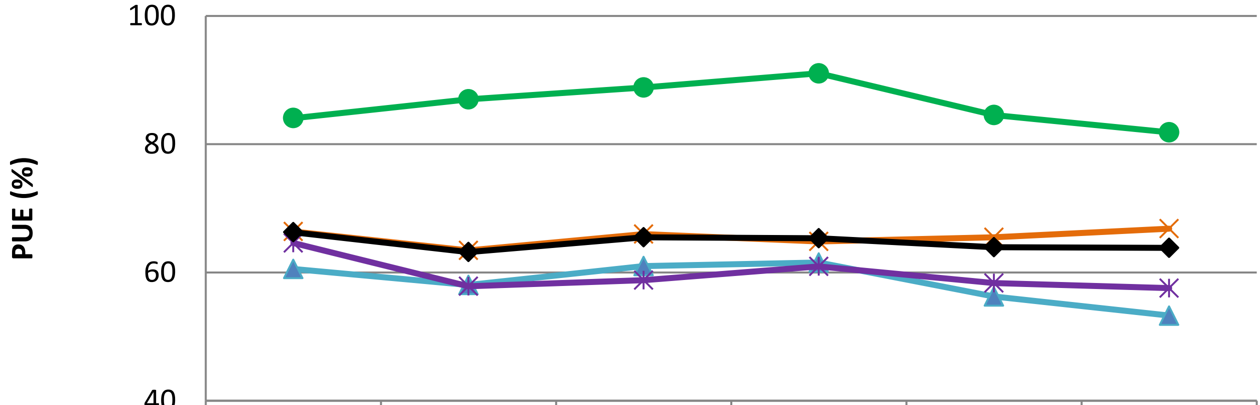
Figure 133: Nitrogen Use Efficiency: 3 year rolling average 2014-2019



	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
Dairy	21.4	22.3	23.7	24.5	23.3	23.4
Cattle	21.3	21.5	23.7	24.5	22.7	22.4
Sheep	26.8	28.1	29.7	31.0	28.5	28.5
Tillage	61.1	64.5	66.3	68.3	64.7	64.9
All Farms	25.2	25.8	26.9	27.6	26.5	26.3

Figure 134 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. 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 134: Phosphorus Use Efficiency: 3 year rolling average 2014-2019

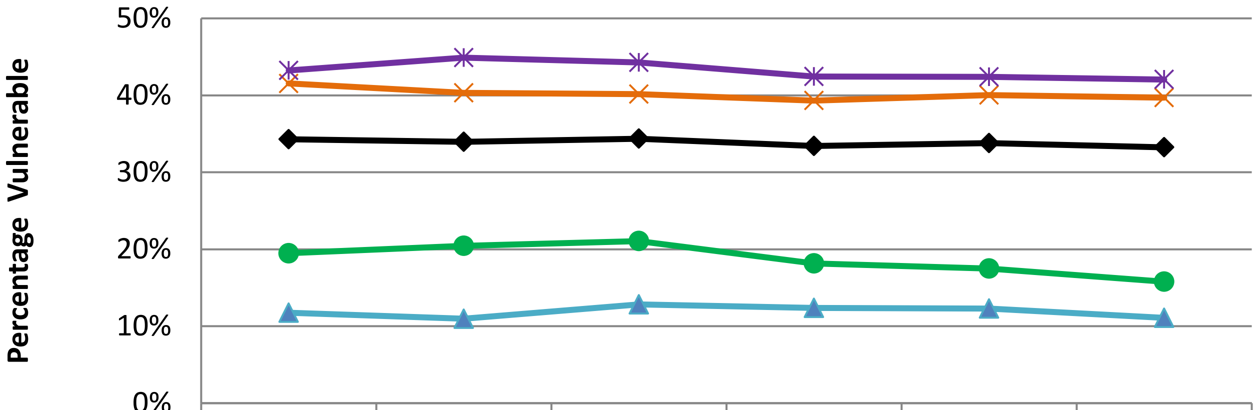


	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
Dairy	60.6	58.0	61.0	61.6	56.3	53.3
Cattle	66.4	63.4	66.0	64.8	65.5	66.8
Sheep	64.6	57.8	58.8	60.9	58.4	57.6
Tillage	84.1	87.0	88.8	91.1	84.5	81.9
All Farms	66.3	63.2	65.5	65.3	63.9	63.8

6.3 Social Sustainability Indicators

Figure 135 shows that the rate of vulnerability (non-viable farm business and no off-farm employment) of all farming households has remained stable over the 2014-2019 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.

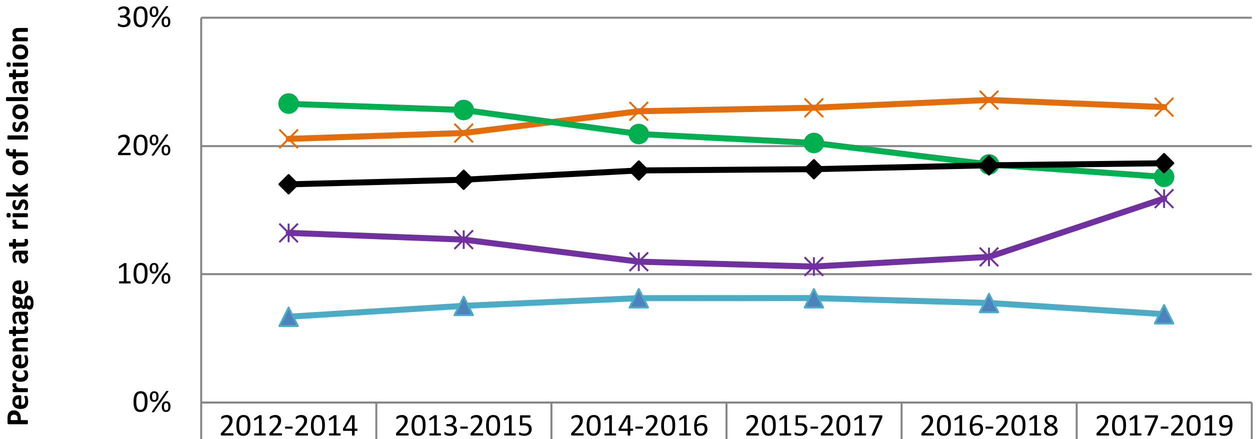
Figure 135: Farm Household Vulnerability: 3 year rolling average 2014-2019



	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
Dairy	12%	11%	13%	12%	12%	11%
Cattle	42%	40%	40%	39%	40%	40%
Sheep	43%	45%	44%	42%	42%	42%
Tillage	19%	20%	21%	18%	17%	16%
All Farms	34%	34%	34%	33%	34%	33%

Figure 136 shows that the percentage of farmers at risk of isolation increased from the start (17%) 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 (23% to 18%) while the percentage of cattle farmers at risk increased (21 to 23%). However, overall isolation risk tended to be higher on tillage and cattle farms as compared to dairy and sheep based systems.

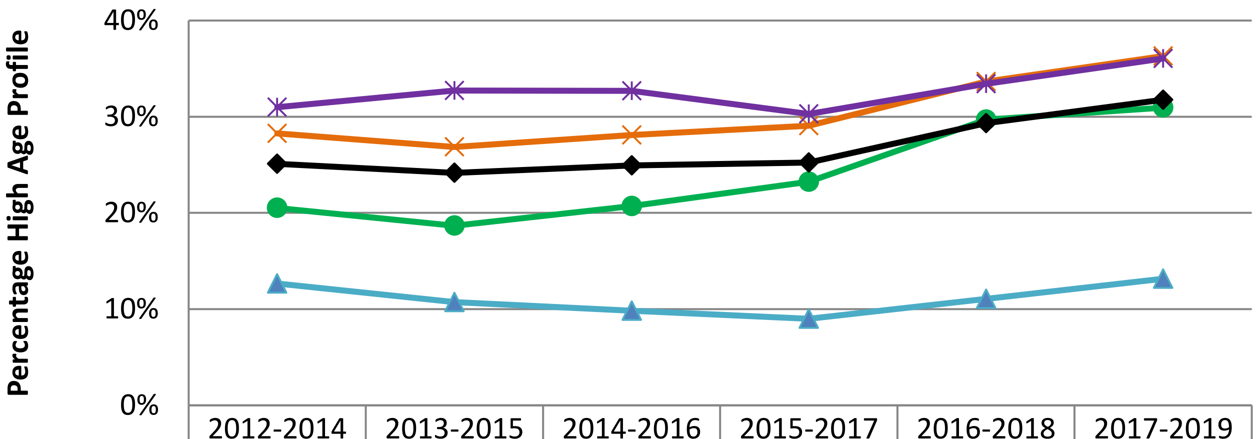
Figure 136: Isolation Risk: 3 year rolling average 2014-2019 (average per system)



	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
Dairy	7%	8%	8%	8%	8%	7%
Cattle	21%	21%	23%	23%	24%	23%
Sheep	13%	13%	11%	11%	11%	16%
Tillage	23%	23%	21%	20%	19%	18%
All Farms	17%	17%	18%	18%	19%	19%

Figure 137 shows that the percentage of all farms with a high age profile increased between the start and end of the study period (25% to 32%) 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.

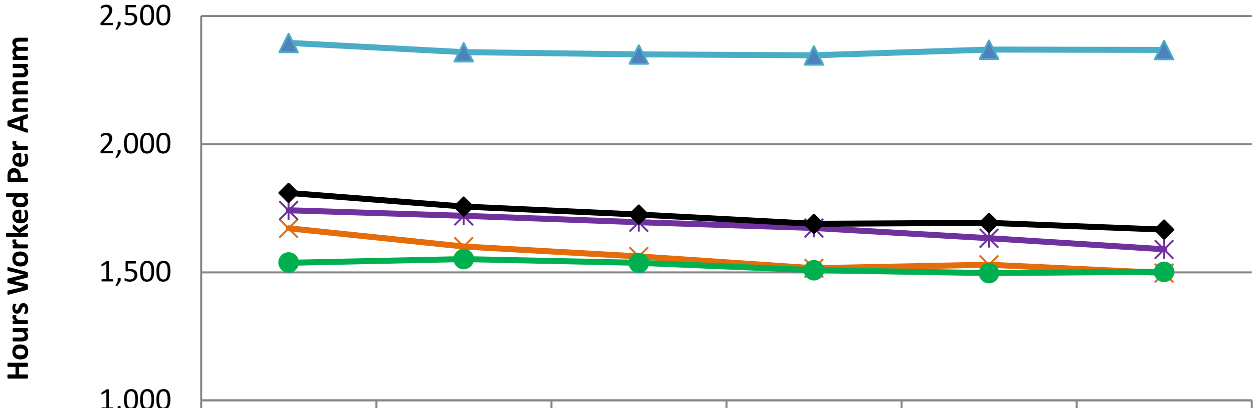
Figure 137: High Age Profile: 3 year rolling average 2014-2019 (average per system)



	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
Dairy	13%	11%	10%	9%	11%	13%
Cattle	28%	27%	28%	29%	34%	36%
Sheep	31%	33%	33%	30%	33%	36%
Tillage	21%	19%	21%	23%	30%	31%
All Farm	25%	24%	25%	25%	29%	32%

Figure 138 shows that the hours worked on-farm per annum declined slightly across all farms between 2014 and 2019. 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. Hours worked on farm per annum were significantly higher on dairy farms, compared to all other farm systems.

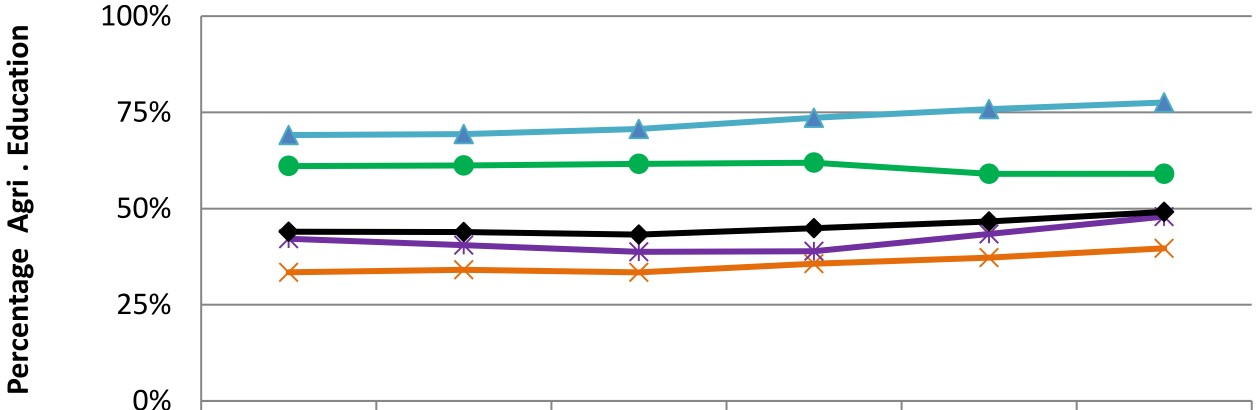
Figure 138: Hours Worked Per Annum: 3 year rolling average 2014-2019 (average per system)



	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
Dairy	2,395	2,359	2,351	2,347	2,369	2,368
Cattle	1,672	1,601	1,562	1,516	1,529	1,497
Sheep	1,742	1,720	1,695	1,673	1,633	1,590
Tillage	1,537	1,551	1,536	1,509	1,497	1,502
All Farms	1,810	1,756	1,725	1,689	1,693	1,666

Figure 139 indicates that the percentage of famers who have received some form of agricultural education has increased over the period 2014-2019 at between 44% and 49%. Significantly, higher levels of formal agricultural education were prevalent among dairy and tillage farmers, compared to cattle / sheep farms.

Figure 139: Formal Agricultural Education: 3 year rolling average 2014-2019 (average per system)



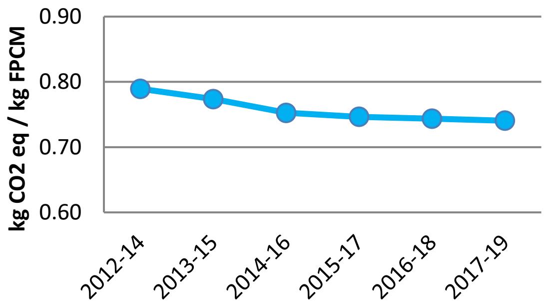
	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
Dairy	69%	69%	71%	74%	76%	78%
Cattle	33%	34%	33%	36%	37%	40%
Sheep	42%	40%	39%	39%	43%	48%
Tillage	61%	61%	62%	62%	59%	59%
All Farms	44%	44%	43%	45%	47%	49%

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 and sheep meat). Results are again reported on the basis of a three year rolling average (e.g. the 2012-2014 results are the average of 2012, 2013 and 2014 results). Results for individual years are reported in the appendices by farm system.

Results presented in Figure 140 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 2012.

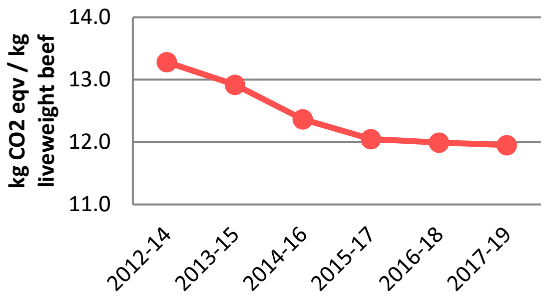
Figure 140: Ag. GHG Emissions per kg FPCM: 2014-2019 Dairy Farms*



Note: (IPCC approach) 3 year rolling average

Figure 141 indicates that kg of CO2 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.

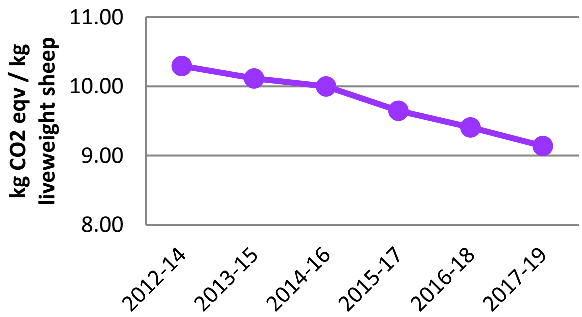
Figure 141: Ag. GHG Emissions per kg live-weight beef produced: 2014-2019 (Cattle Farms*)



Note: (IPCC approach) 3 year rolling average

Figure 142 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 2014 and 2019.

Figure 142: Ag. GHG Emissions per kg live-weight sheep produced: 2014-2019 Sheep Farms*

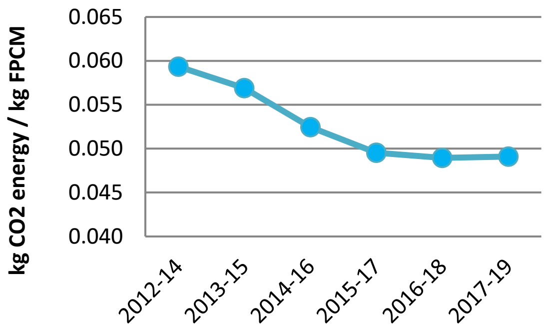


Note: (IPCC approach) 3 year rolling average

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 143 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 of the period studied.

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

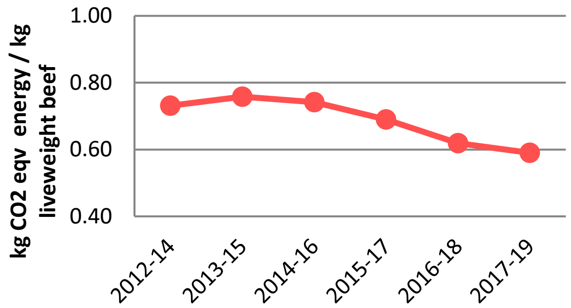
Figure 143: Energy use related GHG emissions per kg FPCM: 2014-2019 Dairy Farms



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 declining trend evident toward the end of the study period as illustrated in Figure 144.

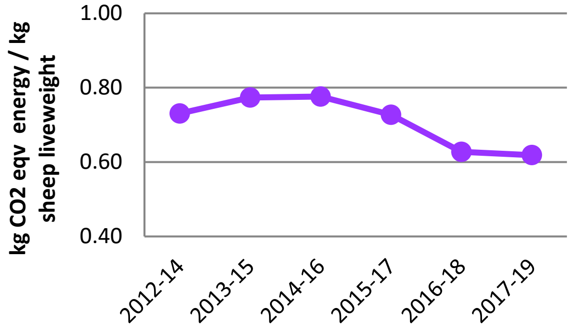
Figure 144: Energy use related GHG emissions per kg live-weight beef produced: 2014-2019 Cattle Farms*



Note: (IPCC approach) 3 year rolling average

Energy related GHG emissions from the production of live-weight sheep were also relatively static over the first part of the study period with a declining trend evident towards the end of the period as illustrated in Figure 145.

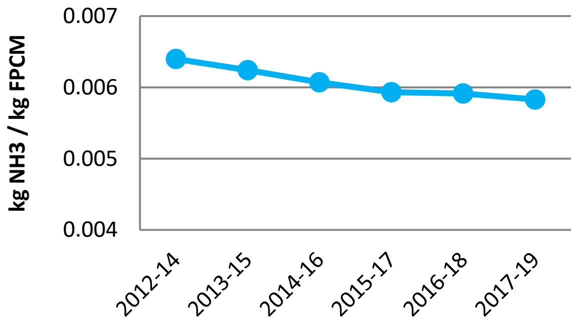
Figure 145: Energy use related GHG emissions per kg live-weight sheep produced: 2014-2019 Sheep Farms*



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 as outlined in Figure 146.

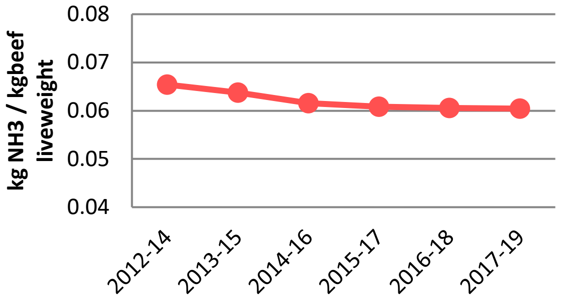
Figure 146: Ammonia emissions per kg FPCM: 2014-2019 3 year rolling average Dairy Farms



On a three year rolling average basis, NH3 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 147.

Methodological update from previous report, numbers have been amended.

Figure 147: Ammonia emissions per kg live-weight beef produced: 2014-2019 Cattle Farms



This pattern was repeated for NH_3 emissions per kg of live-weight sheep meat produced on sheep farms, as illustrated in Figure 148.

Figure 148: Ammonia emissions per kg live-weight sheep produced: 2014-2019 Sheep Farms*

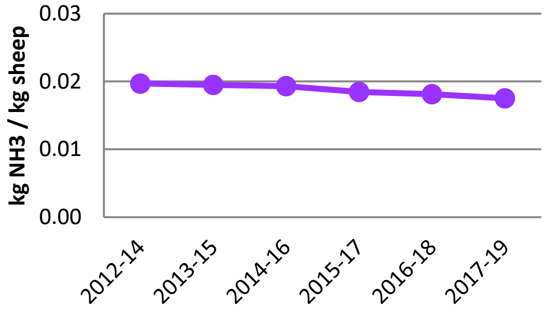


Figure 149 illustrates the trend on dairy farms in terms of kg of FPCM produced per kg of N surplus (excess of N input over outputs), on a three year rolling average basis. The graph shows an increase in FPCM produced per kg of N surplus followed by a decline at the end of the period.

Figure 149: kg of FPCM produced per kg of N surplus: 2014-2019 Dairy Farms

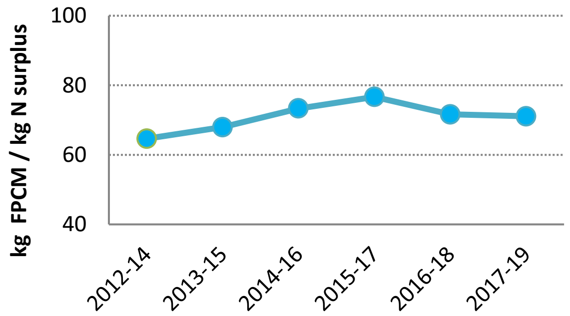
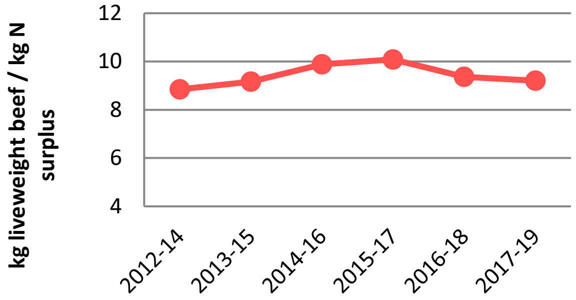


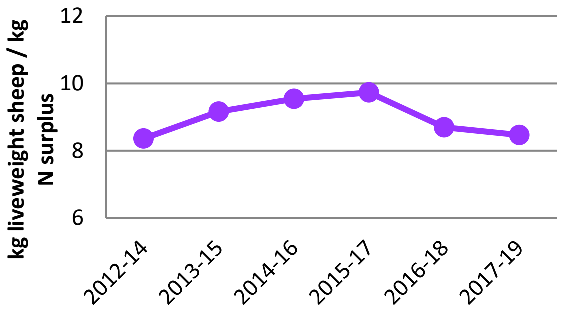
Figure 150 shows the trend per kg of live-weight beef produced per kg of N surplus. Based on a three year rolling average, results indicate a relatively static trend at the start of the study period followed by a slight increase mid study period, before a decline at the end.

Figure 150: kg of live-weight beef produced per kg of N surplus: 2014-2019 Cattle Farms*



Results for kg of live-weight sheep meat produced per kg of N surplus on sheep farms are presented in Figure 151. 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.

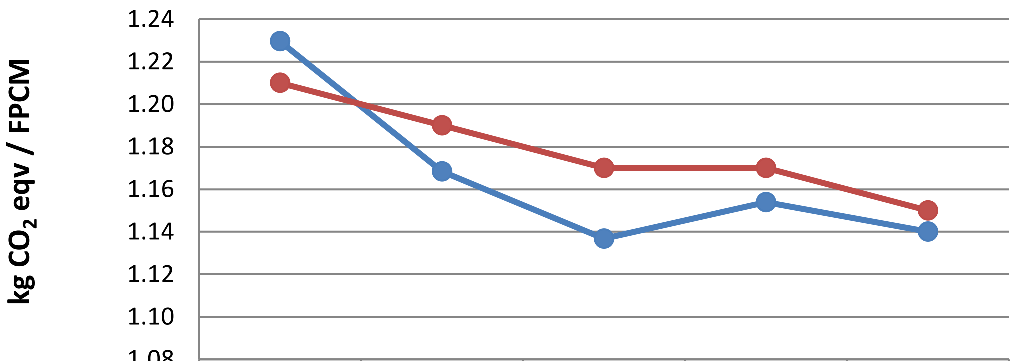
Figure 151: kg of live-weight sheep produced per kg of N surplus: 2014-2019 Sheep Farms



7. National Cross Validation on Carbon Footprint of Milk Production

Using the broader 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, an increase was evident for the 2016-2018 period, this can be largely attributed to adverse weather experienced in 2018. However, this trend was reverse and reverted to the more long terms downward trend for the 2017-2019 period both on a on a weighted farm and national aggregate basis. 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) (Murphy, 2020) as outlined below.

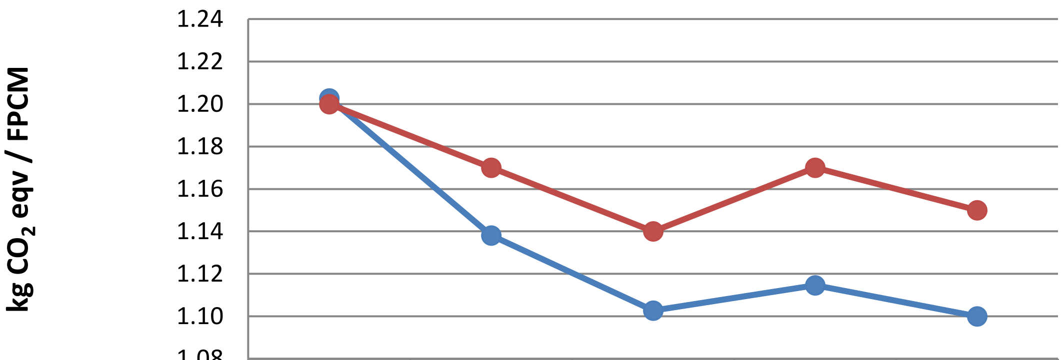
Figure 152: GHG per kg FPCM (LCA Approach) – 3 year rolling nationally weighted farm average



	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
Teagasc NFS	1.23	1.17	1.14	1.15	1.14
Bord Bia SDAS*	1.21	1.19	1.17	1.17	1.15

* 2019 data is based on preliminary results

Figure 153: GHG per kg FPCM (LCA Approach) – 3 year rolling average weighted by milk supply.



	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019
Teagasc NFS	1.20	1.14	1.10	1.11	1.10
Bord Bia SDAS*	1.20	1.17	1.14	1.17	1.15

* 2019 data is based on preliminary results

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 Teagasc Sustainability Reports (Hennessy et al., 2013; Lynch et al., 2016; Buckley et al., 2019, Buckley et al., 2020) 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 as compared to beef 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 using Teagasc NFS data.

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 now allowed ecologists to use remote mapping to identify farmland habitat biodiversity on close to 300 NFS farms. If further funding for this initiative could be secured this would allow the habitat biodiversity assessment to be undertaken on all NFS farms. It could also allow this assessment to be repeated on a periodic basis to track changes in habitat biodiversity over time. In turn this would allow the inclusion of habitat biodiversity as an the indicator set of the Teagasc Sustainability Report.

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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 – Individual year results by farm system 2014-2019

Table 5: Sustainability Indicator results for Dairying Farms 2014-2019

Indicator	***2014***	***2015***	***2016***	***2017***	***2018***	***2019***
Economic Sustainability Metrics			€			
Economic return per hectare	3,404	3,283	3,021	3,720	3,637	3,605
Profitability per hectare	1,767	1,710	1,457	2,111	1,728	1.793
Family farm income per hectare	1,219	1,149	942	1,538	1,063	1,123
Productivity of labour	50,803	49,363	41,188	68,646	47,947	50,683
		percentage				
Market orientation	88	88	87	90	89	88
Viability	80	75	69	85	73	74
Social Sustainability Metrics						
Household vulnerable	9%	13%	16%	8%	13%	12%
Isolation	8%	8%	8%	8%	7%	6%
High age profile	14%	6%	9%	12%	12%	15%
Hours worked	2,354	2,329	2,370	2,341	2,397	2,365
Agricultural education	67%	71%	74%	76%	81%	79%
Environmental Sustainability Metrics						
		tonnes CO2 eqv per farm				
Total farm average Ag. GHG emissions*	445.9	465.7	487.9	502.2	503.0	507.6
of which dairy*	265.2	287.4	301.5	313.4	314.2	329.6
cattle*	179.3	176.7	185.1	187.4	187.5	176.8
sheep*	1.2	1.3	1.2	1.2	1.1	1.1
other*	0.2	0.1	0.1	0.1	0.1	0.1
energy use	17.2	17.4	17.6	17.5	17.7	17.5
		tonnes CO_2 eqv per ha				
Ag GHG Emissions*	8.07	8.32	8.45	8.65	8.63	8.69
Energy GHG Emissions	0.46	0.46	0.42	0.42	0.43	0.43
		kg CO_2 eqv				
GHG Emissions per kg milk*	0.76	0.74	0.75	0.74	0.74	0.74
GHG Emissions per kg FPCM*	0.77	0.74	0.74	0.75	0.73	0.73
GHG Emissions per € output*	2.73	2.92	3.30	2.71	2.76	2.56
Energy Emissions per kg milk	0.06	0.05	0.05	0.05	0.05	0.05
Energy Emissions eqv per kg FPCM	0.06	0.05	0.05	0.05	0.05	0.05
GHG Emissions per kg FPCM (LCA)	1.24	1.14	1.13	1.14	1.19	1.14
		tonnes NH_3 per farm				
Total farm average NH3 emissions	2.47	2.57	2.76	2.82	2.88	2.9
of which dairy	1.94	2.05	2.13	2.19	2.18	2.25
cattle	0.24	0.22	0.25	0.25	0.28	0.23
sheep	0.0	0.0	0.0	0.0	0.0	0.0
chemical fertiliser	0.29	0.3	0.38	0.38	0.42	0.42
kg NH_2						
NH_3 emissions per hectare	44.3	45.6	47.1	47.8	48.8	49.0
NH_3 emissions per Euro output	0.015	0.016	0.018	0.015	0.016	0.014
NH_3 emissions per kg milk	0.0062	0.0059	0.0060	0.0059	0.0059	0.0058
NH_3 emissions per kg FPCM	0.0063	0.0059	0.0059	0.0059	0.0059	0.0057

Indicator	***2014***	***2015***	***2016***	***2017***	***2018***	***2019***
		kg per ha				
N Balance per hectare	170.3	155.9	164.8	171.9	200.7	178.7
P Balance per hectare	10.4	9.0	9.0	11.4	15.6	13.3
		percentage				
N use efficiency	22.2	25.0	24.0	24.4	21.5	24.4
P use efficiency	56.8	63.8	62.4	58.4	48.7	53.5
		Per kg of N Surplus				
Kg FPCM	66.1	78.6	75.3	76.0	63.6	73.7

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

Table 6: Sustainability Indicator results for Cattle Farms 2014-2019

Indicator	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
Economic Sustainability Metrics						
Economic return per hectare	1,154	1,189	1,312	1,336	1,312	1,306
Profitability per hectare	374	463	507	533	483	497
Family Farm Income per hectare	264	346	381	391	317	311
Productivity of labour	11,225	15,029	14,809	16,909	13,344	13,688
	percentage					
Market orientation	61%	64%	64%	64%	62%	60%
Viability	15%	24%	23%	25%	18%	18%
Social Sustainability Metrics						
Household vulnerable	41%	38%	42%	39%	40%	41%
Isolation	22%	22%	24%	23%	24%	22%
High age profile	28%	25%	31%	32%	38%	39%
Hours worked	1,646	1,474	1,566	1,508	1,513	1,470
Agricultural education	31%	36%	33%	38%	41%	40%
Environmental Sustainability Metrics						
	tonnes CO_2 eqv per farm					
Total farm average Ag. GHG emissions*	139.5	131.0	138.0	139.8	141.8	137.1
of which dairy*	0.0	0.0	0.0	0.0	0.0	0.0
cattle*	135.3	127.4	134.3	136.6	138.3	133.6
sheep*	4.1	3.6	3.7	3.2	3.4	3.4
other*	0.1	0.0	0.0	0.0	0.1	0.1
energy use	9.5	9.5	8.5	8.1	8.2	8.1
	tonnes CO_2 eqv per ha					
Ag GHG Emissions*	4.1	3.8	4.3	4.3	4.3	4.2
Energy GHG Emissions	0.29	0.30	0.28	0.26	0.26	0.26
	kg CO_2 eqv					
Ag. GHG Emissions per kg live-weight beef*	13.0	12.2	11.9	12.0	12.1	11.7
Ag. GHG Emissions per € output*	5.6	5.0	4.9	4.8	5.3	5.1
Energy Emissions per kg live-weight beef	0.74	0.77	0.59	0.48	0.60	0.58
	tonnes NH_3 per farm					
Total farm average NH3 emissions	0.71	0.68	0.73	0.74	0.75	0.73
of which dairy	0.0	0.0	0.0	0.0	0.0	0.0
cattle	0.66	0.64	0.69	0.7	0.7	0.68
sheep	0.01	0.0	0.0	0.0	0.0	0.0
chemical fertiliser	0.04	0.04	0.04	0.04	0.05	0.05
	kg NH_3					
NH_3 emissions per hectare	21.0	20.0	23.2	23.2	22.9	22.3
NH_3 emissions per Euro output	0.029	0.026	0.026	0.025	0.028	0.027
NH_3 emissions per kg live-weight beef	0.0637	0.0609	0.0601	0.0614	0.0602	0.0598
	kg per ha					
N Balance per hectare	61.3	53.6	63.0	65.2	70.7	65.4
P Balance per hectare	5	5.4	5.6	6.2	6.0	6.1

Indicator	***2014***	***2015***	***2016***	***2017***	***2018***	***2019***
			percentage			
N use efficiency	22.4	22.4	23.1	24.2	20.8	22.3
P use efficiency	67.5	61.2	69.3	64.0	63.2	73.3
			Per kg of N Surplus			
kg Live weight beef	8.7	10.8	10.2	9.3	8.7	9.7

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

Table 7: Sustainability Indicator results for Sheep Farms 2014-2019

Indicator	***2014***	***2015***	***2016***	***2017***	***2018***	***2019***
Economic Sustainability Metrics						
Economic return per hectare	1,265	1,134	1,291	1,375	1,322	1,246
Profitability per hectare	475	417	435	545	400	414
Family Farm Income per hectare	371	332	383	461	277	326
Productivity of labour	13,289	14,122	14,266	17,043	12,316	14,259
			percentage			
Market orientation	57%	57%	61%	60%	59%	55%
Viability	24%	24%	24%	27%	20%	23%
Social Sustainability Metrics						
Household vulnerable	46%	45%	42%	41%	44%	41%
Isolation	13%	11%	9%	12%	13%	23%
High age profile	37%	28%	33%	30%	38%	41%
Hours worked	1,710	1,700	1,675	1,644	1,581	1,543
Agricultural education	41%	36%	39%	42%	50%	52%
Environmental Sustainability Metrics						
			tonnes CO_2 eqv per farm**			
Total farm average Ag. GHG emissions*	134.1	124.7	135.1	140.3	134.1	130.8
of which dairy*	0.8	1.2	0.0	1.7	0.0	0.0
cattle*	72.9	65.7	73.5	73.3	69.8	67.9
sheep*	60.3	57.7	61.5	65.2	64.1	62.7
other*	0.1	0.1	0.1	0.1	0.2	0.2
energy use	9.7	9.9	7.9	8.7	8.2	8.3
			tonnes CO_2 eqv per ha			
Ag GHG Emissions*	3.5	3.1	3.5	3.7	3.5	3.3
Energy GHG Emissions	0.25	0.27	0.22	0.26	0.23	0.23
			kg CO_2 eqv			
Ag. GHG Emissions per kg live-weight sheep produced*	9.4	9.4	8.9	8.5	8.5	8.3
Ag. GHG Emissions per € output*	4.3	4.4	4.4	4.3	4.2	4.1
Energy Emissions per kg live-weight sheep produced	0.78	0.91	0.64	0.63	0.61	0.61
			tonnes NH_3 per farm			
Total farm average NH3 emissions	0.51	0.47	0.52	0.53	0.51	0.50
of which dairy	0.0	0.0	0.0	0.0	0.0	0.0
cattle	0.37	0.34	0.38	0.38	0.35	0.35
sheep	0.09	0.09	0.09	0.10	0.09	0.09
chemical fertiliser	0.05	0.04	0.05	0.05	0.07	0.06
			kg NH_3			
NH_3 emissions per hectare	12.9	11.2	13.5	13.5	12.8	12.6
NH_3 emissions per Euro output	0.015	0.015	0.016	0.015	0.016	0.018
NH_3 emissions per kg live-weight sheep	0.019	0.020	0.018	0.017	0.019	0.017
			kg per ha			
N Balance per hectare	51.4	42.4	52.5	53.4	70.2	51.7
P Balance per hectare	5.8	5.9	5.6	6.5	8.0	6.9

Indicator	***2014***	***2015***	***2016***	***2017***	***2018***	***2019***
			percentage			
N use efficiency	27.7	32.1	29.3	31.5	24.7	29.4
P use efficiency	57.1	58.6	60.6	63.6	50.9	58.2
			Per kg of N Surplus			
kg Live weight sheep	8.3	10.9	9.5	8.9	7.7	8.8

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

Table 8: Sustainability Indicator results for Tillage Farms 2014-2019

Indicator	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
Economic Sustainability Metrics						
Economic return per hectare	1,638	1,784	1,671	1,734	1,852	2,038
Profitability per hectare	618	757	671	817	904	921
Family farm income per hectare	419	559	502	616	658	627
Productivity of labour	34,252	38,978	36,355	44,330	43,620	36,410
			percentage			
Market orientation	73%	77%	73%	76%	78%	75%
Viability	61%	62%	60%	74%	62%	59%
Social Sustainability Metrics						
Household vulnerable	20%	20%	23%	11%	18%	18%
Isolation	22%	21%	21%	19%	16%	18%
High age profile	20%	15%	28%	27%	34%	31%
Hours worked	1,544	1,540	1,525	1,462	1,504	1,542
Agricultural education	60%	62%	62%	61%	62%	62%
Environmental Sustainability Metrics						
			tonnes CO_2 eqv per farm			
Total farm average Ag. GHG emissions*	149.4	147	140.2	135.5	132.5	130.9
of which dairy*	0.0	0.0	0.0	0.0	0.0	0.0
cattle*	117	116.9	105.9	109	108.9	104.3
sheep*	13.3	11.7	10.9	10	10	12.6
other*	19.1	18.4	23.4	16.5	13.6	14.0
energy use	25.4	23.3	23.3	19.3	20.1	20.3
			tonnes CO_2 eqv per ha			
Ag GHG Emissions*	2.3	2.3	2.0	2.1	2.2	2.1
Energy GHG Emissions	0.4	0.3	0.4	0.3	0.3	0.3
			kg CO_2 eqv			
Ag. GHG Emissions per € output*	2.0	1.7	1.6	1.6	1.5	1.6
			tonnes NH_3 per farm			
Total farm average NH3 emissions	0.59	0.60	0.61	0.52	0.57	0.58
of which dairy	0.0	0.0	0.0	0.0	0.0	0.0
cattle	0.49	0.49	0.45	0.43	0.44	0.42
sheep	0.01	0.01	0.01	0.01	0.01	0.01
chemical fertiliser	0.09	0.10	0.15	0.08	0.12	0.15
			kg NH_3			
NH_3 emissions per hectare	8.82	8.87	8.50	7.82	8.84	8.48
NH_3 emissions per Euro output	0.0076	0.0065	0.0068	0.0062	0.0061	0.0065
			kg per ha			
N Balance per hectare	50.8	45.2	46.6	43.0	62.0	49.9
P Balance per hectare	7.4	4.3	5.0	4.7	9.6	7.2
			percentage			
N use efficiency	63.8	67.8	67.4	69.8	57.1	67.8
P use efficiency	84.0	92.9	89.7	90.6	73.3	81.6

Table 9: Sustainability Indicator results for All Farms 2014-2019

Indicator	***2014***	***2015***	***2016***	***2017***	***2018***	***2019***
Economic Sustainability Metrics						
Economic return per hectare	1,627	1,605	1,638	1,793	1,766	1,758
Profitability per hectare	668	703	676	835	722	745
Family Farm income per hectare	470	505	490	622	468	481
Productivity of labour	20,763	22,958	21,024	28,164	21,529	21,976
			percentage			
Market orientation	66%	68%	68%	69%	68%	65%
Viability	32%	36%	34%	40%	31%	32%
Social Sustainability Metrics						
Household vulnerable	34%	33%	36%	32%	34%	34%
Isolation	18%	18%	19%	18%	19%	19%
High age profile	27%	21%	27%	28%	33%	34%
Hours worked	1,779	1,670	1,724	1,674	1,681	1,645
Agricultural education	42%	44%	43%	47%	49%	51%
Environmental Sustainability Metrics						
			tonnes CO_2 eqv per farm			
Total farm average Ag. GHG emissions	195.8	191.5	199.5	203.6	203.8	201.1
energy use	13.7	13.4	12.1	11.6	11.8	11.8
			tonnes CO_2 eqv			
Ag GHG Emissions per hectare	4.6	4.4	4.8	4.8	4.8	4.7
Ag GHG Emissions per Euro output	4.6	4.3	4.3	4.9	4.4	4.4
Energy GHG Emissions per hectare	0.3	0.3	0.3	0.3	0.3	0.3
			tonnes NH_3 per farm			
Total farm average NH3 emissions	0.99	0.98	1.05	1.06	1.08	1.06
			kg NH_3			
NH_3 emissions per hectare	22.94	22.42	24.78	24.88	24.85	24.47
NH_3 emissions per Euro output	0.0222	0.0208	0.0218	0.0204	0.0219	0.0215
			kg per ha			
N Balance per hectare	80.1	71.0	79.1	81.7	93.6	83.7
P Balance per hectare	6.4	6.1	6.2	7.2	8.3	7.6
			percentage			
N use efficiency	25.9	27.7	27.1	28.1	24.1	26.6
P use efficiency	64.9	63.5	68	64.5	59.0	67.7