Teagasc National Farm Survey 2021 Sustainability Report

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Any errors or omissions remain the responsibility of the authors.

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Abbreviations

CH_4	Methane
CO_2	Carbon dioxide
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
GWP	Global Warming Potential
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

Glossary of Terms

CO_2 equivalent: For reporting purposes all non-carbon dioxide (CO_2) emissions of GHG are converted to CO_2 equivalents using appropriate global warming potentials (GWP100) for CH_4 and N_2O which are respectively 28 and 265 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) per farm: The average amount of territorial greenhouse gas emissions (CO_2, N_2O, CH_4) produced in a particular farm type. The approach follows the recognised IPCC methodology used in the calculation on the National GHG inventory

Greenhouse Gases (GHG) per hectare: The average amount of territorial greenhouse gas emissions (CO_2, N_2O, CH_4) produced in a particular farm system expressed on a per hectare basis. The approach follows the recognised IPCC methodology used in the calculation on the National GHG inventory

Greenhouse Gases (GHG) per unit of output: The average amount of territorial greenhouse gas emissions (CO_2, N_2O, CH_4) associated with the production of a specific type of agricultural product, expressed as kg CO_2 equivalent per kg of produce (e.g. per kg liveweight beef, milk). The approach follows the recognised IPCC methodology used in the calculation on the National GHG inventory

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, per head payments are included in gross output in this report.

Gross Margin: Gross output minus direct costs.

Global Warming Potential: When counting the emissions of various greenhouse gases they are brought to a common base, or CO_2 equilavent. This common base is arrived at by applying a global warming potential (GWP) to each gas (e.g. N_2O, CH_4). The GWP for CH_4 and N_2O used in this report are those published by the IPCC AR5 report.

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 that 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 an indicator 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.

Executive Summary

This report provides the latest available information on the sustainability performance of farms in Ireland, based on detailed analysis of data collected through the Teagasc National Farm Survey. Economic, Social, Environmental and Innovation sustainability dimensions are measured for Dairy, Cattle, Sheep and Tillage farms in 2021. The report also includes time series results over several years, which allows an assessment of how farm sustainability has changed temporally. Note that methodological changes have led to the revision of results for earlier years. This means that previously published figures for earlier years are now superseded by the revisions published in this report. In general, the revisions are larger for the dairy system than for the other systems.

Methodological Updates

- New data on the composition of the farm population provided in the Census of Agriculture has led to an **updated set of farm population weights** for the 2017 to 2021 period. Hence, the 2021 sustainability report includes a recalculation of all of the farm related measures including average farm size, income and emissions for the full 2017-2021 period. The Census of Agriculture 2020 indicates that there are fewer dairy farms over the study period that previously estimated, but that a greater proportion of these farms fall into larger size classes.
- The IPCC periodically publishes an Assessment Report which lays out the state of knowledge with respect to the science of climate change. The most recent assessment report, called the Fifth Assessment Report (AR5), has updated the global warming potential (GWP) values for methane and nitrous oxide, giving methane a higher GWP value (increased from 25 to 28 tonnes of CO2 equivalent) and nitrous oxide a lower GWP value (decreased from 298 to 265 tonnes of CO2 equivalent) than was previously the case in the Fourth Assessment Report (AR4). This updated approach **has been adopted this year** in Ireland's National GHG Inventory and similarly it has been applied in this year's Sustainability Report. This has resulted in revised estimates for the level of greenhouse emissions produced across each farm type.
- For these reasons, the historical time series for the sustainability indicators presented in the current report will differ from those presented in earlier Teagasc Sustainability reports. Reflecting development of our scientific understanding of the global warming potential of different GHG and our understanding of the composition of the Irish farm population, the revised and updated set of historical sustainability indicators supersede previously published Teagasc Sustainability report data.

Economic sustainability

- Consistent with the established trend of earlier years, Dairy farms remains an economic powerhouse in Irish agriculture. Average **economic returns per hectare** in Dairy tend to be multiples of those in the other farm systems in Ireland and the gap between Dairy and the other farm systems is widening.
- When allowance is made for the amount of labour required in different systems and income is expressed on a per labour unit basis, on average Dairy and Tillage farms can be considered as comparable when adjustment is made for their relative labour input requirements. The results show that both of these farm system types considerably outperform the drystock farm systems.

Social sustainability

- Again reflecting established trends, Dairy continues to exhibit a stronger performance in terms of **social sustainability** relative to other farm systems. Dairy tends to be associated with a lower **isolation risk**, with fewer households having a **high age profile** in comparison with other farm systems. Tillage farms also tend to generally outperform livestock farms on these social sustainability metrics.
- However, in terms of **labour input**, on average the main dairy farm operator works significantly more **hours per year** than the farm operator in the other farm systems. Even when time spent working off farm (which

can be significant for drystock systems) is combined with time spent working on-farm, the labour input of dairy farm operators tends to exceed that of other farm systems.

Environmental sustainability

a) Greenhouse gas emissions

- **Dairy**: Taking account of methodological changes, **Total farm GHG emissions** on the average dairy farm increased in 2021, largely due to an increase in the average herd size and increased liming activity. However, **GHG emissions per hectare** on dairy farms increased to a lesser degree, as the average dairy farm area also increased. The **GHG emissions intensity of milk production** (CO_2e per kilogramme of Fat and Protein Corrected Milk) improved. Effectively this means that the average kilogramme of milk on Irish dairy farms was produced with a lower carbon footprint. However, this improvement in GHG emissions intensity was offset by a higher volume of milk produced on the back of a larger average herd size. Hence, absolute farm level GHG emissions increased on dairy farms in 2021.
- **Non-Dairy Systems: Farm level and per hectare level GHG emissions** on cattle, sheep and tillage farms increased somewhat in 2021 on the back of a higher livestock stocking rates and increased liming activity.
- While liming is not a significant GHG emissions source, the liming rates increased across all farm systems, in 2021 which led to emissions in this category doubling or trebling (depending on the farm system) from previous years. It therefore contributed to the overall increase in GHG emissions that was observed. Increased liming to adjust soil pH towards its optimum will ultimately improve plant nutrient take up. This should be considered as a positive development on the part of farmers as it is a prerequisite for a sustainable transition to lower levels of synthetic fertiliser use.

b) Ammonia emissions

- Following the positive developments observed in 2020, further positive developments are evident for 2021. On average, **ammonia emissions** showed some a decline in 2021 relative to preceding years, across the majority of farm systems on a farm level and per hectare basis. It is notable that, on average, ammonia emissions fell even on dairy farms in 2021 in spite of their increase in agricultural output.
- The driver of reduced ammonia emissions is the continuing increase in the adoption of low emissions slurry spreading. In aggregate terms, 48% of all slurry was applied using a LESS (low emission slurry spreading) approach in 2021, compared to 38% in 2020.

c) Nitrogen balance and use efficiency

- **N surpluses** declined and **N use efficiency** tended to improve in 2021 on Dairy and Tillage farms, but went in the opposite direction for drystock farms. These metrics tend to be significantly influenced by weather conditions, although improved N management on farms also plays a role.

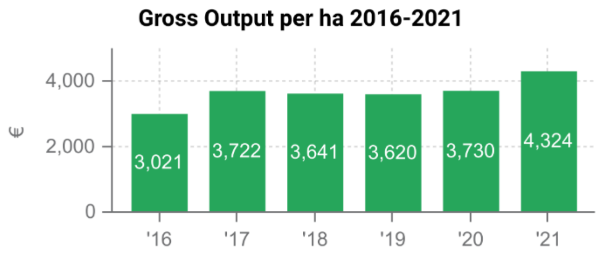
Innovation

- There was a significant increase in the percentage of farms liming in 2021.
- There was also a significant transition towards the use of Low Emissions Slurry Spreading equipment when applying slurry to land.
- However, the use of protected urea fertiliser remains low.

Dairy: Economic Sustainability

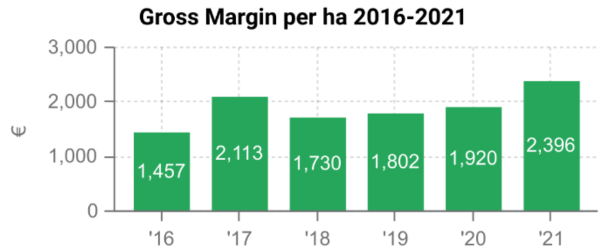
Gross Output per ha 2021

€4,324



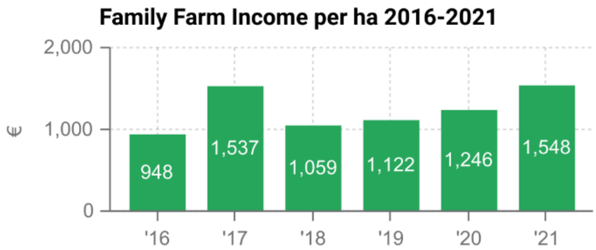
Gross Margin per ha 2021

€2,396



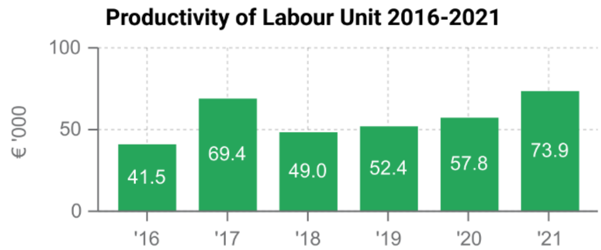
Family Farm Income per ha 2021

€1,548



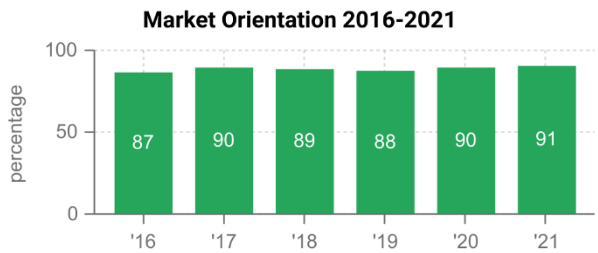
Productivity of Labour 2021

€73,941



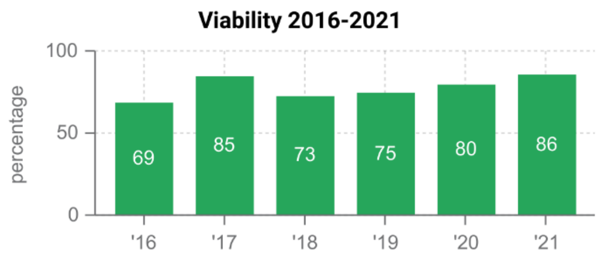
Market Orientation 2021

91%



Viability 2021

86%

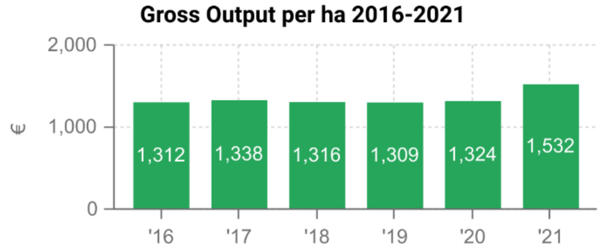


Source: Teagasc National Farm Survey

Cattle: Economic Sustainability

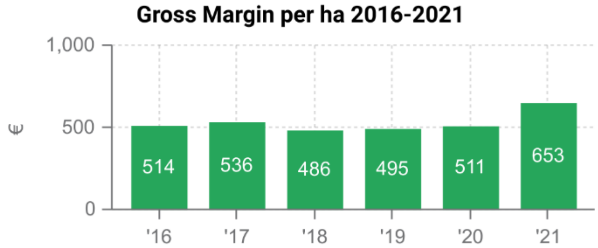
Gross Output per ha 2021

€1,532



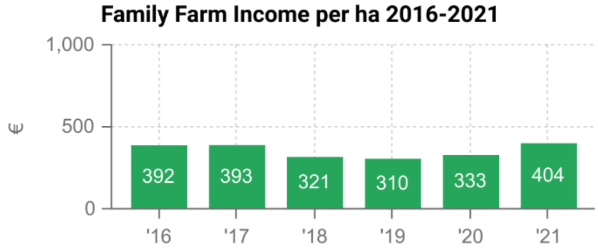
Gross Margin per ha 2021

€653



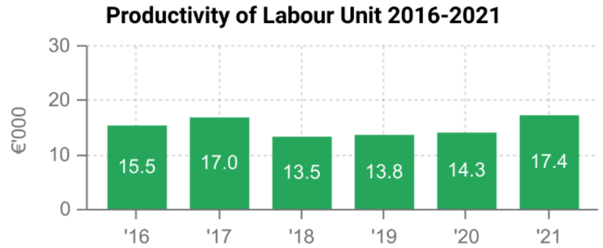
Family Farm Income per ha 2021

€404



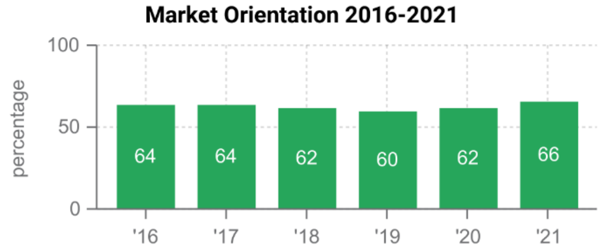
Productivity of Labour 2021

€17,445



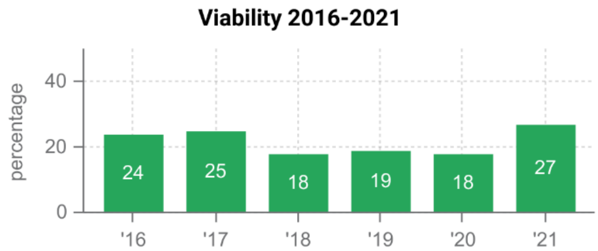
Market Orientation 2021

66%



Viability 2021

27%

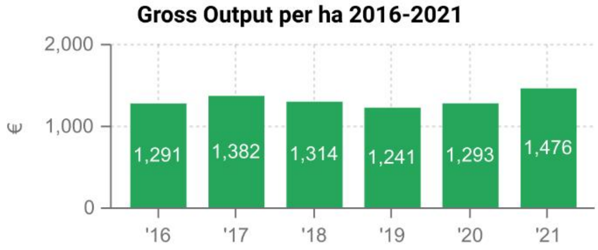


Source: Teagasc National Farm Survey

Sheep: Economic Sustainability

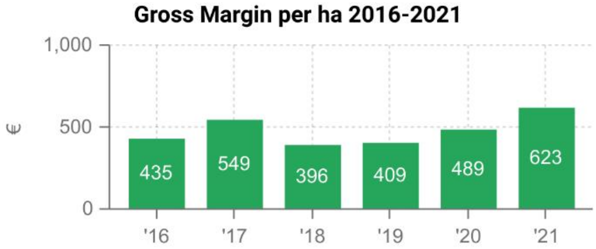
Gross Output per ha 2021

€1,476



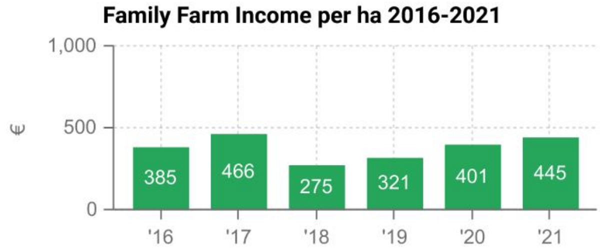
Gross Margin per ha 2021

€623



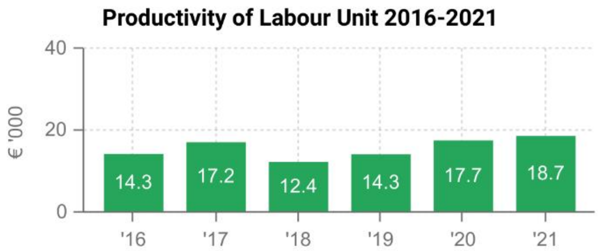
Family Farm Income per ha 2021

€445



Productivity of Labour 2021

€18,725



Market Orientation 2021

66%

Viability 2021

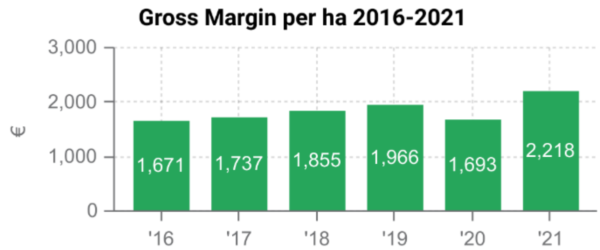
39%

Source: Teagasc National Farm Survey

Tillage: Economic Sustainability

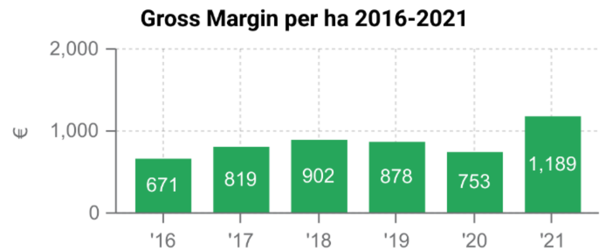
Gross Output per ha 2021

€2,218



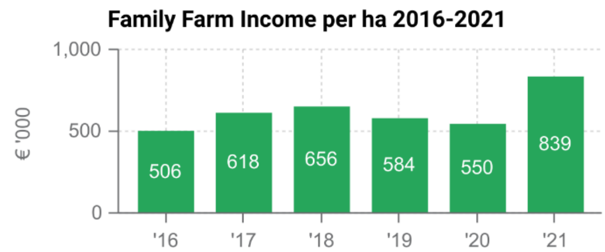
Gross Margin per ha 2021

€1,189



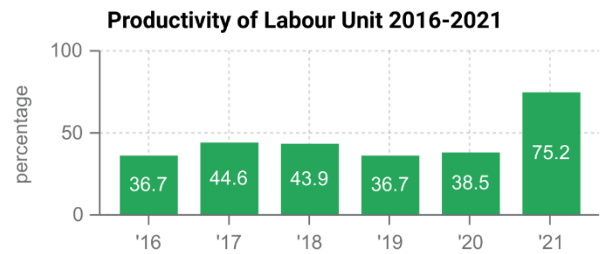
Family Farm Income per ha 2021

€839



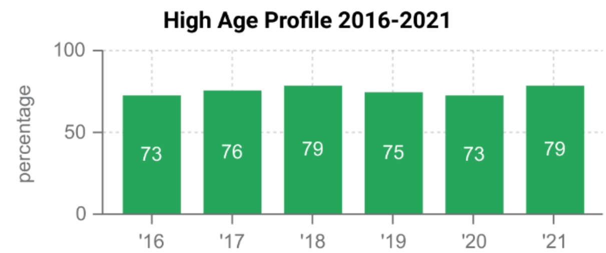
Productivity of Labour Unit 2021

€75,185



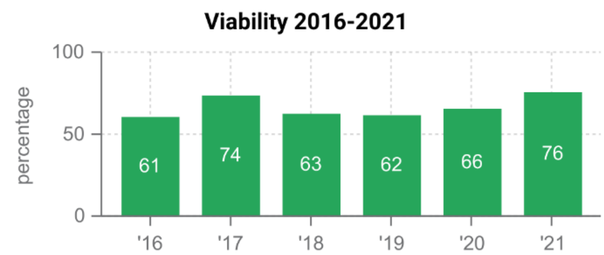
Market Orientation 2021

79%



Viability 2021

76%



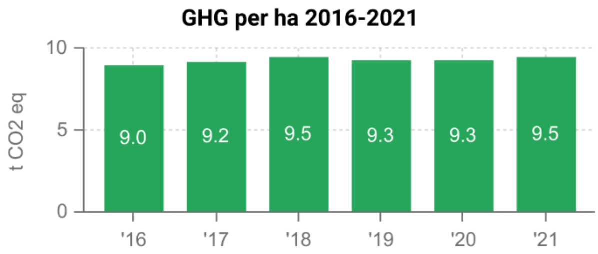
Source: Teagasc National Farm Survey

Agriculture and Food Development Authority

Dairy: Environmental Sustainability

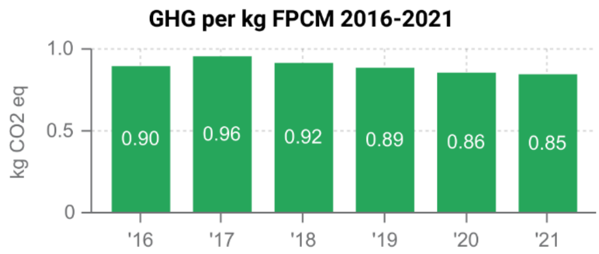
CO_2 eq per ha 2021

9.5



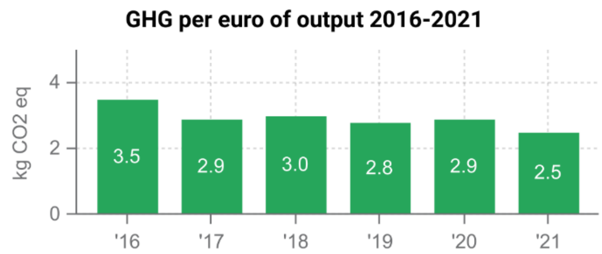
CO_2 Eq per kg FPCM 2021

0.85



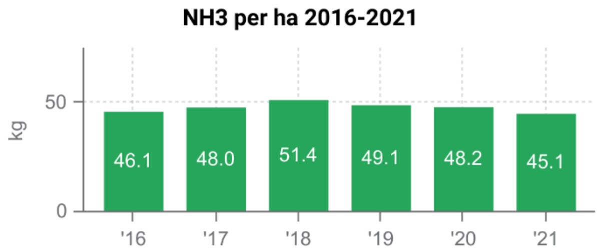
CO_2 Eq per euro of output 2021

2.5



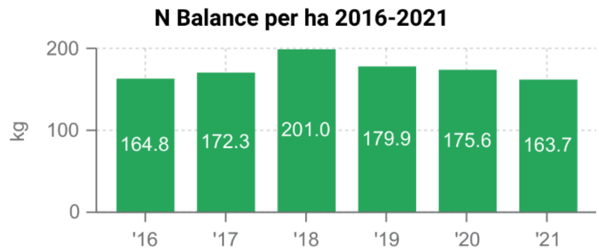
NH_3 kg per ha 2021

45.1



N Balance kg per ha 2021

163.7

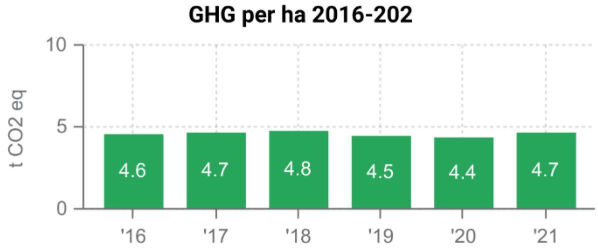


Source: Teagasc National Farm Survey

Cattle: Environmental Sustainability

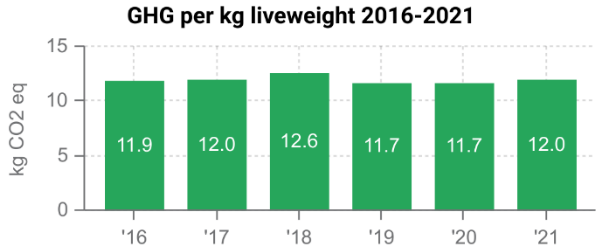
CO2 eq per ha 2021

4.7



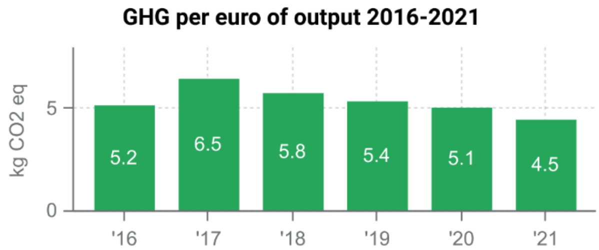
CO2 eq per kg of liveweight 2021

12.0



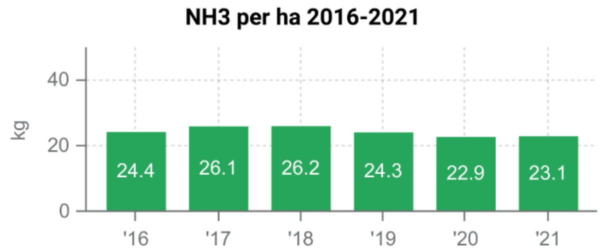
CO2 per euro of output 2021

4.5



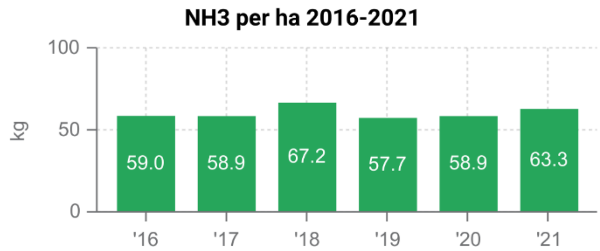
NH3 kg per ha 2021

23.1



N Balance kg per ha 2021

63.3

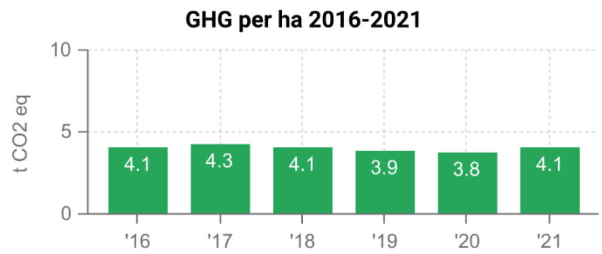


Source: Teagasc National Farm Survey

Sheep: Environmental Sustainability

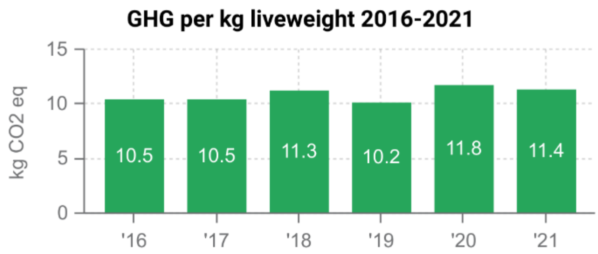
CO_2 eq per ha 2021

4.1



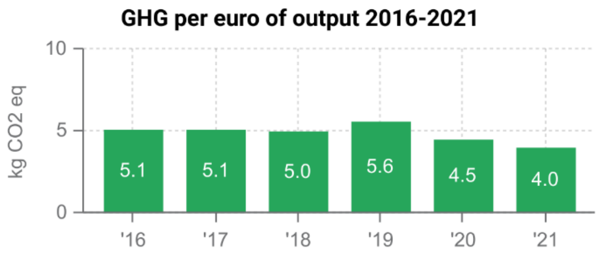
CO_2 per kg liveweight 2021

11.4



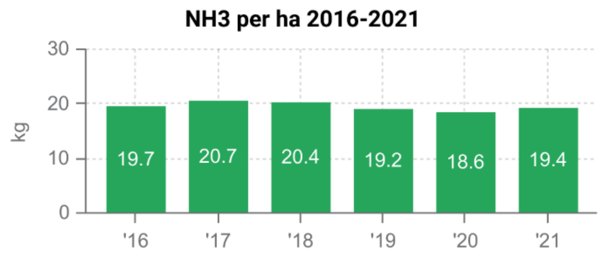
CO_2 per euro of output 2021

4.0



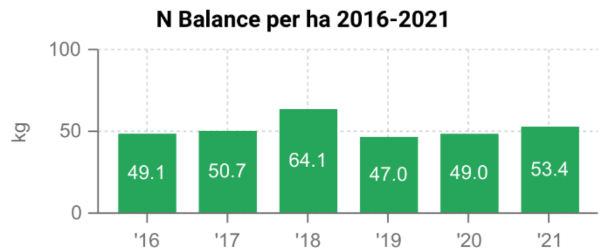
NH_3 kg per ha 2021

19.4



N Balance kg per ha 2021

53.4

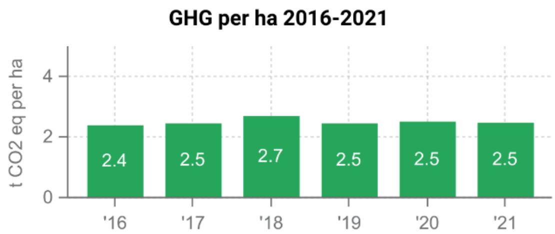


Source: Teagasc National Farm Survey

Tillage: Environmental Sustainability

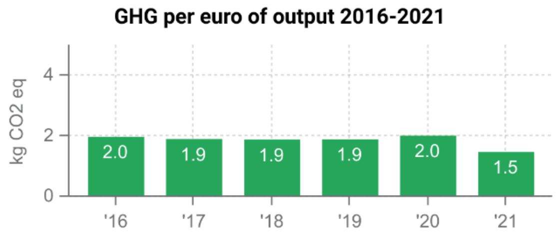
CO2 eq per ha 2021

2.5



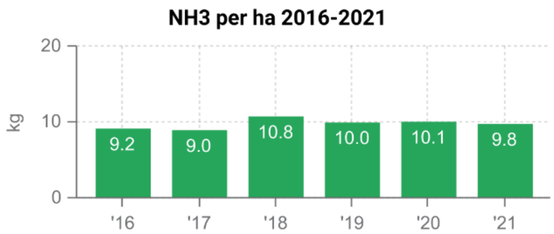
CO2 eq per euro of output 2021

1.5



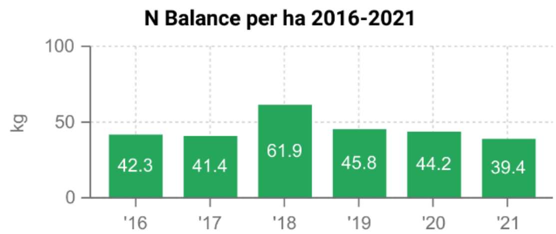
NH3 kg per ha 2021

9.8



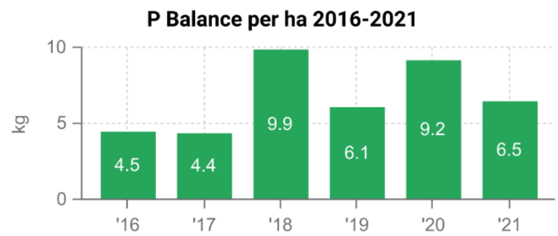
N Balance kg per ha 2021

39.4



P Balance kg per ha 2021

6.5

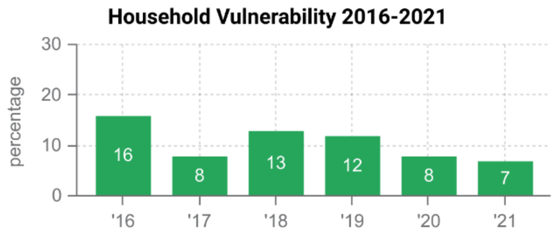


Source: Teagasc National Farm Survey

Dairy: Social Sustainability

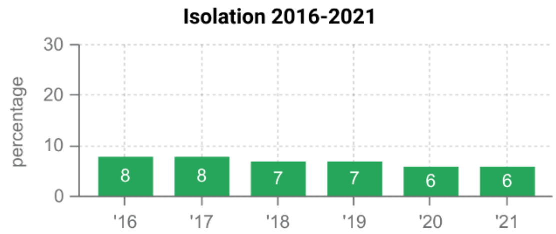
Household Vulnerability 2021

7%



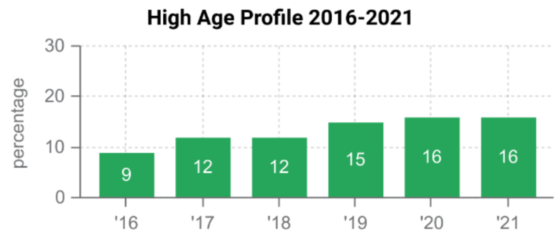
Isolation 2021

6%



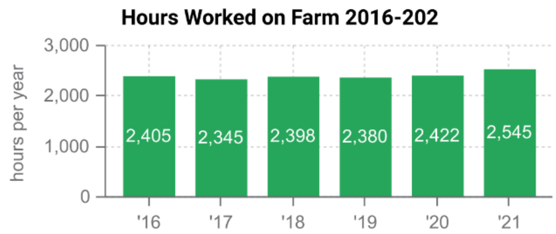
High Age Profile 2021

16%



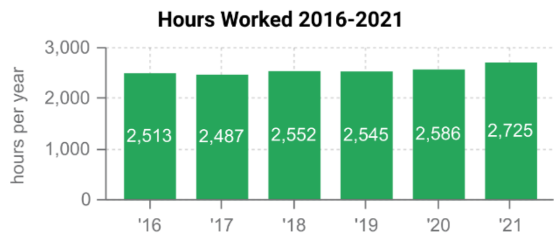
Hours Worked on Farm 2021

2,545



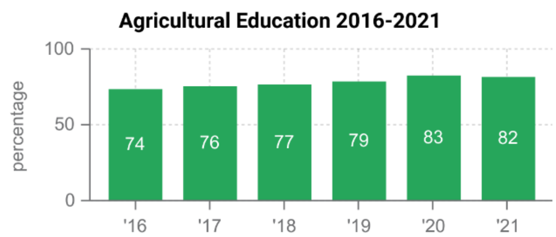
Total Hours Worked 2021

2,725



Agricultural Education 2021

82%

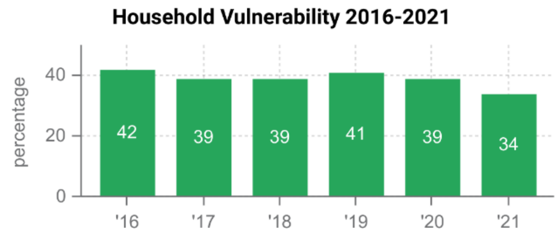


Source: Teagasc National Farm Survey

Cattle: Social Sustainability

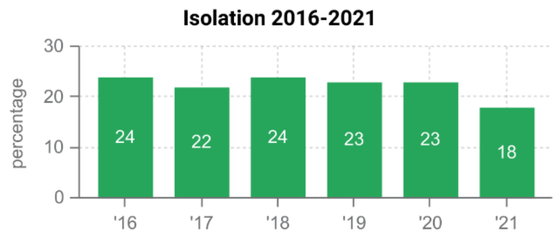
Household Vulnerability 2021

34%



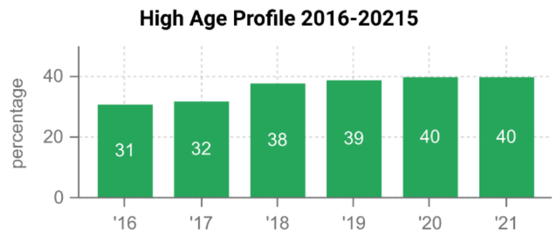
Isolation 2021

18%



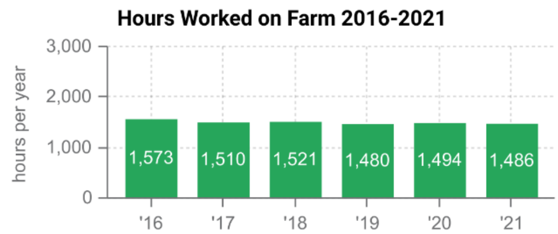
High Age Profile 2021

40%



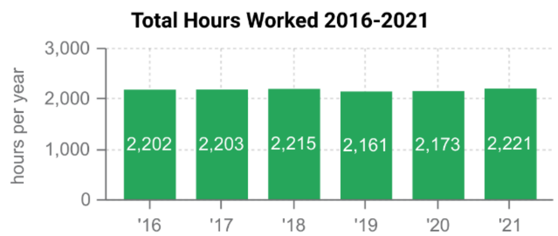
Hours Worked on Farm 2021

1,486



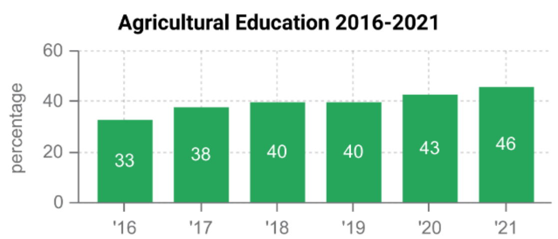
Total Hours Worked 2021

2,221



Agricultural Education 2021

46%

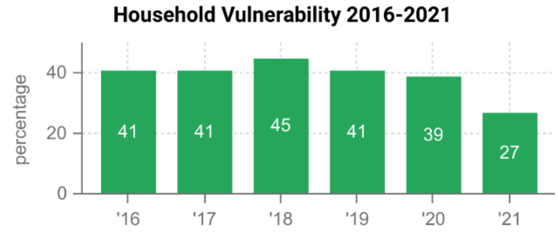


Source: Teagasc National Farm Survey

Sheep: Social Sustainability

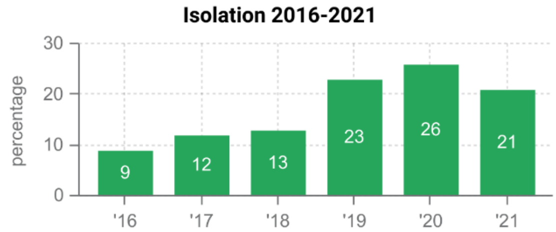
Household Vulnerability 2021

27%



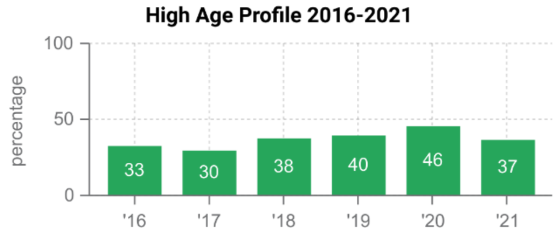
Isolation 2021

21%



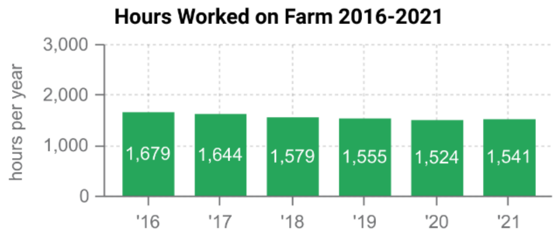
High Age Profile 2021

37%



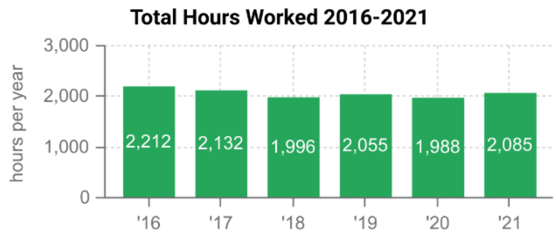
Hours Worked on Farm 2021

1,541



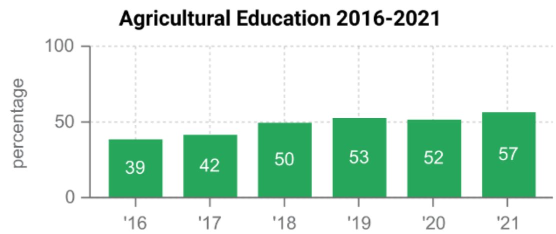
Total Hours Worked 2021

2,085



Agricultural Education 2021

57%

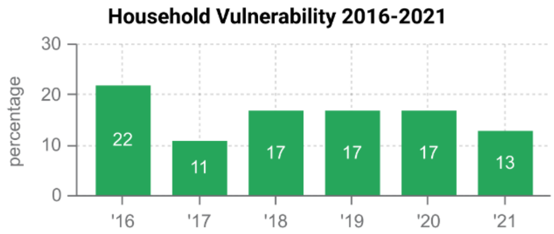


Source: Teagasc National Farm Survey

Tillage: Social Sustainability

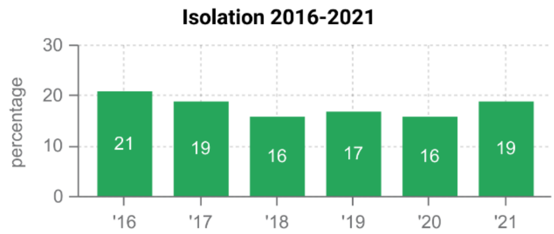
Household Vulnerability 2021

13%



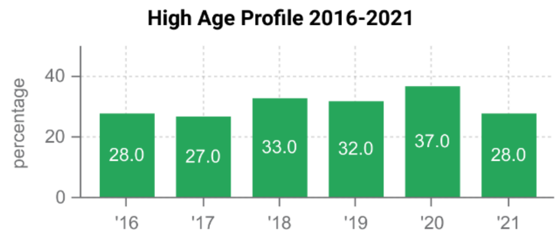
Isolation 2021

19%



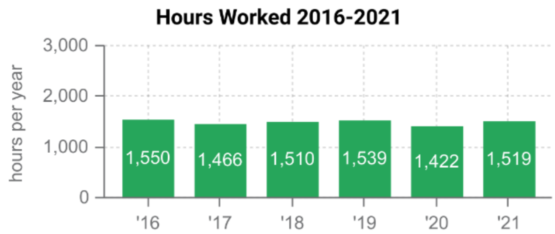
High Age Profile 2021

28%



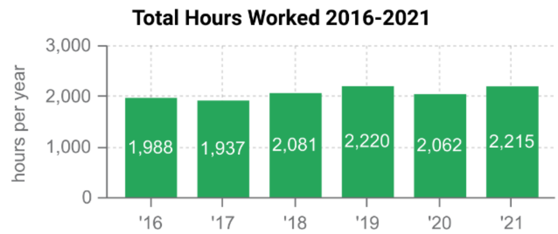
Hours Worked on Farm 2021

1,519



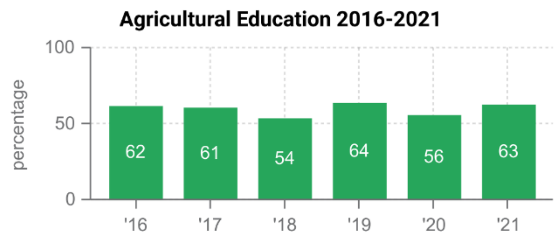
Total Hours Worked 2021

2,215



Agricultural Education 2021

63%

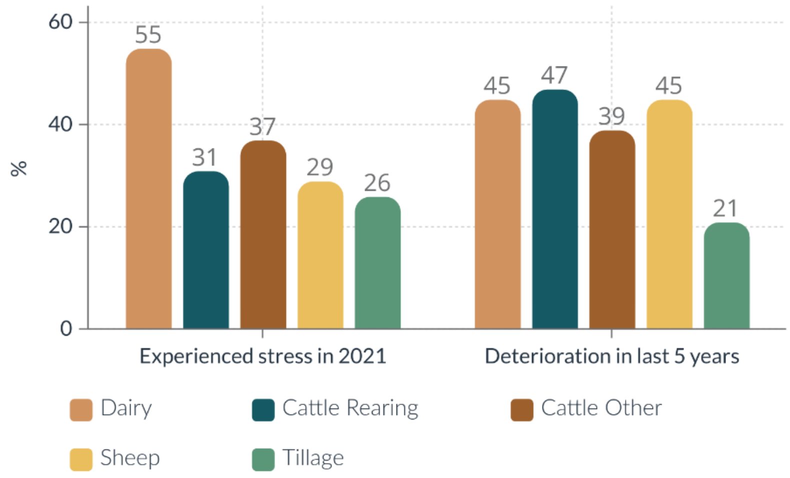


Source: Teagasc National Farm Survey

Special Focus: Social Sustainability 2021

Farmer health & wellbeing

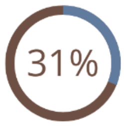
Farm business related stress



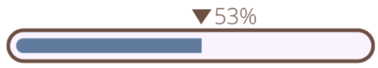
Across farm systems

78%

of famers reported good or very good health



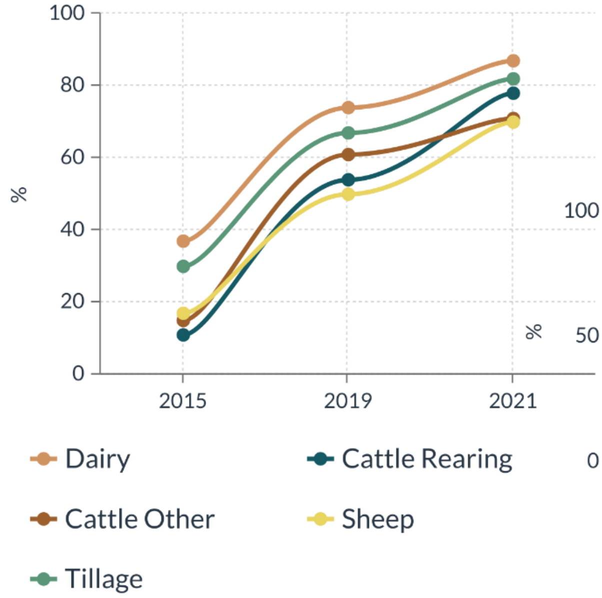
of Sheep farmers report poor or fair health



of farmers with poor or fair health have an identified replacement, lowest on Sheep farms at 31%.

Connectivity

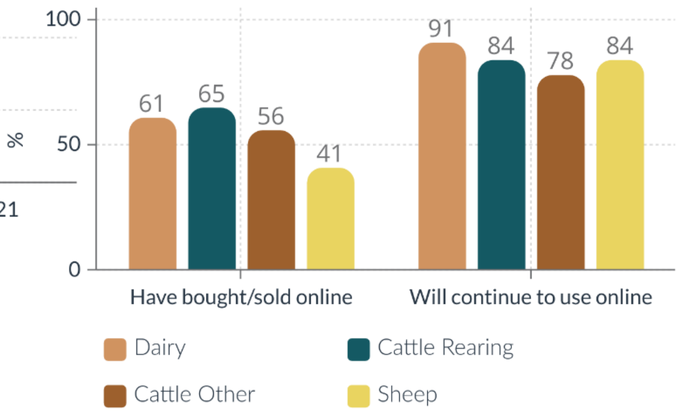
Farmer smartphone use



88% of farm households have internet access

report above average internet quality

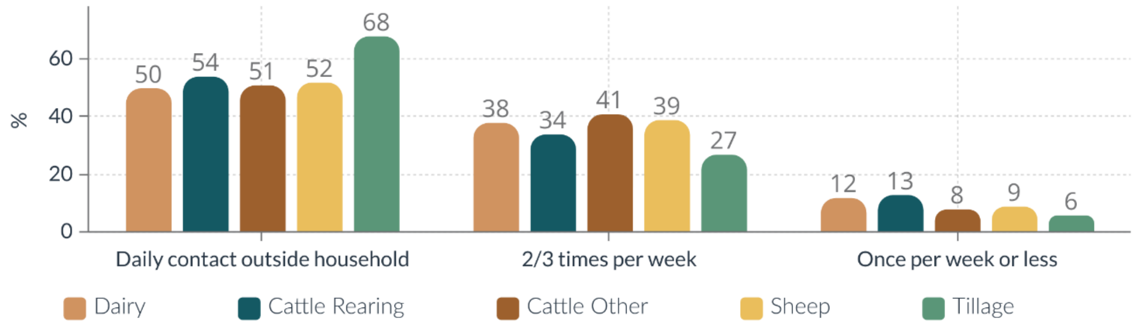
Use of online livestock marts

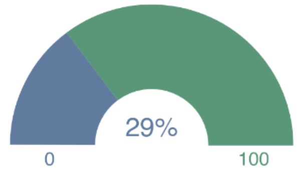


The development of social sustainability indicators through the Teagasc National Farm Survey is ongoing. Data from 2021 is based on a sample of 611 farms, representing over 85,000 farms nationally.

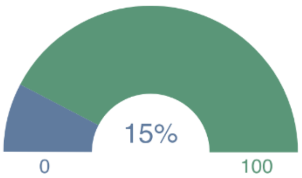
Social engagement

Farmer networks



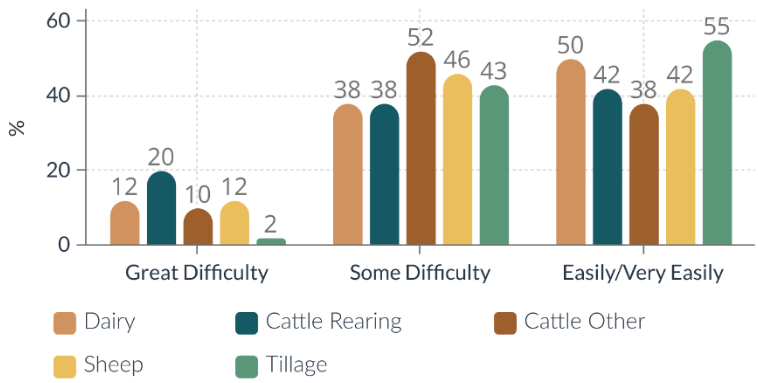


members of a discussion/producer group, 48% of Dairy farmers



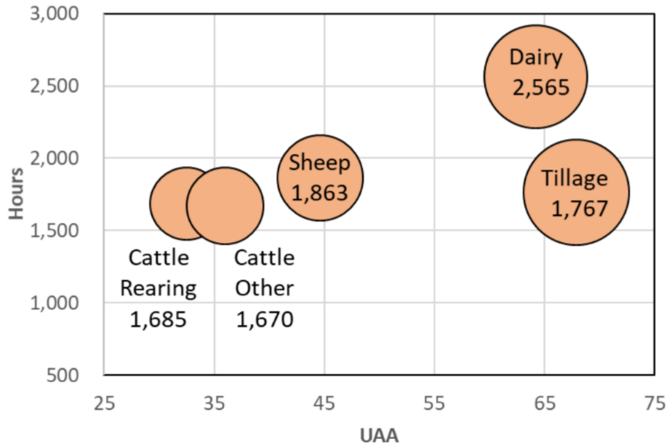
members of community groups, 19% of Cattle Other farmers

Ease of access to banking services

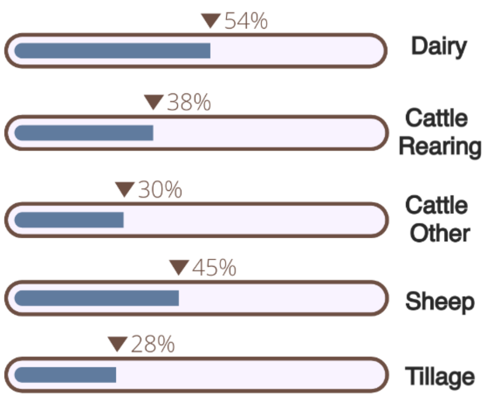


Farm Labour

Labour hours and Farm size



Proportion of farms with female labour input



The development of social sustainability indicators through the Teagasc National Farm Survey is ongoing. Data from 2021 is based on a sample of 611 farms, representing over 85,000 farms nationally.

1 Introduction - Agricultural Sustainability

Civilization faces a grand challenge in trying to feed a growing human population, while minimising the environmental impacts of food production, especially in the context of climate change, deteriorating water quality and biodiversity loss. To sustainably feed a growing global population, agricultural output must increase 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).

Since the publication of the previous Sustainability Report for 2020, there have been significant developments in environment policy in Ireland, including legislation requiring a 25% reduction in agricultural greenhouse gas emissions by 2030 and an aspiration towards a climate neutral society by 2050.

Agricultural systems are complex and tend to have multiple objectives 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 sustainability (and its component farm systems) in terms of its economic, environmental, social and innovation dimensions.

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. While Irish agriculture is dominated by grassland systems, these production systems are heterogeneous, with substantial variations between the typical farms in each farm system in terms of farm size, stocking rates and input usage. Relevant indicators which capture this diversity are required to assess the sustainability status of Irish farms through time. Such metrics can highlight particular areas of concern or trends through time and indicate areas where improvement may be needed. Ireland is at the forefront in Europe in the development and use of wide ranging sustainability metrics for agriculture.

Deriving and maintaining 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) has evolved in response to the changing needs of stakeholders to provide such a dataset. The NFS is a nationally representative sample of approximately 840 farms from across Ireland. Data from the Teagasc NFS represent the Irish component of the European Union's Farm Accountancy Data Network (FADN) dataset[1]. However, the data collected in the Teagasc NFS surpasses the requirements of FADN, giving the Teagasc NFS dataset much more capacity to measure and track developments in agricultural sustainability. The Teagasc NFS collects data on an ongoing basis, with the results published annually. A weighting system, produced with reference to data published by the Central Statistics Office (CSO), reflective of the national farm population is applied to the data from the individual NFS farms. In this way, national level representation is achieved in terms of size and farm type for the principal farm systems in Ireland. This population weighting is important to ensure that aggregations of farm types can be made at an appropriate scale (for example, based on farm system type). It also

[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 circa 85,000 farms are represented in this study for 2021.

means that the survey results are capable of accurately highlighting synergies and/or trade-offs between different indicators, depending on how farms are managed.

Within the Teagasc NFS, farms are classified into major farming systems according to the standardised EU typology as set down by European Commission regulations and applied by the EU FADN (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 (Donnellan et al., 2020)). This report presents results for the four dominant land based farm systems in Ireland, namely, dairy, cattle, sheep and tillage.

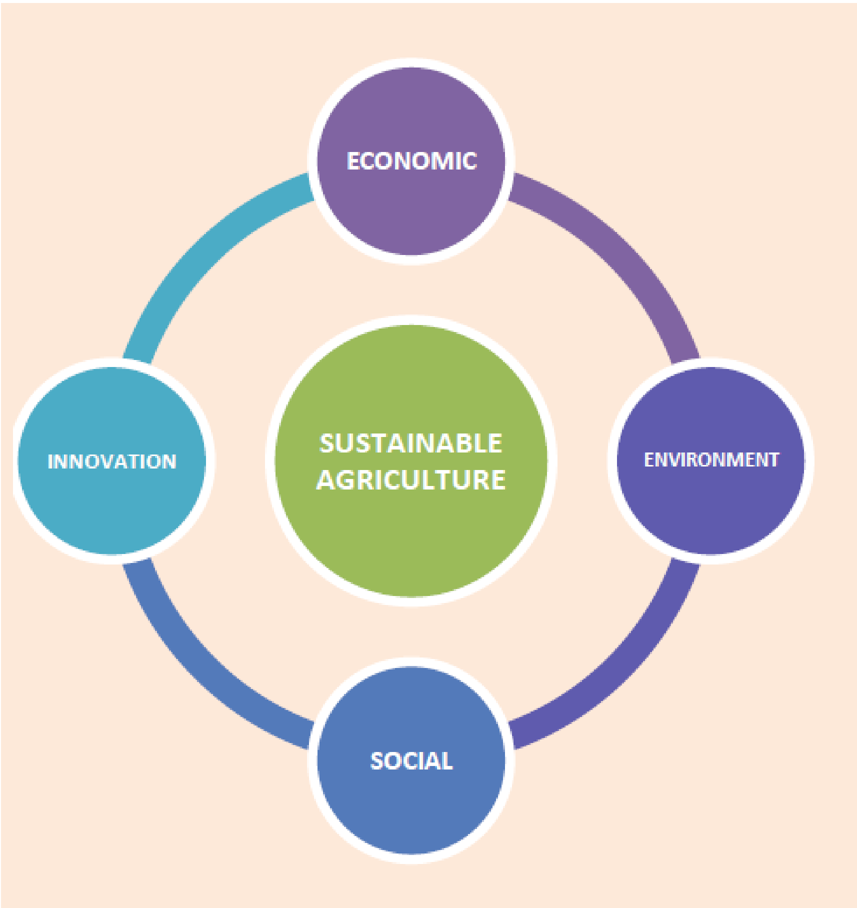
As the required data are produced on an annual basis, it is possible to generate and compare indicators over time. As methodologies are updated and data requirements evolve to reflect scientific developments, the entire time series of sustainability metrics are revised to reflect current scientific knowledge. This is evident in the time-series analysis for key indicators presented in the report, which are revised to reflect recognised developments in the measurement of sustainability. 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 relevance. The aim is that as indicator methodologies develop, they will still be capable of being generated using Teagasc NFS data, ensuring an on-going accurate inter-temporal assessment of the sustainability performance of Irish farm systems. Furthermore, as the NFS is part of the EU 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 (FSDN), with a view to collecting data on sustainability indicators and reporting these in a common framework across the EU. The Teagasc NFS is leading the way on this, as evidenced by the content of 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, 2020a; Buckley & Donnellan 2020b; Buckley & Donnellan 2021). Updates presented here reflect 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 the farming year 2021, there have been significant methodological developments in the estimation of gaseous emissions since the publication of the report covering 2020. There has also been adjustments to farm population weights on foot of the latest farm population statistics as published in the Census of Agriculture (CSO, 2022). Both these developments will be discussed later in the report. For these reasons, the historical time series for some of the sustainability indicators presented in the current report differ and supercede those presented in earlier Teagasc Sustainability reports (Buckley et al., 2019; Buckley & Donnellan, 2020a; Buckley & Donnellan 2020b, Buckley & Donnellan 2021). This approach to revising historic sustainability indicators is to ensure they fully reflect our current scientific knowledge. It mirrors the approach used by the Environmental Protection Agency (EPA) in national inventory reporting and is hence 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 3-1: Sustainability Overview



Methodological Update – NFS Sample Reweighting for 2017 to 2020

The National Farm Survey (NFS) is a survey of approximately 840 farms which are representative of approximately 85,000 farms in Ireland. In order to ensure that the sample is representative of this population, farms in the sample are selected at random from strata (categories) in the farm population. These strata ensure that the sample contains an appropriate mix of farm types and that the economic size (measured in farm output) of the farms selected is also representative of the farm population.

The nationally representative results that are produced are not a simple aggregation of the results for each individual farm. Each farm in the sample is assigned a weighting factor, hence each farm in the sample is representative of a specific number of farms in the population. The total number of farms and the numbers in each size class can change over time.

The population of farms and its composition is determined by the Central Statistics Office (CSO). Each decade the CSO conducts a Census of Agriculture which provides details on, amongst other things, the number of farms and their economic size. In the period between each Census, the CSO conducts Farm Structures Surveys, which also provide information on farm numbers and farm size. Information from the Census of Agriculture and Farm Structures Survey provide the weighting factors for the NFS farms. The weighting factors used in the NFS will relate to either of these two CSO data sources and will depend on which of these CSO enumerations is more recent.

The CSO conducted a Census of Agriculture in 2020 and initial results became available in 2021 (CSO, 2022). These census results allowed us to update the weighting factors that had been used in the NFS for the period 2017 to 2020 (which had previously been based on the Farm Structures Survey 2016). This updating of farm weights in the NFS takes place periodically to reflect the availability of more up-to-date data. Normally this reweighting results in minor and generally unremarkable changes to the NFS results for the preceding years, reflecting relatively small changes in weighting factors applied.

The application of new weighting factors based on the Census of Agriculture in 2020, has resulted in minor changes to NFS income results for the period 2017 to 2020 for cattle, sheep and tillage farms. However, following the removal of the EU milk quota system, there has been a period of considerable structural change in the dairy sector in Ireland and this is reflected in the newest weighting factors from the Census of Agriculture 2020. Compared to the Farm Structures Survey of 2016, the Census of Agriculture 2020 indicates that there are now fewer dairy farms than in 2016, but that a greater proportion of these farms fall into larger size classes.

When applied to the NFS sample, these new weights increase the average absolute output, income and emissions of dairy farms compared to previously reported estimates for the period 2017 to 2020 (per hectare estimates are changed). The basis for this increase is that dairy farms in these years were typically larger in area and had a larger herd size than previously estimated. As well as containing detailed sustainability results for 2021, this report also contains updated estimates for the years 2017 to 2020 to reflect this updated set of population weights.

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 owned capital and labour employed. At a national level, agriculture is an important component of the Irish economy. The NFS is well equipped to generate economic indicators. Its origins derive from the need to submit data on economic farm performance to the European Commission through the EU FADN, primarily to aid in the understanding of the effectiveness of the Common Agricultural Policy. 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:

Table 3.1: 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

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, livestock based products & crops, plus the 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 in order to avoid double counting of activity.

b) Profitability of Land

The profitability of a farm is measured as the **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 the labour of farm family members, which is generally unpaid and therefore is not classified as a production cost, and hired labour, which in accounting terms does represents a production cost to the family 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, one 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 1,800 hours). Labour unit equivalents of 0.75 and 0.5 are used for individuals aged 16-18 years and 14-16 years respectively.

Economic Viability

The **economic viability** of a farm business is measured by a **binary variable**. 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, 2021a) and there is also sufficient income generated by the farm to provide an additional five per cent return on non-land based assets employed on the farm.

d) 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 which can referred to as **market based gross output**), as opposed to grants and subsidies, which are treated as a non-market based gross output of the farm.

e) 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.

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 covering 69.3% of the State's land area (CSO, 2021a). Hence, the environmental sustainability of 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.

Table 3.2: Overview of Environmental Indicators

Indicator	***Measure***	***Unit***
Ag. GHG emissions per farm	Absolute GHG emissions per farm	Tonnes CO_2 equivalent / farm
Ag. GHG emissions per hectare	Absolute 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 emissions per farm	Tonnes CO_2 equivalent / farm
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	Absolute NH_3 emissions per farm	Tonnes NH_3 equivalent / farm
NH_3 emissions per hectare	Absolute 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
P balance	P transfer risk	kg P surplus / ha^{-1}
P use efficiency	P retention efficiency	% P outputs / P inputs

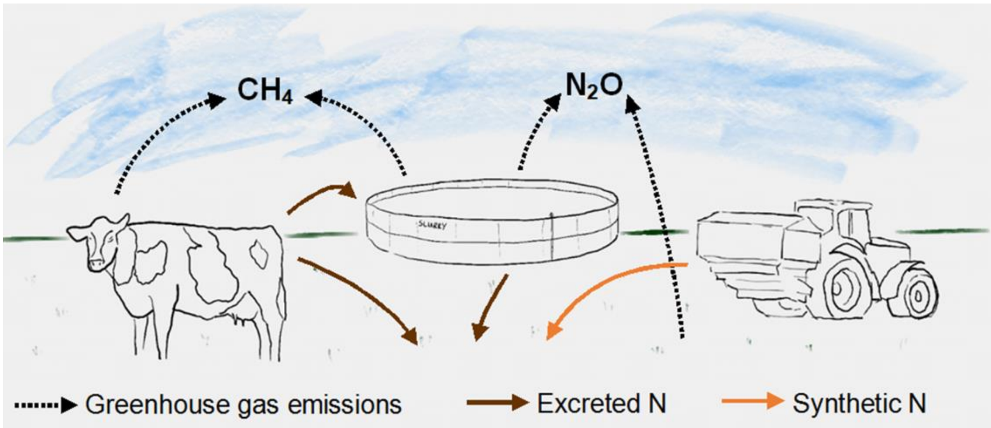
3.2.1 Greenhouse gas emissions

To minimise the extent and impact 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 37.5% of the national emissions total in 2020 (EPA, 2022a). The agricultural sector must reduce its emissions in the context of Ireland's commitment to reduce national GHG emissions. The Climate Action and Low Carbon Development (Amendment) Act 2021 (Government of Ireland, 2021b) sets out an ambition for a climate neutral economy by 2050 for the state. Agriculture now has a sectoral target of 25% reduction by 2030 (Government of Ireland, 2022). Maintaining or even increasing food production will be very difficult, while at the same time reducing aggregate emissions (Breen et al., 2010).

1. 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 2020 National Inventory Report for Ireland (Duffy et al., 2021). The three main agricultural GHG 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. **Carbon dioxide (CO_2)** emissions 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 aggregate** emissions inventory approach), is that some animals move between farms via inter-farm sales as part of the agricultural production process. Unless this is factored into the calculations, it could lead to an over estimate or underestimate of activity and associated emissions. Accordingly, a farm level 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_2e)** using appropriate global warming potentials (GWP) for CH_4 and N_2O which are respectively 28 and 265 times greater than the GWP of CO_2.

Figure 3-2: An illustration of some of the major agricultural greenhouse gas emissions



Emissions resulting from on-farm fuel and electricity use are considered independently of the IPCC's agricultural emissions category, as they are recognised under a separate IPCC category (Energy). Energy emissions (CO_2 only) are estimated from expenditure on electricity and fuels (relevant quantities used are estimated by using national average prices (CSO, 2021b; SEAI, 2021)) and by applying national level emissions factors to these quantities.

Using the IPCC methodology, the main indicators developed include:

a. **Total agricultural emissions per farm**: with emissions calculated for each farm system. These are 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:** 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).
c. **Agricultural greenhouse gas emissions per hectare & € of output:** 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.
d. **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.

2. LCA Methodology: An alternative method to the **IPCC approach** of measuring GHG emissions is the **Life Cycle Assessment (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, the LCA used here 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.

Relative to the territorial IPCC approach, 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 Teagasc Dairy LCA model was used for this analysis (O'Brien et al., 2014; Herron et al., 2021). This model, which is accredited by the National Carbon Trust (UK) underpins the carbon footprint results from the Bord Bia Sustainable Dairy Assurance Scheme (SDAS). 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.

As with the other indicators presented in this report, emphasis should not be placed on the absolute level of the carbon footprint measure, since this will be the subject of ongoing revision. Of greater relevance is the direction in which the indicator evolves over time. The main objective of this research is to establish indicators through which changes in sustainability performance can be documented and evaluated.

Methodological Update – Global Warming Potential of Methane & Nitrous Oxide

The increasing carbon concentration in the atmosphere resulting from human activity is responsible for climate change. There are a number of greenhouse gases generated by human activity which are associated with climate change. The impact which a tonne of each of these gases has on the global warming process is not equivalent, with some gases being more potent than others. Therefore when counting the emissions of various greenhouse gases they are brought to a common base. This common base is arrived at by applying a global warming potential (GWP) to each gas.

The GWP of gases are subject to change in light of improved scientific understanding of the role which each gas has in driving climate change. So each greenhouse gas is assigned an agreed GWP coefficient and the total for each gas is then multiplied by this coefficient to arrive at what is called a carbon dioxide equivalent (CO_2e) for each gas. The carbon dioxide equivalent for each of the gases can in turn be added together to arrive at an overall total figure.

The three greenhouse gases that are of interest in agriculture are methane, nitrous oxide and carbon dioxide. Carbon dioxide has a GWP of 1, but the GWP values for methane and nitrous oxide are far higher.

The IPCC periodically publishes an Assessment Report which lays out the state of knowledge with respect to the science of climate change. The most recent assessment report, called the Fifth Assessment Report (AR5), has updated the GWP values for methane and nitrous oxide, giving methane a higher GWP value (increased from 25 to 28 tonnes of CO_2 equivalent) and nitrous oxide a lower GWP value (decreased from 298 to 265 tonnes of CO_2 equivalent) than was previously the case.

These revisions have now been adopted by the Environmental Protection Agency in compiling its inventory of Ireland's greenhouse gas emissions. These revised GWP values have been incorporated into the greenhouse gas emission estimates for each of the farm systems tracked in the Teagasc National Farm Survey Sustainability Report. The impact of this revision leads to an increase in the estimated greenhouse gas emission produced by each of the farm systems, including the emissions produced by Irish farms in the past.

3.2.2 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 NH_3. Within the EU, NH_3 emissions are regulated through the National Emissions Ceiling (NEC) Directive (EU, Commission 2016). Over 99.4% of Ireland's NH_3 emissions originate within agriculture, principally from animal waste and the application of synthetic fertilisers (EPA, 2022b). The fact that NH_3 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 NH_3 ceiling of 112.2 kilotonnes per annum, representing a 1% NH_3 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., 2021) 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 per farm**: with emissions calculated for each farm system. These are also disaggregated to show the emissions originating from different farm enterprises (dairy, cattle, sheep and fertilisers).
b. **Ammonia emissions per unit of output/hectare:** 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.

3.2.3 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 the farms output, which would include milk, crops, wool, manures exported and livestock sold (including livestock for slaughter). Imports are comprised of fertilisers applied, feeds purchased, livestock brought onto the farm and imported organic manures. 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.

c. **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.

d. **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.

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 the 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 in the absence of knowledge of 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.
b. **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.

3.3 Social Indicators

A farm will only be sustainable if employment in agriculture can provide a suitable economic return for the labour employed, 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 further work is required 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:

Table 3.3: 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 by the farmer	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 on-farm	Farm work load of farmer	Hours worked on the farm
Total hours worked	Work load of farmer	Total hours worked on and off-farm

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** which 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 influencing wider farm management decisions that can affect other dimensions of farm sustainability (e.g. willingness to adopt new technologies).

c) High Age Profile

Farm households 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 household 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 on farm

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**.

f) Total Hours worked

This indicator is the **number of hours worked** by the farmer **on and off the farm**. This **includes** hours worked in **off-farm employment**.

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. The majority 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 or environmental performance, as they will highlight the benefits of specific technologies or behaviours.

Table 3.4: 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*	Break Crop
Protected urea use	Protected urea use	Protected urea use	
Reseeding	Reseeding	Reseeding	
Low emission slurry spreading	Low emission slurry spreading		
Milk Recording			

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

Dairy innovation indicators

- ***Discussion group membership*** was selected as indicating the degree of interaction farmers have with farm extension services and their peers. This is reported in binary (yes/no) format.
- ***Liming*** and ***Reseeding*** were identified as important practices in grassland management. This is reported in binary (yes/no) format.
- ***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. This is reported in binary (yes/no) format.

- ***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. The indicator reported is the proportion of chemical N applied in protected urea form.
- ***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. The indicator reported is the proportion of farm slurry applied using LESS techniques.
- ***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. This reported is in binary (yes/no) format.

Cattle and sheep innovation indicators

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

- ***Discussion group membership*** was selected as indicating the degree of interaction with extension services and farming peers. This is reported in binary (yes/no) format.
- ***Liming* and *Reseeding*** were identified as important practices in grassland management. These indicators are reported in binary (yes/no) format.
- ***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. This is reported in binary (yes/no) format.
- ***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. The reported indicator is the proportion of chemical N applied in protected urea form.
- ***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. The indicator reported is the proportion of farm slurry applied using LESS techniques.

Tillage innovation indicators

- ***Discussion group membership*** was selected as indicating the degree of interaction with extension services and farming peers. This is reported in binary (yes/no) format.
- ***Liming*** was identified as important practices in arable production. This is reported in binary (yes/no) format.

- ***Growing a main break crop*** (oilseed rape, peas, beans, linseed) was identified as best practice for tillage farms for disease and pest control. This is reported in binary (yes/no) format.

4 Interpretation of Sustainability Indicator Results

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 4-1 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 4-1 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 hypothetical 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 4-2 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 4-2, 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 4-1: Example Boxplot Gross Margin € per hectare

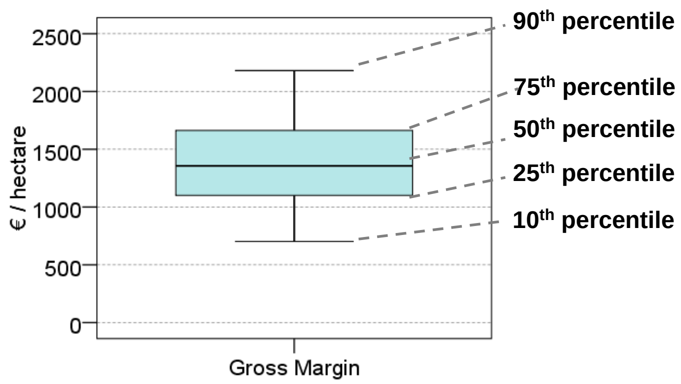
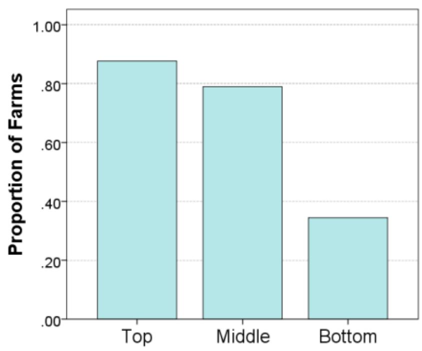


Figure 4-2: Example Bar Chart Proportion of farms

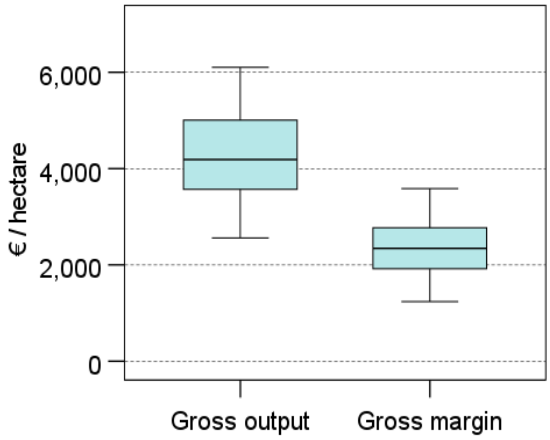


5 Dairy Farm Sustainability 2021

Economic Sustainability Indicators

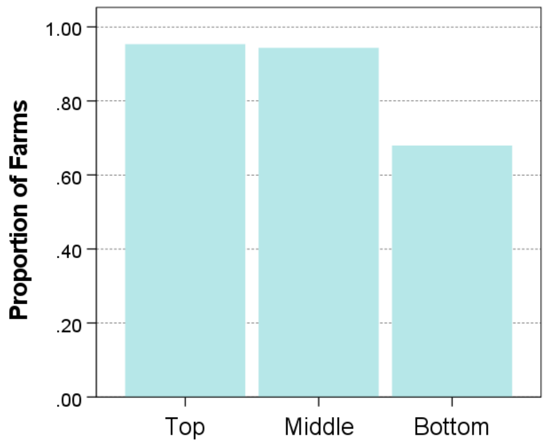
In 2021, the average dairy farm output per hectare was €4,324, and the average market based gross margin per hectare was €2,396. Median values were slightly lower than the average, as shown in Figure 5-1.

Figure 5-1: Economic Return and Profitability of Land: Dairy Farms



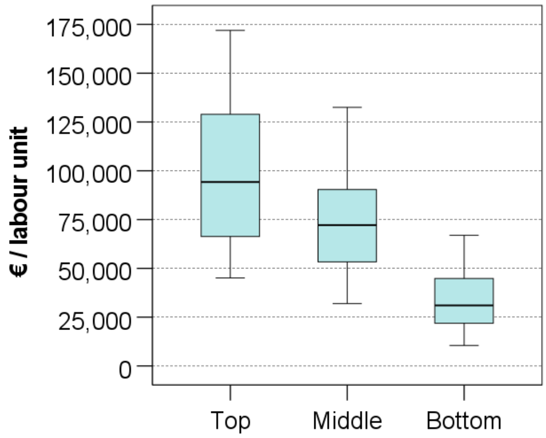
Overall 86% of dairy farms were economically viable in 2021. This ranged from 95% for the top and middle third of economic performing dairy farms to 68% for the bottom third, as illustrated in Figure 5-2.

Figure 5-2: Economic Viability: Dairy Farms



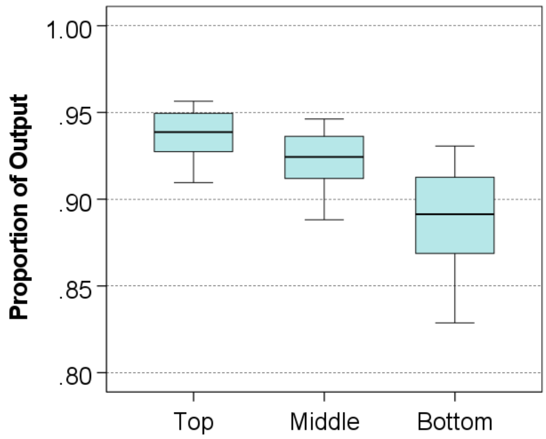
Average income per labour unit (unpaid family labour) for dairy farms in 2021 was €73,941. Average incomes per labour unit were €108,209, €76,099 and €36, 897 for the top, middle and bottom performing farm cohorts respectively. However, there was a large range in the return to labour for dairy farms, especially for the higher performing farms, as shown in Figure 5-3.

Figure 5-3: Productivity of Labour: Dairy Farms



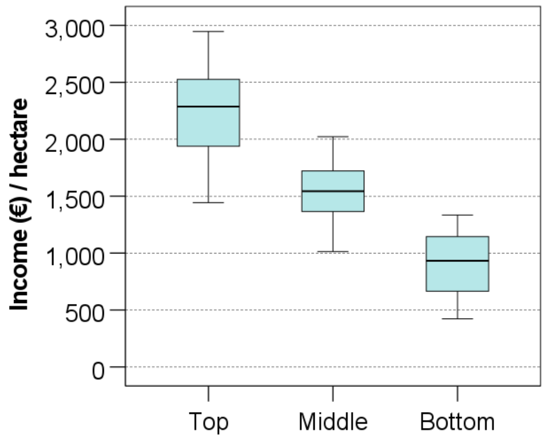
On average, dairy farms derived 91% of gross output directly from the market in 2021. The degree of market orientation was highest for the top third of dairy farms and the range was largest among the bottom third, as illustrated in Figure 5-4.

Figure 5-4: Market Orientation: Dairy Farms



For the full dairy farm population, there was a large range of income per hectare across all three groups as illustrated in Figure 5-5. The average family farm income per hectare on dairy farms was €1,548 in 2021. Within the farm profitability subcategories, the average income ranged from €2,227 per ha^{-1} from the top performing cohort to €893 per ha^{-1} for the bottom performers in economic terms.

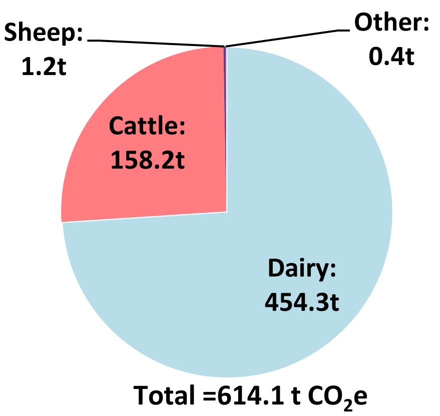
Figure 5-5: Family Farm Income per hectare: Dairy Farms



Environmental Sustainability Indicators

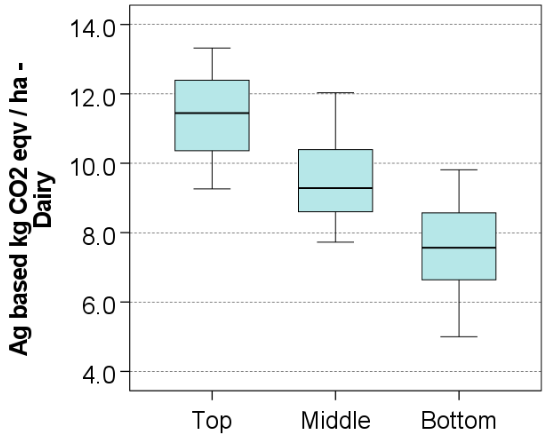
Figure 5-6 indicates that the average dairy farm produced 614.1 tonnes of agricultural GHG emissions (in CO_2 equivalent) in 2021. It should be noted that this measure is based on the IPCC definition of agricultural emissions. At 74%, most dairy farm emissions were from milk based output. A further 25.8% of dairy farm GHG emissions were 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 arable production on dairy farms.

Figure 5-6: Agricultural GHG Emissions for the average Dairy Farm



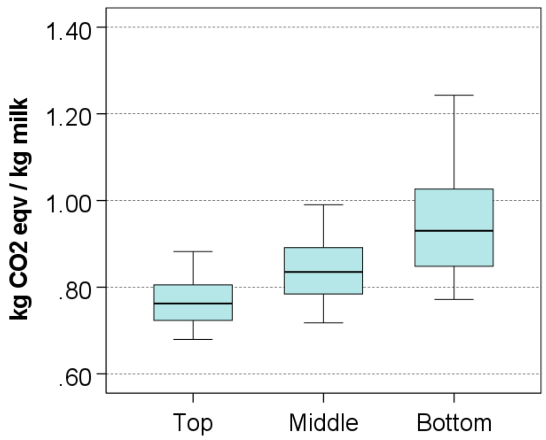
The average dairy farm emitted 9.52 tonnes of CO_2 equivalent per hectare. The better performing dairy farms in an economic sense tended to operate at higher intensities and this is reflected in their higher emissions of GHG per hectare, as shown in Figure 5-7.

Figure 5-7: Agricultural GHG Emissions per hectare: Dairy Farms



When emissions allocated to dairy production are expressed per kilogramme of milk output, the average dairy farm emitted 0.88 kg CO_2 equivalent per kg of milk produced.[2] Figure 5-8 shows that those farms with a better economic performance also tended to have the lowest emissions intensity per kg of milk produced.

Figure 5-8: Agricultural GHG Emissions per kg of milk: Dairy Farms

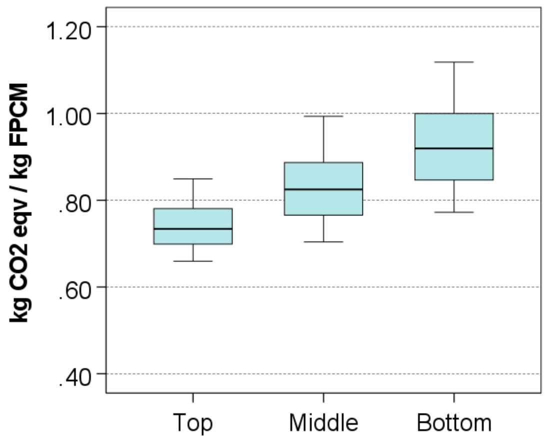


Emissions allocated to dairy output are also expressed per kg of fat and protein corrected milk (FPCM), which is standardized to 4% fat and 3.3% true protein per kg of milk. The average farm emitted 0.85 kg CO_2 equivalent per kg of FPCM produced. Figure 5-9 also shows that those farms with better economic

[2] Convert kg to litre by multiplying by 1.03

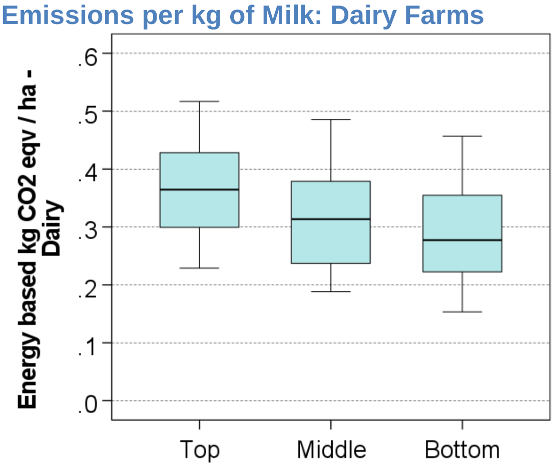
performance also have lower emissions intensity per kg of FPCM produced.

Figure 5-9: Agricultural GHG Emissions per kg of FPCM: Dairy Farms



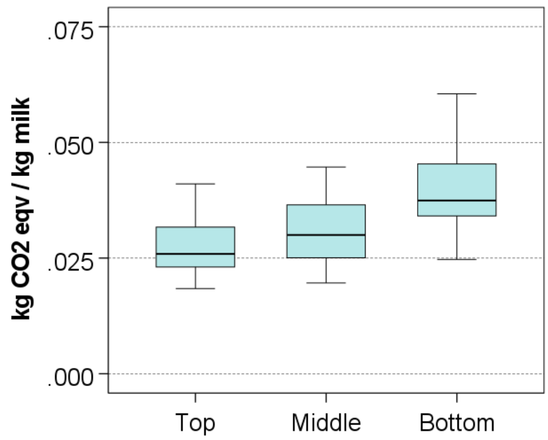
The average dairy farm emitted 0.35 tonnes of energy based CO_2 equivalent per hectare. The better performing dairy farms in an economic sense tended to operate at higher intensities and this is reflected in their higher emissions of energy based GHG per hectare, as shown in Figure 5-10.

Figure 5-10: Energy use related GHG Emissions per kg of Milk: Dairy Farms



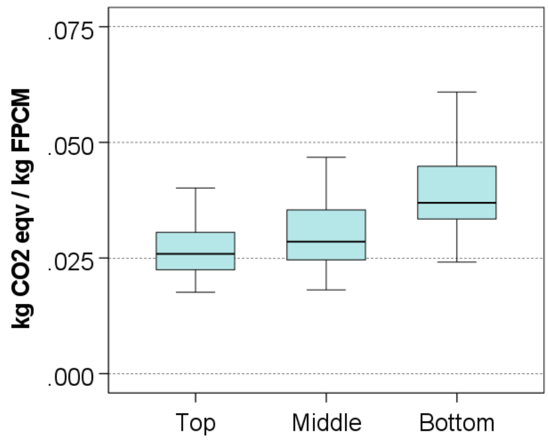
The average energy based GHG dairy farm emissions were 0.0367 kg CO_2 equivalent per kg of milk in 2021. Figure 5-11 indicates that, similar to agricultural based GHG emissions intensity of milk production, lower energy based GHG emissions per kg of milk produced is evident among farms with better economic performance.

Figure 5-11: Energy use related GHG Emissions per kg of Milk: Dairy Farms



The average energy based GHG emissions were 0.0358 kg CO_2 equivalent per kg of FPCM produced as shown in Figure 5-12. This indicator again shows that the top economic performers were more efficient in terms of FPCM produced per kg of energy related CO_2 emissions generated.

Figure 5-12: Energy GHG Emissions per kg of FPCM: Dairy Farms



Using the LCA approach (including both agricultural and energy based emissions) the average dairy farm carbon footprint of milk was 1.05 kg CO_2 equivalent per kg of FPCM in 2021. Figure 5-13 again shows that lower emissions per kg of FPCM (on an LCA basis) was more prevalent among the group of higher economic performing dairy farms.

Figure 5-13: Total LCA based GHG emissions (Agriculture & Energy) per kg of FPCM: Dairy Farms

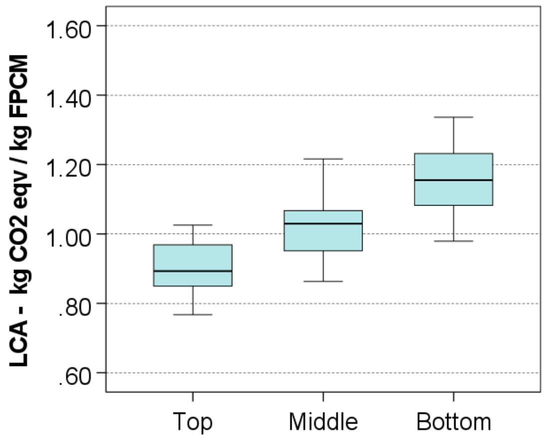
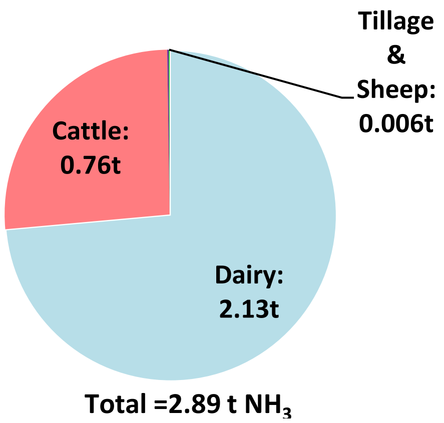


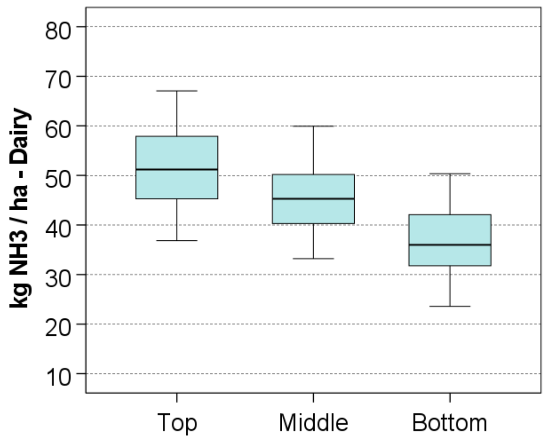
Figure 5-14 indicates that the average dairy farm produced approximately 2.89 tonnes of ammonia (NH_3) emissions in 2021. This calculation is based on an approach consistent with the EPA national ammonia inventory methodology. The majority of dairy emissions, 74%, were from milk based output, with 26% allocated to non-milk producing animals and a minor amount allocated to arable production.

Figure 5-14: Total Ammonia Emissions for the average Dairy Farm



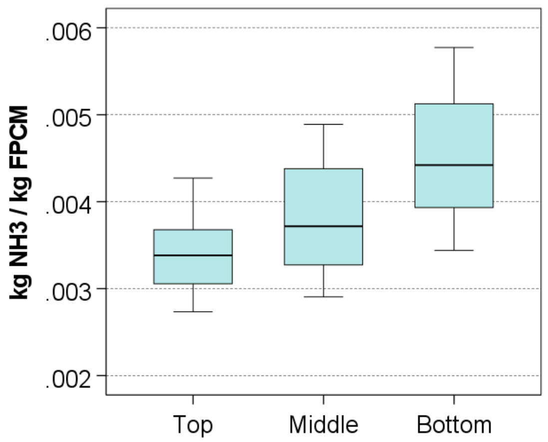
The average dairy farm emitted 45 kg of NH_3 per hectare across the entire farm. Economically better performing farms tend to operate at higher intensities and this is reflected in higher emission of ammonia per hectare, as shown in Figure 5-15.

Figure 5-15: Ammonia Emissions kg per hectare: Dairy Farms



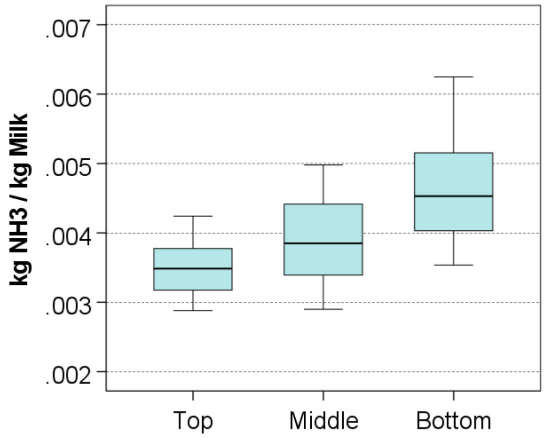
The average dairy farm emitted 0.004 kg of NH_3 per kg of FPCM produced. Figure 5-16 again shows that the top economic performing dairy farms produced milk at a lower NH_3 emissions intensity compared to the middle and bottom cohorts.

Figure 5-16: Ammonia Emissions per kg of FPCM: Dairy Farms



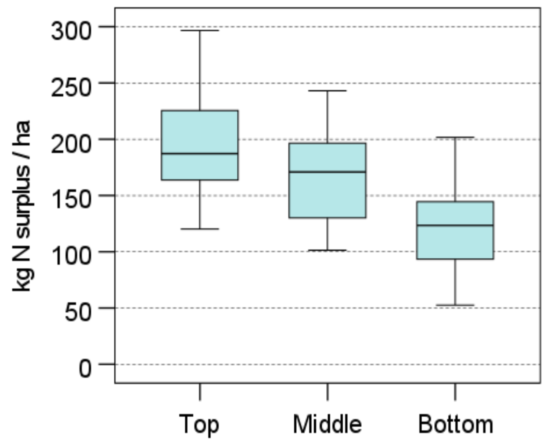
This result was replicated in the outcome on a kg of milk output basis, as shown in Figure 5-17. However, NH3 per kg of milk was slightly higher at 0.0041.

Figure 5-17: Ammonia Emissions per kg of Milk: Dairy Farms



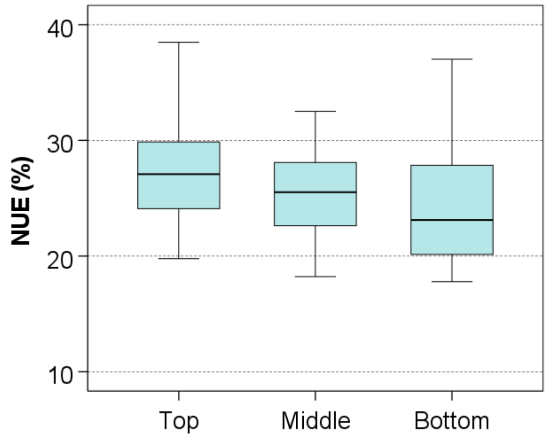
Nitrogen balance (excess of N inputs over outputs) averaged 163.7 kg N surplus per hectare across all dairy farms in 2021. Figure 5-18 indicates that higher N surpluses per hectare are associated with superior economic performance. This is due to the greater production intensity on economically better performing farms.

Figure 5-18: N Balance per ha: Dairy Farms



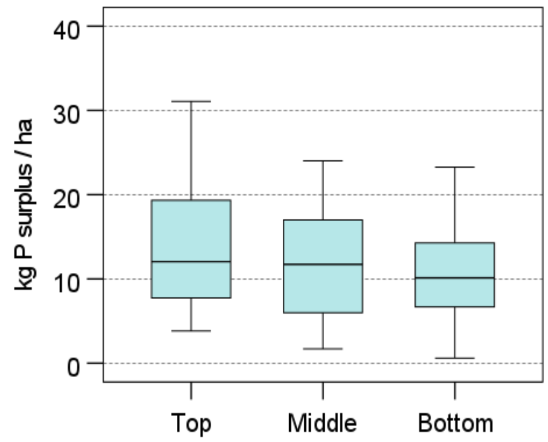
The average dairy farm had a NUE of 26.8% in 2021. Figure 5-15 demonstrates the slightly higher N use efficiency was evident among the better economic performing farmers, with the largest range prevalent among the bottom cohort.

Figure 5-19: N Use Efficiency: Dairy Farms



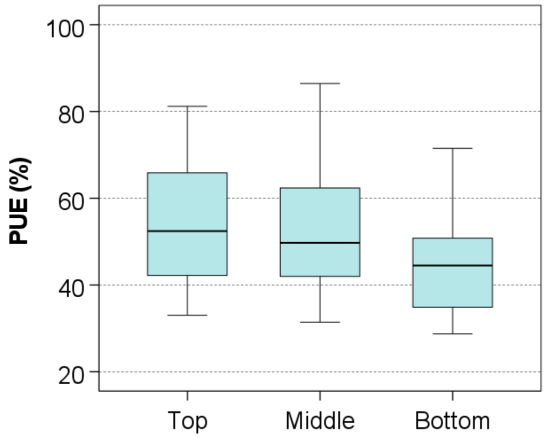
Phosphorus balance (excess of inputs over outputs) averaged 12.9 kg P surplus per hectare across all dairy farms in 2021. Figure 5-20 shows that there was a larger range of results, especially for the top and middle performing cohorts.

Figure 5-20: P Balance per ha: Dairy Farms



The average dairy farm had a P use efficiency of 53.3%. Figure 5-21 indicates higher P use efficiency was more prevalent among the better economic performing farms.

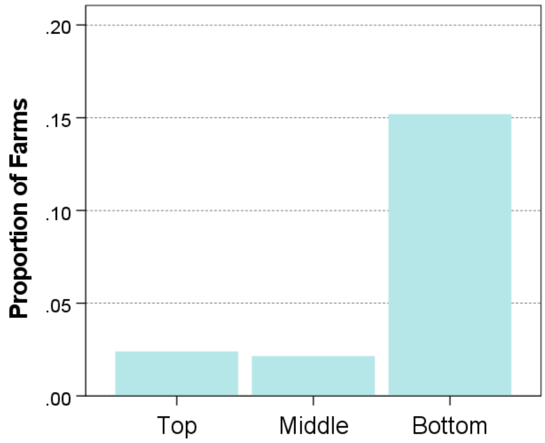
Figure 5-21: P Use Efficiency: Dairy Farms



Social Sustainability Indicators

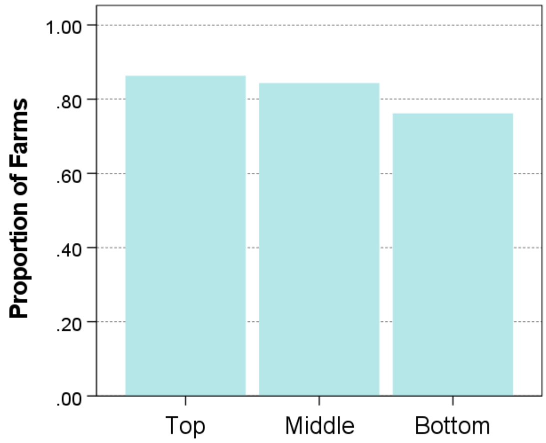
A minority of all dairy farm households, 7%, fell into the vulnerable household category (non-viable and no off-farm employment). Figure 5-22 shows that there was a considerably larger proportion of households at risk among those farms with the lowest gross margin per hectare (15% among bottom third).

Figure 5-22: Household Vulnerability: Dairy



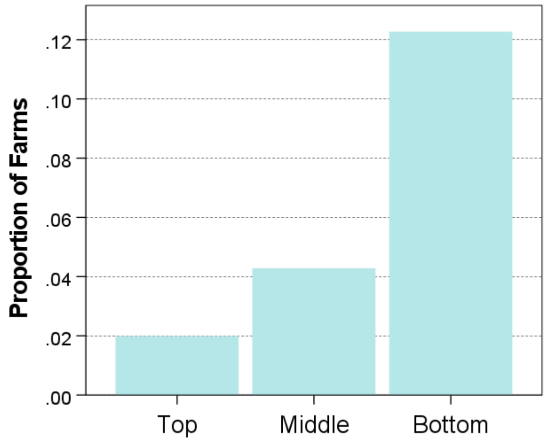
Overall, 82% of dairy farmers had received formal agricultural education of some description. Figure 5-23 shows that agricultural training rates were slightly higher across the middle and top performing cohorts.

Figure 5-23: Agricultural Education: Dairy



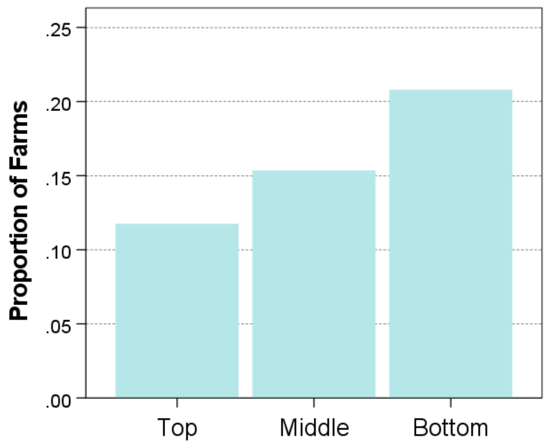
Only 6% of dairy farmers live alone and were thus classified as being at risk of isolation. Figure 5-24 indicates that the risk was lowest for the top economic preforming cohort.

Figure 5-24: Isolation Risk: Dairy Farms



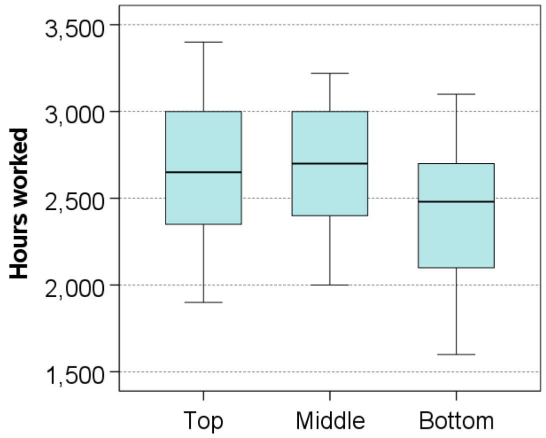
Across all dairy farms, 16% were identified as having a high age profile. Figure 5-25 shows that the percentage was slightly higher for the weaker economic performing dairy farms.

Figure 5-25: High Age Profile: Dairy Farms



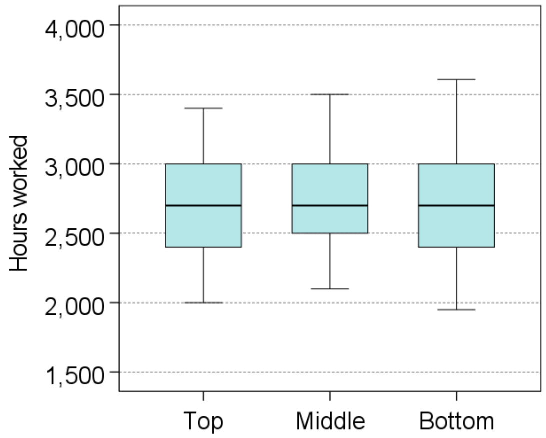
On average, dairy farmers worked 2,545 hours per year on-farm (approximately 48.9 hours per week). Figure 5-26 shows that the number of hours worked was highest for top and middle performing cohorts by economic performance. However, this figure does not take into consideration off-farm employment, or the share of hours worked by hired staff or other family members.

Figure 5-26: Hours Worked on farm: Dairy Farm Operator



On average, dairy farmers worked 2,725 hours per year between on and off-farm work (approximately 52.4 hours per week). Figure 5-27 shows that hours worked was slightly higher for the middle and bottom performing cohorts by economic performance.

Figure 5-27: Total Hours Worked: Dairy Farm Operator

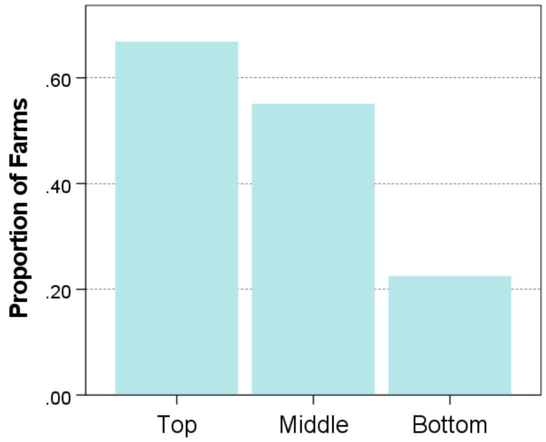


Dairy Innovation Indicators

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 to April, use of low emission slurry spreading equipment, application of protected urea fertiliser, as well as liming & grassland reseeding rates.

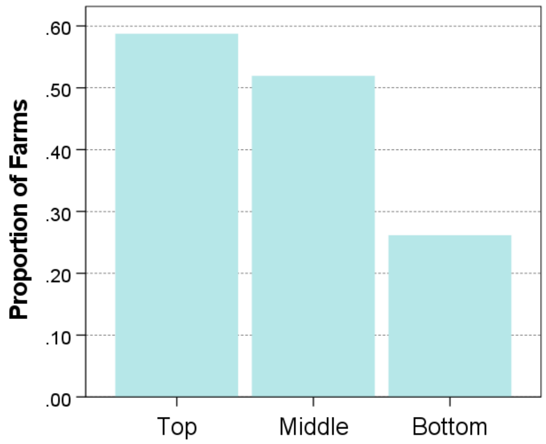
Figure 5-28 shows that those farms with better economic performance were more likely to use milk recording. Over 67% of the dairy farmers in the top group were milk recording, compared to 23% in the bottom group.

Figure 5-28: Milk Recording: Dairy Farms



Better economic performance was more prevalent among discussion group members. Membership rates were higher across the top economic performing group, at 59%, compared to 26% in the bottom cohort, as shown in Figure 5-29.

Figure 5-29: Discussion Group: Dairy Farms



The application of the majority of slurry in early spring was slightly higher across the top performing cohort at 54%, as shown in Figure 5-30. The middle and bottom cohorts had slightly lower level of spring time slurry application at 52% and 47% respectively.

Figure 5-30: Spring Slurry: Dairy Farms

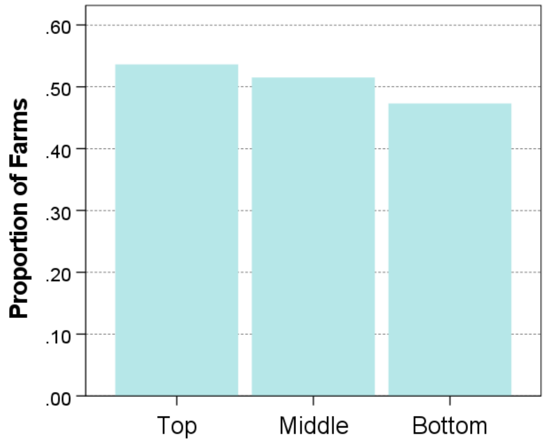
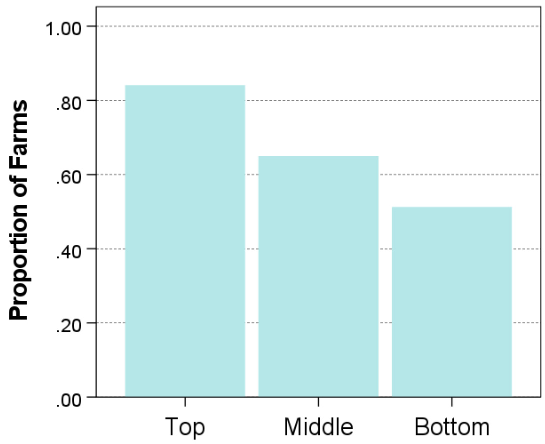


Figure 5-31 illustrates the volume of slurry applied by low emissions slurry spreading equipment. On the average dairy farm, nearly 67% of all slurry applied by dairy farmers was via low emission slurry spreading methods. This ranged from 84% for the top performing cohort to 51% for the bottom performing cohort.

Figure 5-31: Slurry applied by Low emissions slurry spreading methods: Dairy Farms



The percentage of total chemical nitrogen applied in the form of protected urea averaged 7% across all dairy farms. This ranged from 10% for the top performing cohorts to 4% for the bottom group as illustrated by Figure 5-32.

Figure 5-32 Protected Urea Use: Dairy Farms

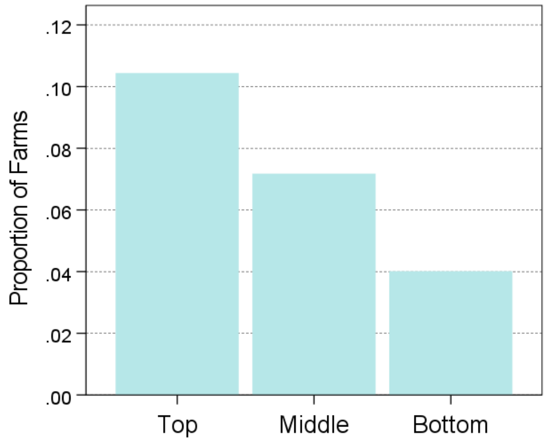


Figure 5-33 shows that liming was more prevalent among the better economic performers, with 51% of the top performing group engaging in this practice in 2021, compared to 32% for the bottom group.

Figure 5-33: Liming: Dairy Farms

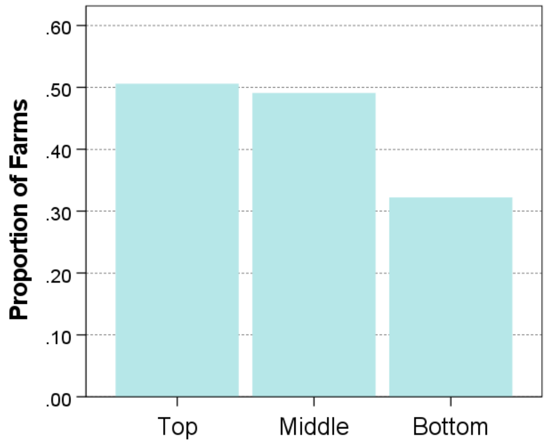
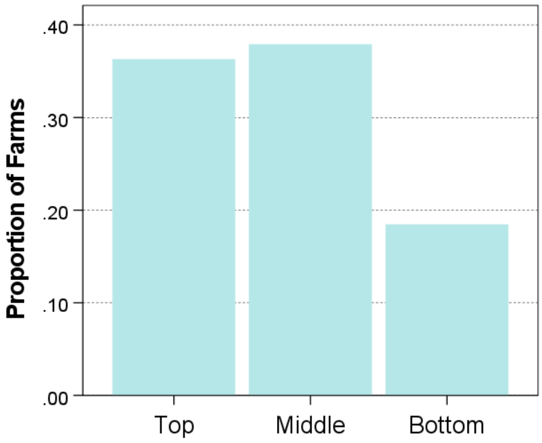


Figure 5-34 shows that reseeding was also more common among the better economic performing farms. A higher percentage of farmers in the top and middle groups (36-37%) engaged in reseeding of grassland compared to the bottom group (19%) in 2021.

Figure 5-34: Reseeding: Dairy Farms



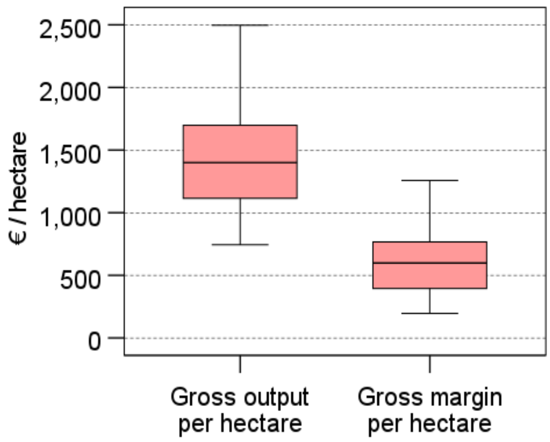
6 Cattle Farm Sustainability 2021

Cattle farms include both cattle rearing (mainly suckler based) and cattle finishing systems. Results for sustainability indicators in 2021 are presented below.

Economic Sustainability Indicators

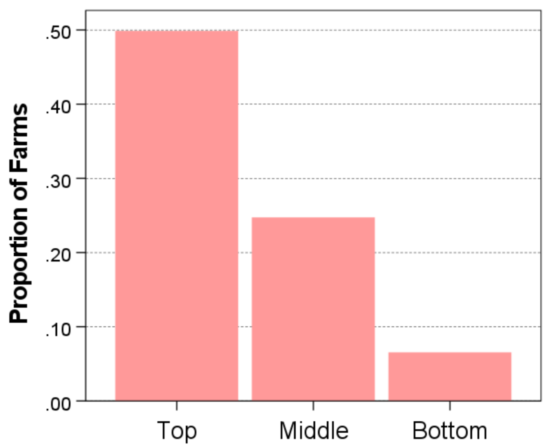
The average output per hectare for cattle farms was €1,532, and the average gross margin per hectare was €653 in 2021. There was a large range in farm economic performance, as shown in Figure 6-1.

Figure 6-1: Economic Return and Profitability of Land: Cattle Farms



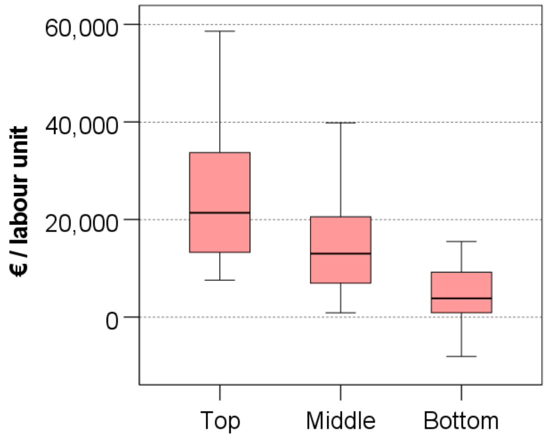
Only 27% of all cattle farms in the Teagasc NFS were defined as economically viable. As illustrated in Figure 6-2, the proportions deemed viable were 50%, 25% and 7% for the top, middle and bottom cohorts of farms by economic performance respectively.

Figure 6-2: Economic Viability: Cattle Farms



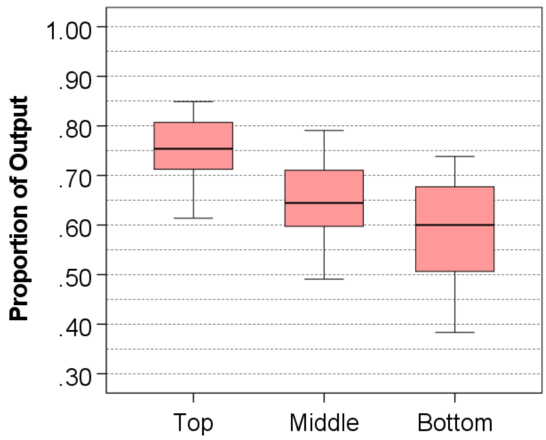
Across all cattle farms, the average income per labour unit was €17,445 in 2021. Figure 6-3 shows that this distribution was skewed by the top third of farms, which included a large number of relatively higher earners, with a mean income per labour unit of €31,005, compared with €17,206 and €3,345 for the middle and bottom cohorts of cattle farms respectively.

Figure 6-3: Productivity of Labour: Cattle



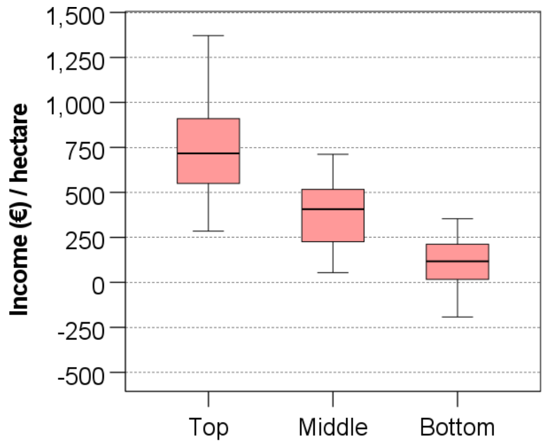
Market based output accounted for 66% of gross output across all cattle farms, with the remaining 34% accounted for by direct payment receipts. Figure 6-4 shows greater market orientation was exhibited across farms with better economic performance.

Figure 6-4: Market Orientation: Cattle Farms



The average family farm income per hectare on cattle farms was €404 in 2021. Across the subgroups, the average ranged from €754 for the top performing cohort to €81 for the bottom performers economically. Figure 6-5 shows significant ranges in income per hectare across the three groups, with a negative income per hectare returned by a section of the bottom performing cohort.

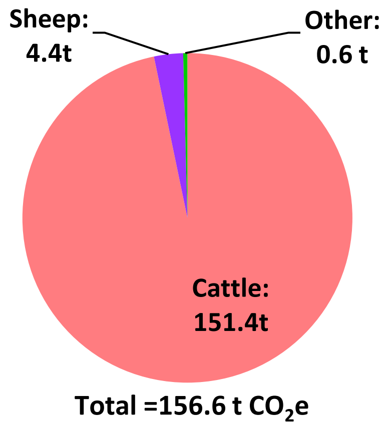
Figure 6-5: Family Farm Income per hectare: Cattle Farms



Environmental Sustainability Indicators

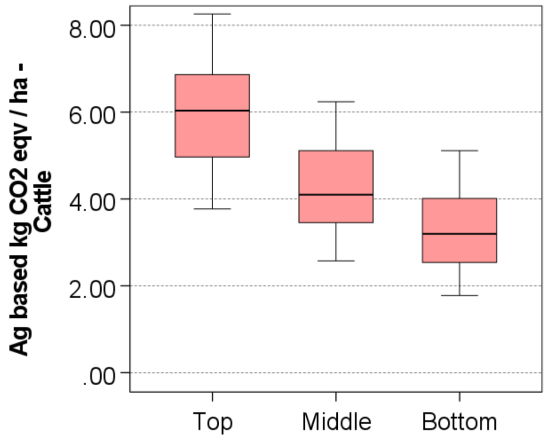
The average cattle farm produced 156.6 tonnes CO2 equivalent of agricultural GHG emissions in 2021. Figure 6-6 shows that beef production was the principal source, generating 96.7% of these emissions. Sheep production was responsible for approximately 2.8% of total emissions on Irish cattle farms, and a very small proportion (less than 0.4%) was derived from other enterprises on these farms.

Figure 6-6: Agricultural GHG Emissions for the average Cattle Farm



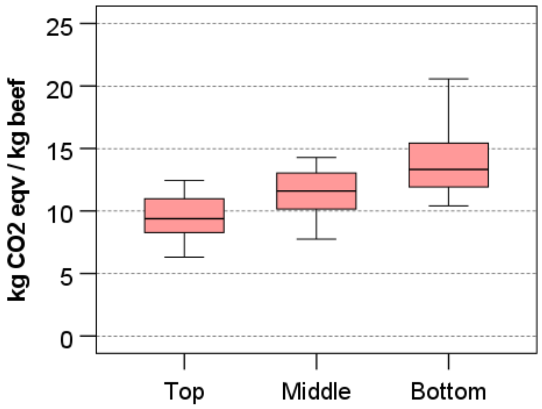
The average cattle farm emitted 4.65 tonnes of CO_2 equivalent of agriculturally generated GHG emissions per hectare in 2021. Emissions per hectare were higher for the more profitable cattle farms, which tended to be stocked at a higher intensity.

Figure 6-7: Agricultural GHG Emissions per hectare: Cattle Farms



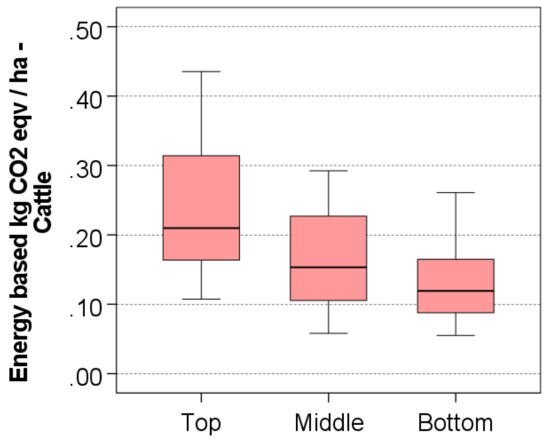
The emissions generated by cattle can be expressed in terms of their live-weight output (estimated using CSO price data). Figure 6-8 illustrates that there is a large range of emissions per kg of beef live-weight output. A positive association exists between emissions efficiency and economic performance. The top performing third of farms emitted, on average, 9.9 kg CO_2 equivalent per kg of live-weight beef produced, compared with 14.3 kg for the bottom performing third of cattle farms. The average level of GHG emissions across all farms was 12.0 kg CO_2 equivalent per kg beef of live-weight produced.

Figure 6-8: Agricultural GHG Emissions per kg live-weight beef produced: Cattle Farms



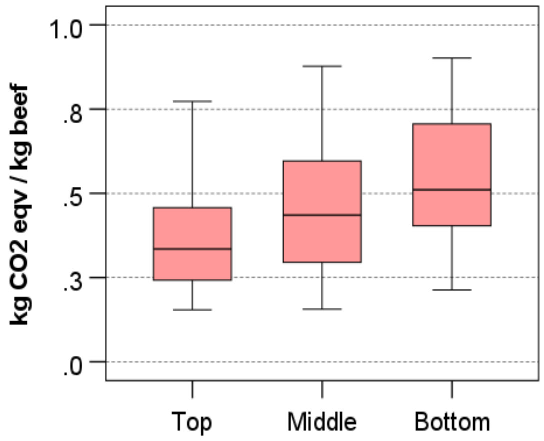
The average cattle farm emitted 0.2 tonnes of CO_2 equivalent of energy based GHG emissions per hectare in 2021, as illustrated in Figure 6-9. Emissions per hectare were higher for the more profitable cattle farms, which tended to be stocked at a higher intensity.

Figure 6-9: Energy GHG Emissions per hectare: Cattle Farms



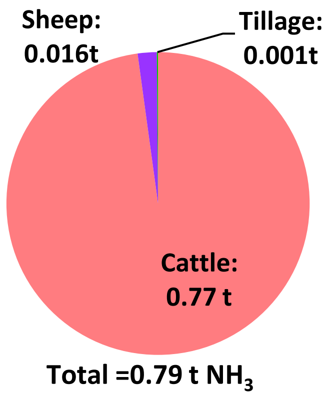
On average, energy based GHG emissions across all cattle farms was 0.51 kg of CO_2 equivalent per kg beef live-weight produced. Figure 6-10 illustrates that energy based GHG emissions per unit of product were also lower on farms with better economic performance. The top third produced an average of 0.45 kg CO_2 energy-based emissions per kg of live-weight beef produced, while for the bottom performing third this figure was 0.61 kg.

Figure 6-10: Energy use related GHG Emissions per kg live-weight beef: Cattle Farms



The average cattle farm emitted 0.79 tonnes of ammonia (NH_3) in 2021. Over 97% of total NH_3 emissions were linked with beef production, the remainder reflected emissions from a sheep and tillage enterprise on cattle farms, as shown by Figure 6-11.

Figure 6-11: Total Ammonia Emissions for the average Cattle Farm



On average, cattle farms emitted 23.1 kg of NH_3 per hectare in 2021. This ranged from 30.2 kg per hectare for the top performing cohort, to 18.2 per hectare for the bottom third, as shown by Figure 6-12. Emissions per hectare were higher for the more profitable cattle farms, which also tend to be stocked at a higher intensity.

Figure 6-12: Ammonia Emissions per hectare: Cattle Farms

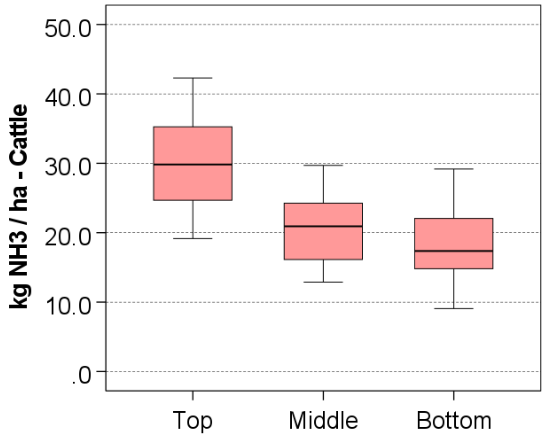


Figure 6-13 illustrates that, in terms of live-weight of beef produced, the more profitable cattle farmers have a lower level of ammonia emissions. There was a large range within the results, especially for the bottom performing cohort of cattle farmers. On average, a kg of live-weight beef was produced at an intensity of 0.0646 kg of NH_3.

Figure 6-13: Ammonia Emissions per kg live-weight beef produced: Cattle Farms

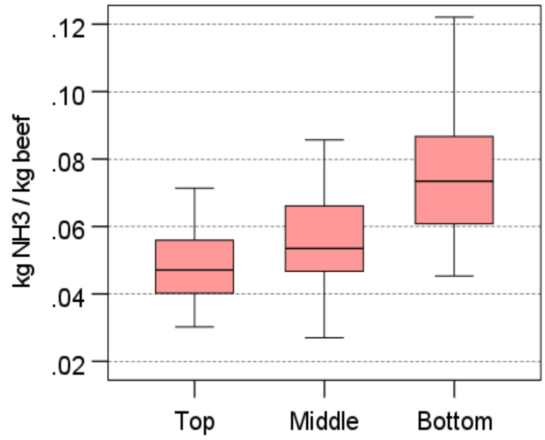
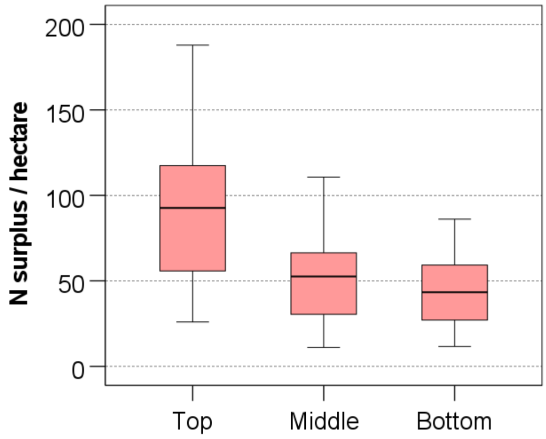


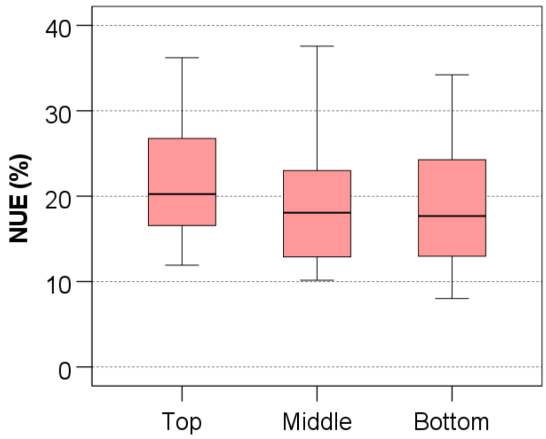
Figure 6-14 indicates that the nitrogen surplus per hectare tended to be higher on cattle farms that performed better economically. In general, these farms are operated more intensively. The top performing third of cattle farms had an average nitrogen surplus of 93.5 kg N per hectare, compared to 49.6 kg N per hectare for the bottom third of farms.

Figure 6-14: N Balance per ha: Cattle Farms



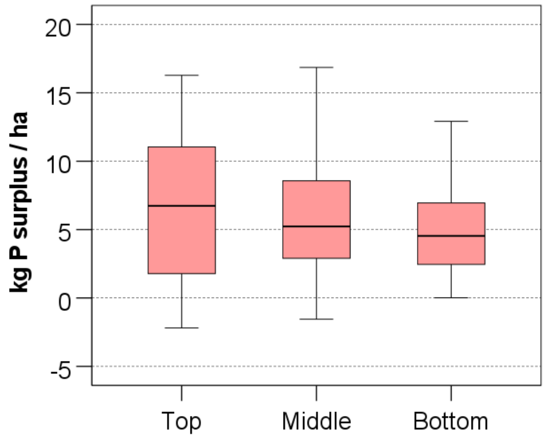
The average NUE across all cattle farms was 21.9%, but the range in NUE across the sample of cattle farms was significant, as shown in Figure 6-15. Despite the higher application rates, NUE tended to be higher across the middle and top economic performing cohorts.

Figure 6-15: N Use Efficiency: Cattle Farms



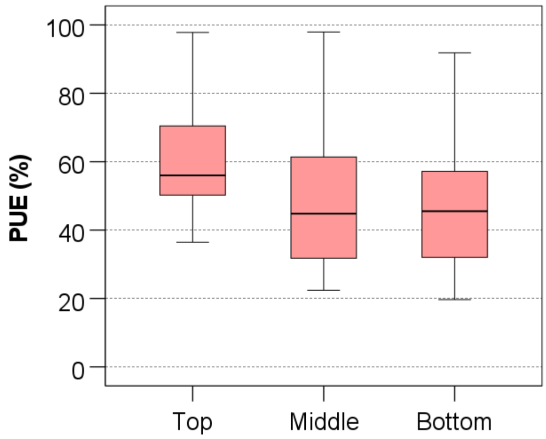
At the farm gate boundary, the P surplus across all cattle farms averaged 6.2 kg per hectare. There was a large range in P surpluses, especially across the better performing farms economically, as shown in Figure 6-16.

Figure 6-16: P Balance per ha: Cattle Farms



At the farm gate boundary, the average farm PUE across all cattle farms was 63.3%. Figure 6-17 shows that higher PUE was again more prevalent on farms that performed best in economic terms. Average PUE ranged from 77.6% for the top third to 51.5% for the bottom third of cattle farmers.

Figure 6-17: P Use Efficiency: Cattle Farms



Social Sustainability Indicators

Overall, 34% of all cattle farm households were considered vulnerable (a non-viable farm business with no off-farm employment). Figure 6-18 confirms that this vulnerability was associated with weaker economic performance, with 33% and 47% of the middle and bottom third of farms deemed vulnerable, compared to 20% of the top third.

Figure 6-18: Household Vulnerability: Cattle

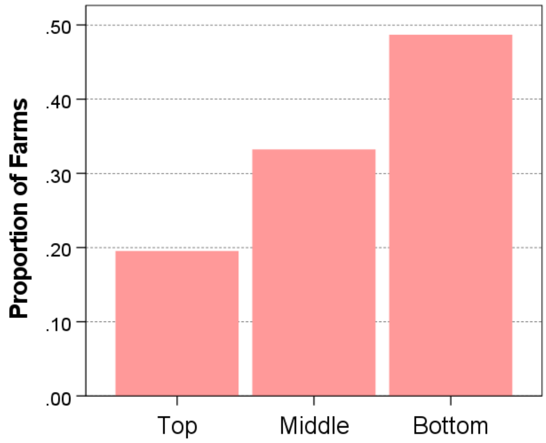
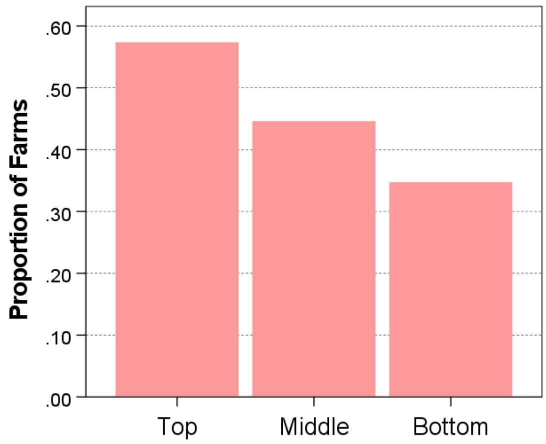


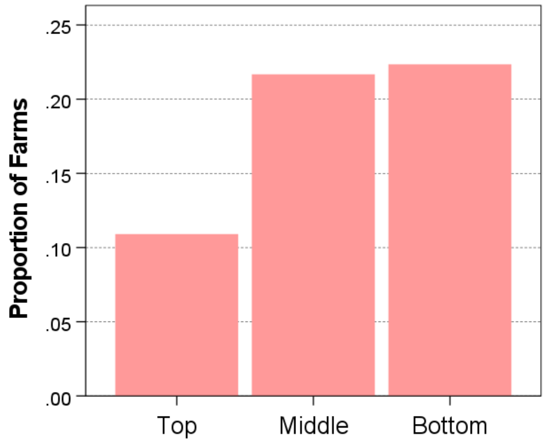
Figure 6-19 indicates that educational attainment was positively associated with the better economic performing farms. A total of 46% of cattle farmers had some level of agricultural education.

Figure 6-19: Agricultural Education: Cattle Farms



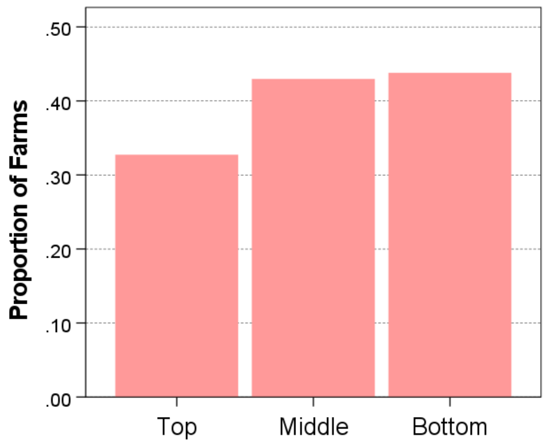
Overall, 18% of cattle farm operators were classified as being at risk of isolation; i.e. where the farmer lives alone. This was especially prevalent among farms in the middle and lower profitability cohorts, where 22% of farmers live alone, as shown in Figure 6-20.

Figure 6-20: Isolation Risk: Cattle Farms



Additionally, 40% of cattle farms were classified as having a high age profile. As with other indicators of social sustainability, this was more prevalent among the middle and bottom cohorts as shown in Figure 6-21.

Figure 6-21: High Age Profile: Cattle Farms



The average cattle farm operator worked on farm for 1,486 hours over the year (an average of 28.6 hours per week). The top economically performing cohort worked on average of 1,600 hours on farm compared to 1,410 and 1,445 for middle and bottom groups as outlined in Figure 6-22.

Figure 6-22: Hours Worked on Farm: Cattle Farm Operator

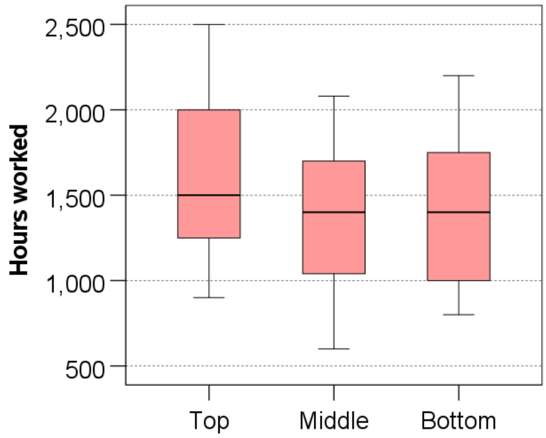
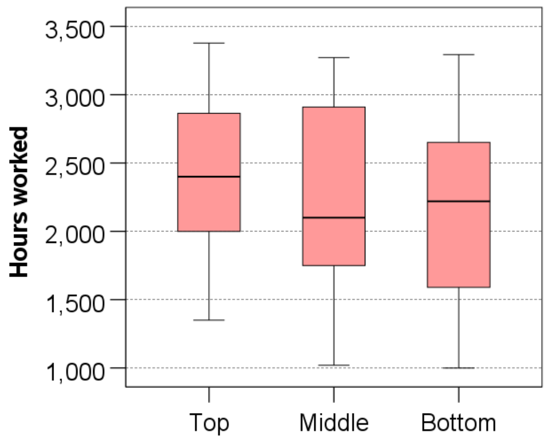


Figure 6-23 shows total hours worked (on and off-farm) was slightly higher for the top and bottom cohorts. On average, cattle farmers worked 2,221 hours in 2021 between on and off-farm work (approximately 42.7 hours per week).

Figure 6-23: Total Hours Worked: Cattle Farm Operator



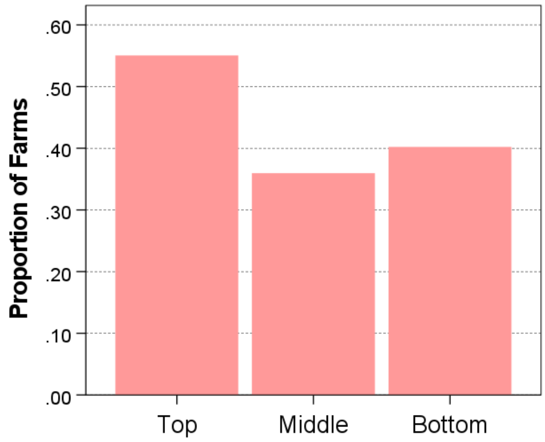
Cattle Farm Innovation Indicators

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

Figure 6-24 shows that those in the top economic performing group applied a lot more of the total slurry in springtime (55%)

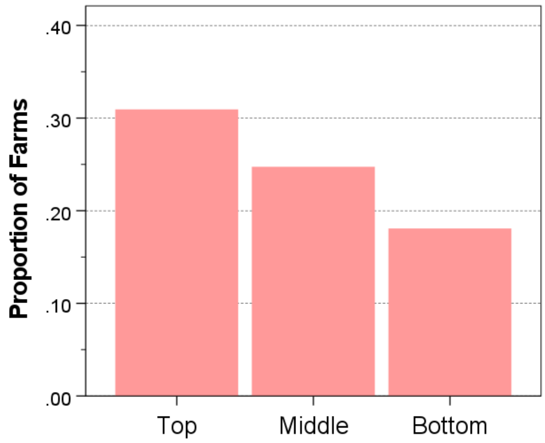
compared to the middle (36%) and bottom (40%) cohorts.

Figure 6-24: Spring Slurry Application: Cattle Farms



On average, nearly 25% of all slurry applied by cattle farmers was via low emission slurry spreading methods. This ranged from 31% for the top performing cohort to 18% for the bottom performing cohort, as outlined in Figure 6-25.

Figure 6-25: Low emission slurry spreading: Cattle Farms



The percentage of total chemical nitrogen applied in the form of protected urea averaged 1.8% across all cattle farms in 2021. This ranged from 3.2% for the top performing cohorts to 0% for the bottom group as illustrated in Figure 6-26.

Figure 6-26: Protected Urea use: Cattle Farms

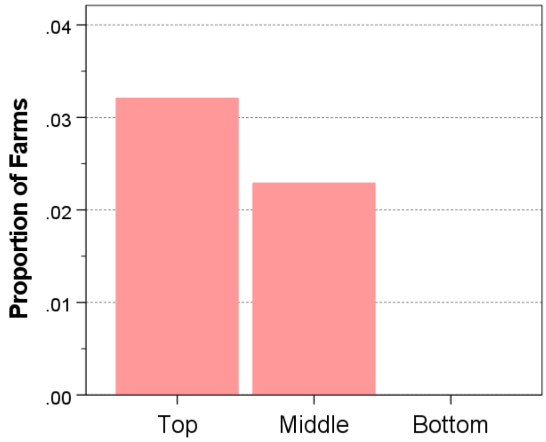


Figure 6-27 shows that liming rates were slightly higher for the top and middle performing cattle farm, at 27-21%, compared to 14% for the bottom cohort.

Figure 6-27: Liming: Cattle Farms

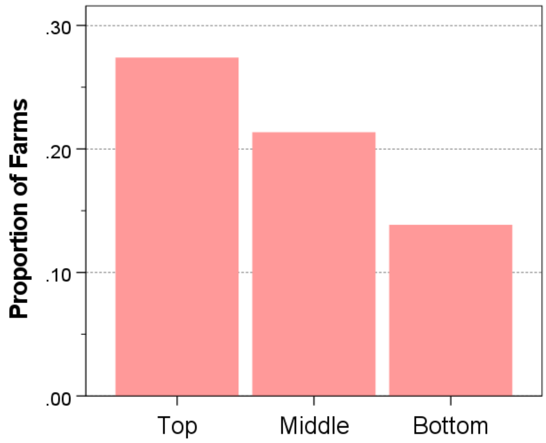
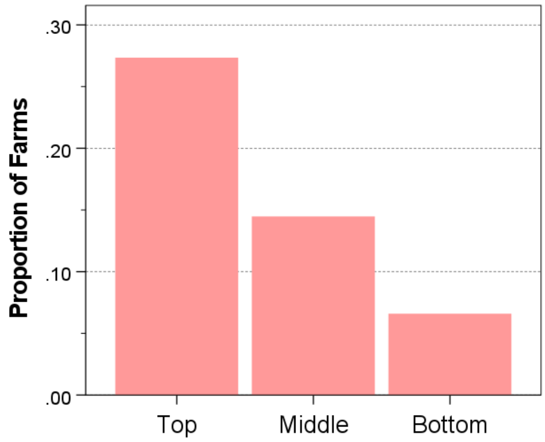


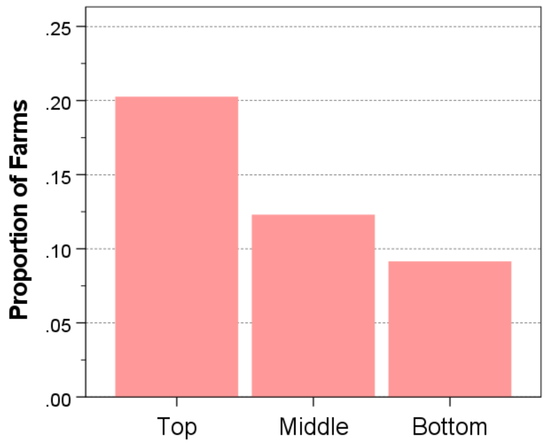
Figure 6-28 shows that 27% of the top economic performing cohort were members of a discussion group, compared to 14% and 7% in the middle and bottom cohort respectively.

Figure 6-28: Discussion Group: Cattle Farms



Reseeding levels ranged from 20% for the top cohorts to 9% for the bottom performing cohort as shown in Figure 6-29.

Figure 6-29: Re-seeding: Cattle Farms

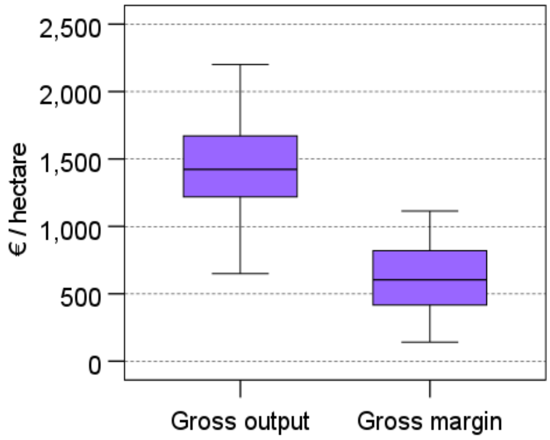


7 Sheep Farm Sustainability 2021

Economic Sustainability Indicators

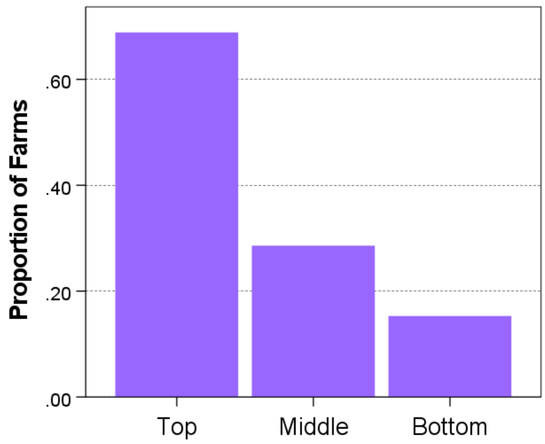
The average gross output per hectare for sheep farms was €1,476 in 2021, and the average gross margin was €623 per hectare.

Figure 7-1: Economic Return and Profitability of Land: Sheep Farms



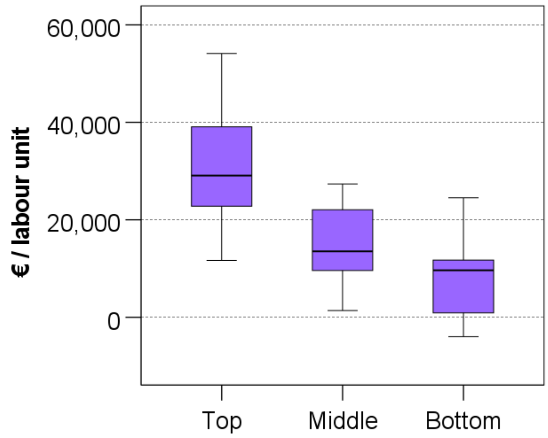
Across all sheep farms, 39% were defined as economically viable. Figure 7-2 shows that, ranked by economic performance, the proportion of viable sheep farms ranged from 69% for the top third to 15% for the bottom third of farms.

Figure 7-2: Economic Viability: Sheep Farms



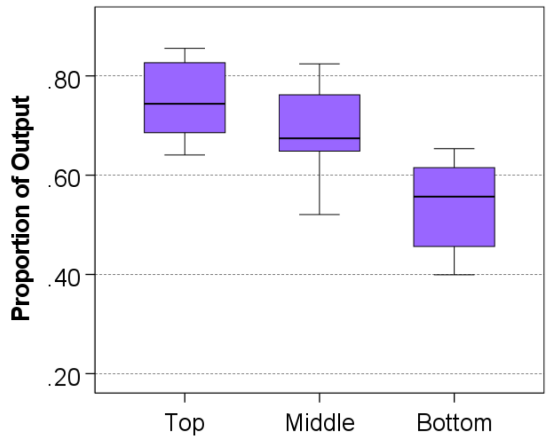
The average income per labour unit on sheep farms was €18,725. In common with cattle farms, there was a large range in economic performance, with the top third of sheep farms earning a mean income per labour unit of €30,078, compared with €11,370 for the bottom third (see Figure 7-3). Median income for the three cohorts was €32,623, €16,254 and €10,336 respectively.

Figure 7-3: Productivity of Labour: Sheep Farms



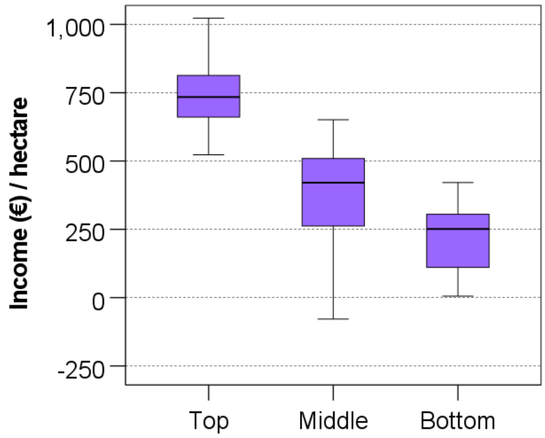
For the average sheep farm, approximately 66% of output was generated from the market, with the remaining 34% derived from direct payments. Figure 7-4 indicates that market orientation was positively associated with economic performance, with the top third of farms, based on economic performance, producing 74% of output from the market, compared with just over 52% on average for bottom third. Figure 7-4 also indicates a significant range across the bottom performing cohort in particular.

Figure 7-4: Market Orientation: Sheep Farms



The average family farm income per hectare on sheep farms was €445 in 2021. Across the subgroups, this average ranged from €804 for the top performing cohort to €173 for the bottom performers economically. Figure 7-5 shows significant ranges in income per hectare across the three groups.

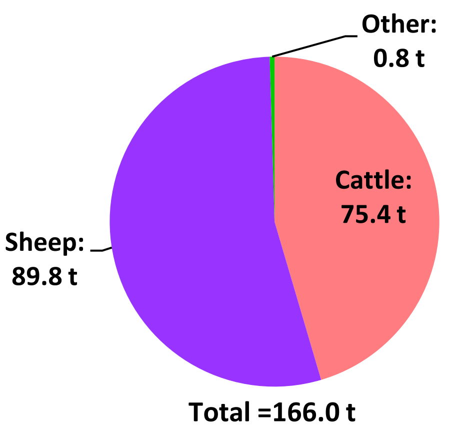
Figure 7-5: Family Farm Income per hectare: Sheep Farms



Environmental Sustainability Indicators

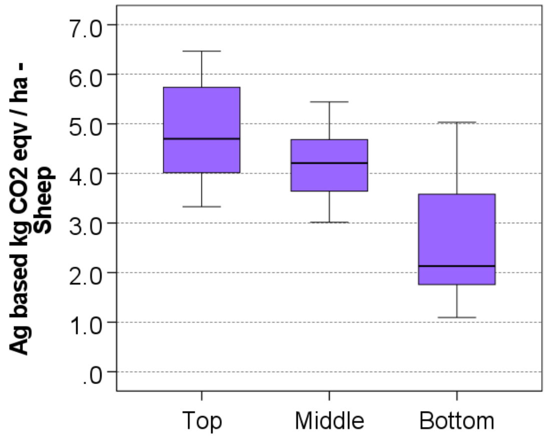
In 2021, the average sheep farm produced 166.0 tonnes CO_2 equivalent of agricultural GHG emissions. Figure 7-6 indicates that 54.1% of these emissions were generated by the sheep enterprise, with the remaining emissions (45.5%) generated by a cattle enterprise present on specialist sheep farms, with the remainder coming from other sources (minor arable enterprise).

Figure 7-6: Agricultural GHG Emissions for the average Sheep Farms



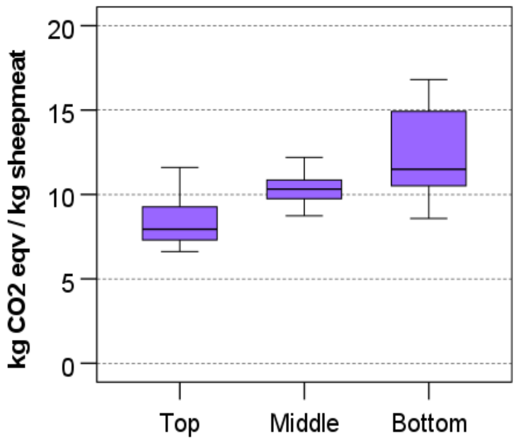
On average, sheep farms emitted 4.1 tonnes of CO_2 equivalent per hectare. Higher emissions per hectare were associated with the more profitable sheep farms, as shown in Figure 7-7. However, there was a large range of results.

Figure 7-7: Agricultural GHG Emissions per hectare: Sheep Farms



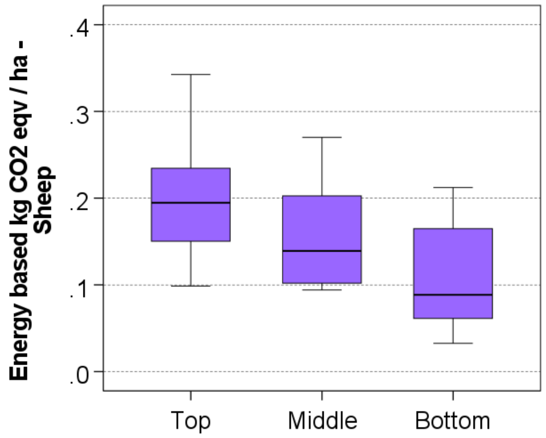
The GHG emissions generated by sheep are shown per kg of live-weight output produced (estimated using CSO price data). Figure 7-8 shows that the emissions intensity per kg of live-weight produced were negatively associated with economic performance. The top and middle third of farms generated 8.4 to 10.4 kg CO_2 equivalent per kg live weight produced respectively, compared to 12.4 kg CO_2 equivalent for the bottom cohorts on average. There was a noticeably large range of results across the bottom cohort.

Figure 7-8: Agricultural GHG Emissions per kg live-weight produced: Sheep Farms



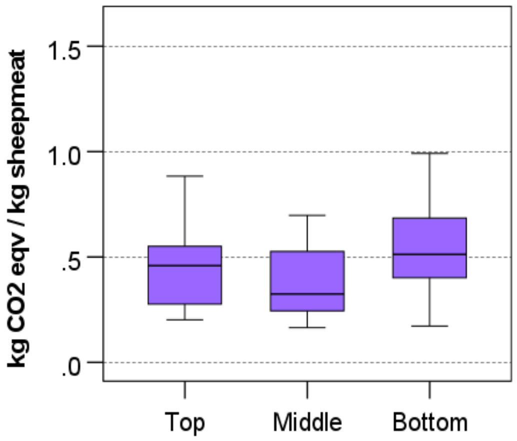
The average sheep farms emitted 0.17 tonnes of energy based CO_2 equivalent per hectare. Higher emissions per hectare were associated with the more profitable sheep farms, as shown in Figure 7-9.

Figure 7-9: Energy GHG Emissions per hectare: Sheep Farms



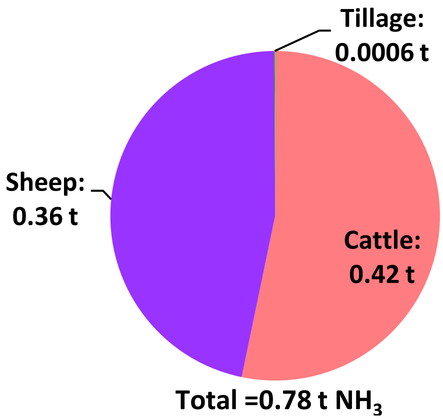
Better economic performance was also linked with lower energy based GHG emissions per unit of output, as shown in Figure 7-10. The bottom third of farms in economic terms emitted 0.6 kg CO_2 equivalent per kg live-weight sheep meat produced from energy based emissions, compared to 0.51 and 0.42 kg CO_2 for the top and middle third respectively.

Figure 7-10: Energy use related GHG Emissions per kg live-weight produced: Sheep Farms



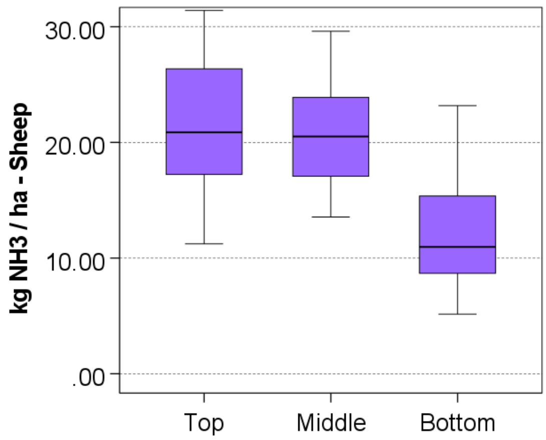
On average, specialist sheep farms emitted 0.78 tonnes of NH_3 in 2021. Even though the main output on these farms is sheep based, the majority of the NH_3 emissions related to cattle production (53%), with 47% relating to sheep production. The remaining residual portion related to tillage crops.

Figure 7-11: Total Ammonia Emissions for the average Sheep Farm



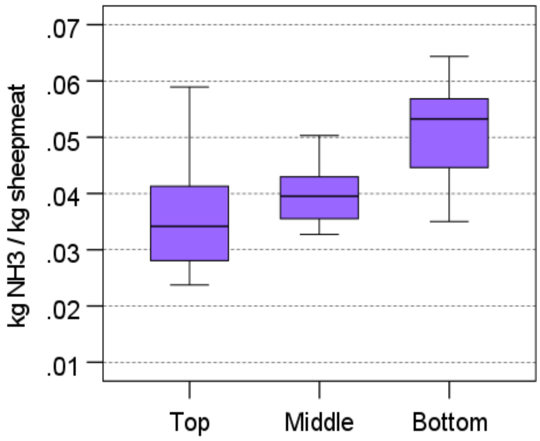
On average, a specialist sheep farm emitted 19.5 kg of ammonia per hectare in 2021. Higher per hectare emissions were associated with economically better performing farms as shown in Figure 7-12. These farms tend to operate at a higher stocking intensity.

Figure 7-12: Ammonia Emissions per hectare: Sheep Farms



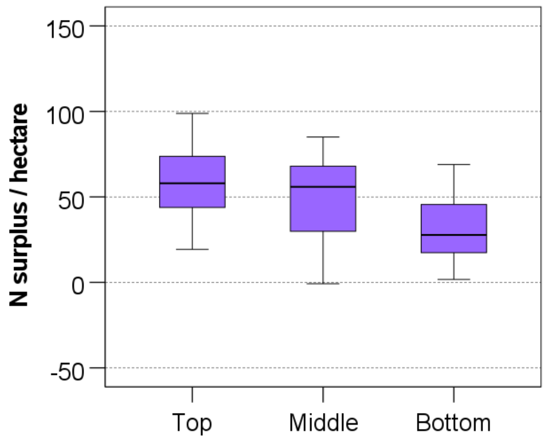
Lower ammonia emissions intensity of production was again more common among the better economically performing sheep farms. Farms in the top and middle performing cohort in economic terms were found to produce a kg of live-weight sheep meat with a lower NH_3 emission footprint, as shown in Figure 7-13. On average, sheep farmers produced 0.044 kg of NH_3 emissions per kg of live-weight sheep meat.

Figure 7-13: Ammonia Emissions per kg live-weight produced: Sheep Farms



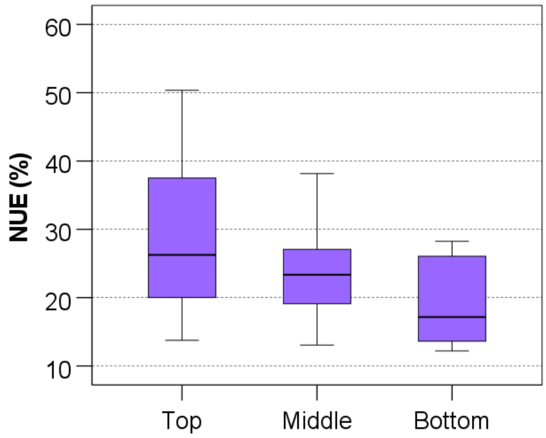
As with cattle farms, the sheep farm based nitrogen surplus per hectare was positively associated with economic performance, due to greater production intensity on the more profitable sheep farms (as shown in Figure 7-14). The top third of farms, ranked by gross margin per hectare, had an average nitrogen surplus of 64.6 kg per hectare, compared with 55.6 and 38.3 kg per hectare for the middle and bottom cohorts respectively.

Figure 7-14: N Balance per ha: Sheep Farms



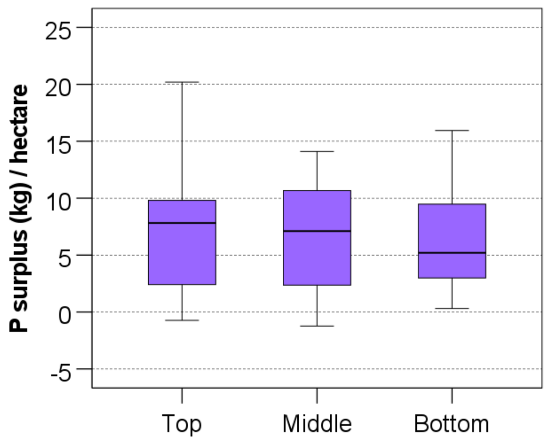
The average NUE across all sheep farms was 25.7%. Higher NUE was again associated with better economic performance, as shown in Figure 7-15.

Figure 7-15: N Use Efficiency: Sheep Farms



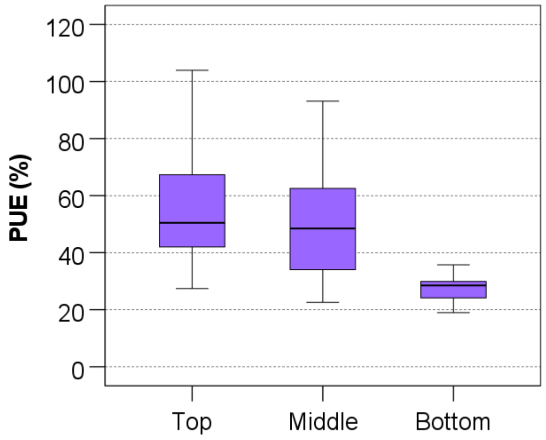
P balances across all specialist sheep farms were 6 to 8 kg per ha^{-1} on average. There was a large range of results across the three cohorts, especially the top performing group, as shown by Figure 7-16.

Figure 7-16: P Balance per ha: Sheep Farms



Farm gate level PUE averaged 57.8% across all sheep farms in 2021. Figure 7-17 shows that higher PUE was associated with farms with better economic performance.

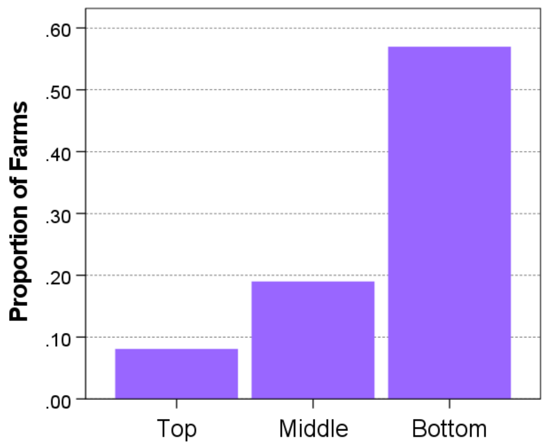
Figure 7-17: P use efficiency: Sheep Farms



Social Sustainability Indicators

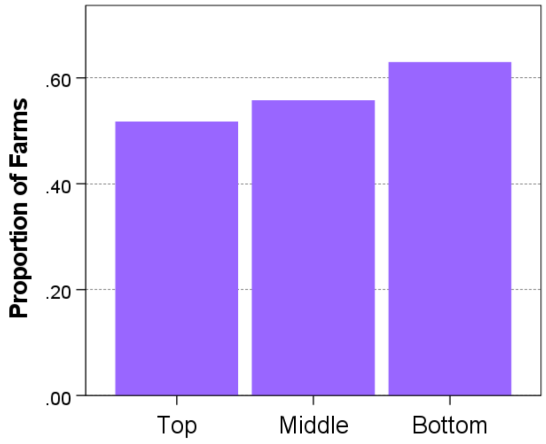
Over 27% of all sheep farm households were considered vulnerable in 2021. Figure 7-18 shows that this ranged from 8% for the top performing sheep farms to 57% for the bottom group.

Figure 7-18: Household Vulnerability: Sheep Farms



Overall, 57% of sheep farmers had received formal agricultural education. Figure 7-19 shows that agricultural education was slightly higher among the middle and bottom third of farms by economic performance.

Figure 7-19: Agricultural Education: Sheep Farms



On average, 21% of all specialist sheep farms were classified as being at risk of isolation. Figure 7-20 shows that this was significantly higher among the bottom performing cohort of sheep farms at 31%.

Figure 7-20: Isolation Risk: Sheep Farms

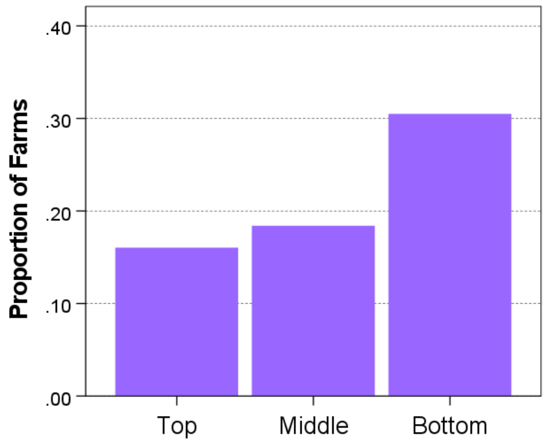
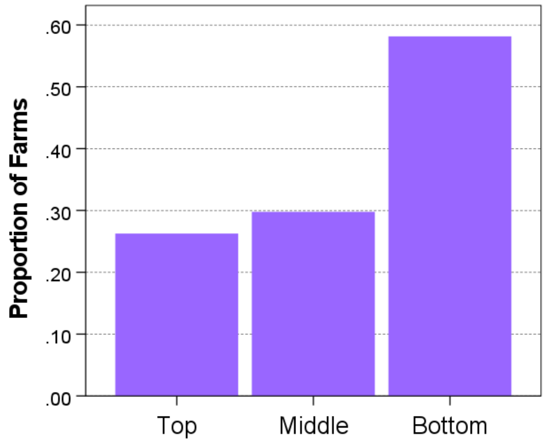


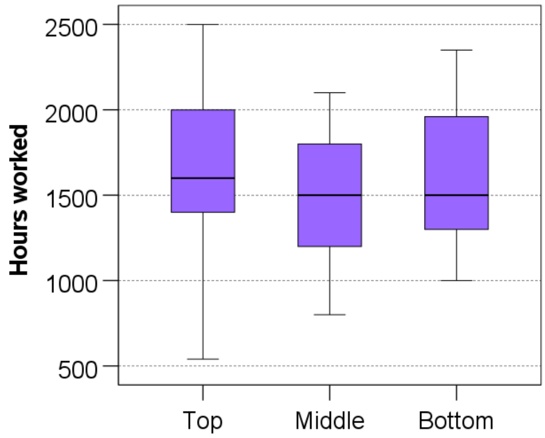
Figure 7-21 shows that the proportion of all specialist sheep farms with a high age profile was 37%. The bottom performing group had the highest age profile on average.

Figure 7-21: High Age Profile: Sheep Farms



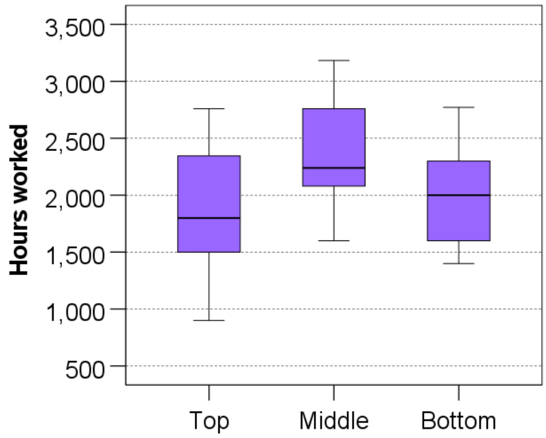
Sheep farmers worked an average of 1,541 hours per year on farm in 2021 (or 29.6 hours a week). The bottom performing cohort tend to work the most hours on farm at 1,586 hours, compared to the middle group at 1,488 hours (Figure 7-22).

Figure 7-22: Hours Worked On Farm: Sheep Farm Operators



On average, sheep farmers worked 2,085 hours in 2021 between on and off-farm work (approximately 40.1 hours per week). Figure 7-23 shows that total hours worked was lower across the better performing farms economically.

Figure 7-23: Total Hours Worked: Sheep Farm Operator

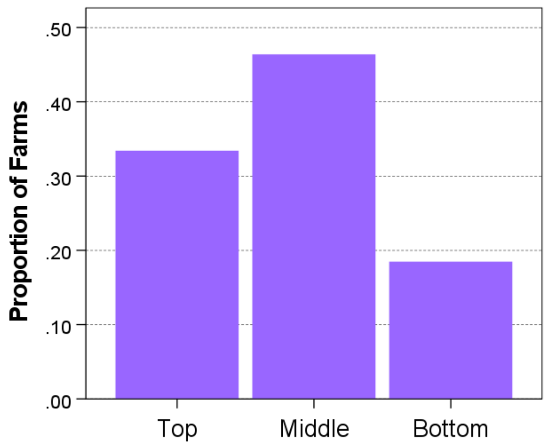


Sheep Farm Innovation Indicators

The five innovation indicators selected for sheep farms were whether at least 50% of slurry was spread in the period January to April, the portion of chemical N fertiliser applied in the form of protected urea, application of lime, grassland reseeding and whether or not the farm operator was a member of a discussion group.

Figure 7-24 shows that those in the top and middle economic performing group (33 to 46%) applied more of the total slurry in springtime, compared to the bottom cohort (19%). 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 7-24: Spring Slurry: Sheep Farms



As illustrated in Figure 7-25, the use of protected urea fertiliser by sheep farmers was very limited. On average only 2% of chemical N fertiliser applied was in the form of protected urea in 2021.

Figure 7-25: Protected Urea use: Sheep Farms

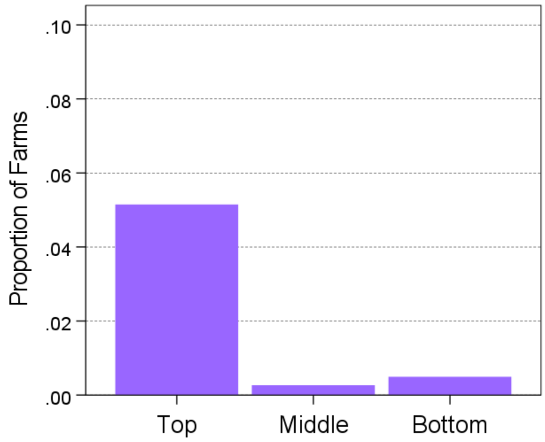


Figure 7-26 shows that liming activity was again more prevalent across the better economic performing farms, with 36% of the middle performing cohort by economic performance engaged in liming, compared to 21% of the bottom group.

Figure 7-26: Liming: Sheep Farms

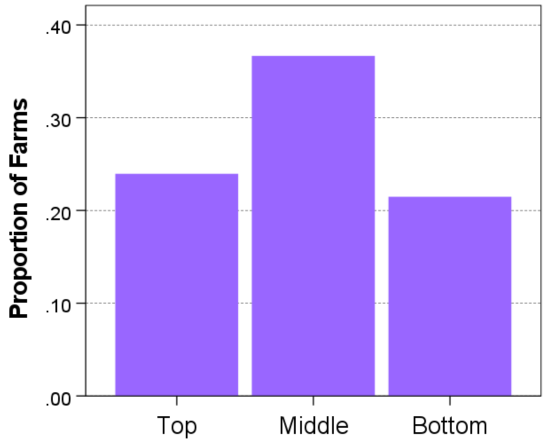


Figure 7-27 shows that higher levels of reseeding were associated with the sheep farms that performed better in economic terms.

Figure 7-27: Reseeding: Sheep Farms

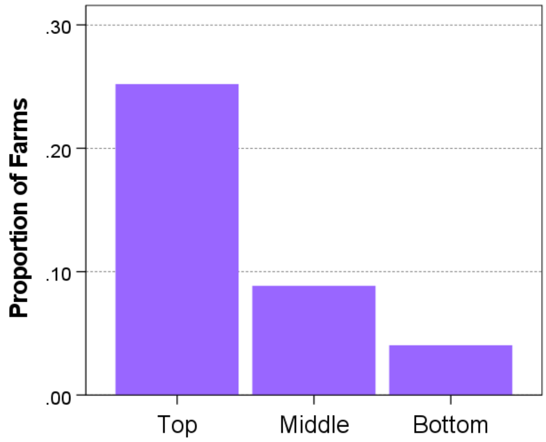
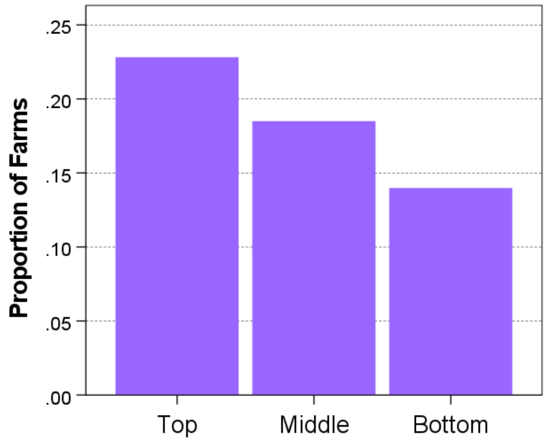


Figure 7-28 shows that membership of a discussion group was higher (23%) among the top cohorts versus 14% for bottom group.

Figure 7-28: Discussion Group: Sheep Farms

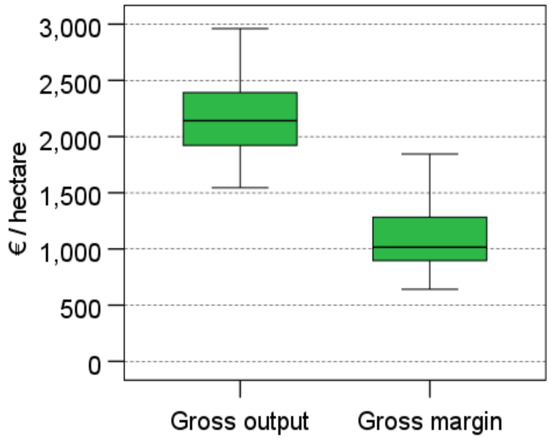


8 Tillage Farm Sustainability 2021

Economic Sustainability Indicators

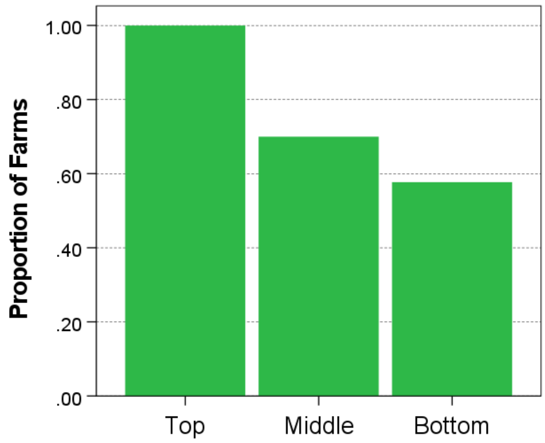
The average gross output and gross margin per hectare for tillage farms was €2,218 and €1,189 respectively in 2021. But there was a large distribution around the average, as illustrated by Figure 8-1.

Figure 8-1: Economic Return and Profitability of Land: Tillage Farms



Overall, 76% of tillage farms were classified as economically viable. Figure 8-2 shows that the middle and bottom groups had lower levels of viability, at 70% and 57% compared to 100% for the top performing group.

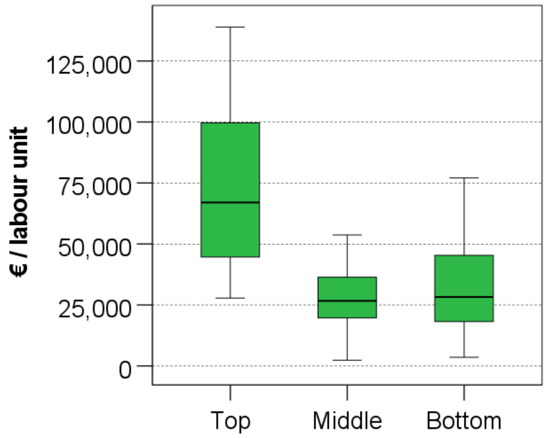
Figure 8-2: Economic Viability: Tillage Farms



The average tillage farm income per labour unit (for unpaid family labour) was €75,185. Figure 8-3 shows that there is a large range in incomes on tillage farms, with the top one-third (ranked by gross margin per hectare) earning significantly more than the middle and bottom cohorts per labour unit provided.

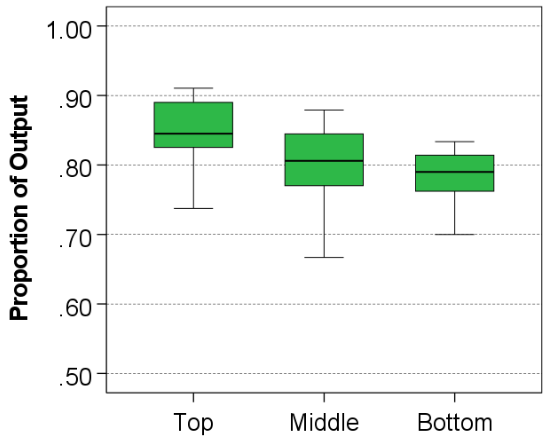
For some of the most profitable tillage farms, income per labour unit is especially high, due to the large proportion of the labour utilised on tillage farms being supplied by hired labour (via the use of external contractors).

Figure 8-3: Productivity of Labour: Tillage Farms



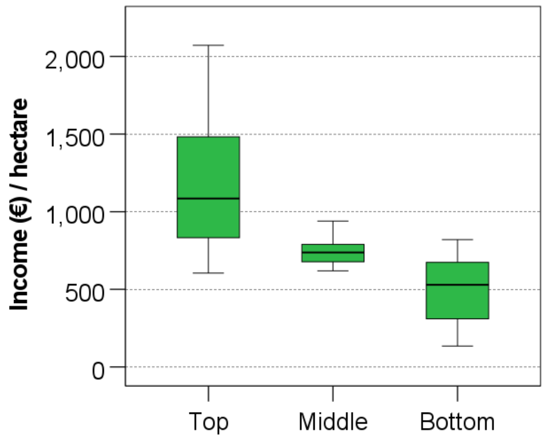
In 2021, tillage farms generated 79% of their output value from the market on average. Figure 8-4 shows that the top third of tillage farms derived 83% of farm output from the market compared to 74% for the bottom group on average.

Figure 8-4: Market Orientation: Tillage Farms



The average family farm income per hectare on tillage farms was €839 in 2021. Median income ranged from €1,255 from the top performing cohort to €529 for the bottom performers economically. Figure 8-5 shows significant ranges in income per hectare across the three groups.

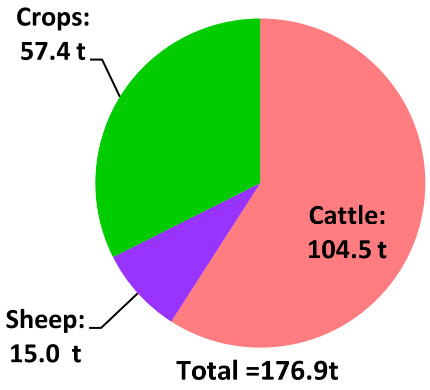
Figure 8-5: Family Farm Income per hectare: Tillage Farms



Environmental Sustainability Indicators

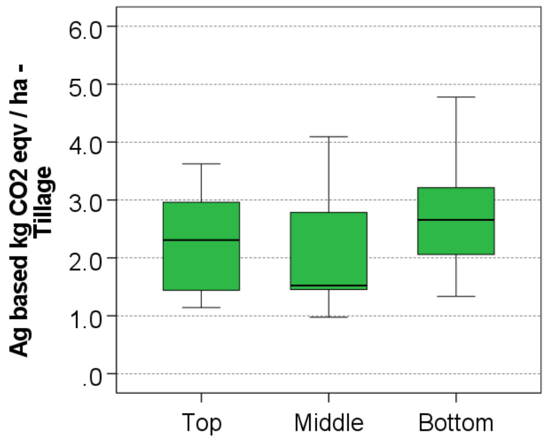
The average tillage farm produced 176.9 tonnes CO_2 equivalent of agricultural GHG emissions in 2021 as illustrated in Figure 8-6. However, only 32.4% of GHG emissions were generated from crop production. Despite being specialised in crop production, 59% of tillage farm emissions were from cattle present on these farms, with a further 8.5% from sheep.

Figure 8-6: Agricultural GHG Emissions for the average Tillage Farm



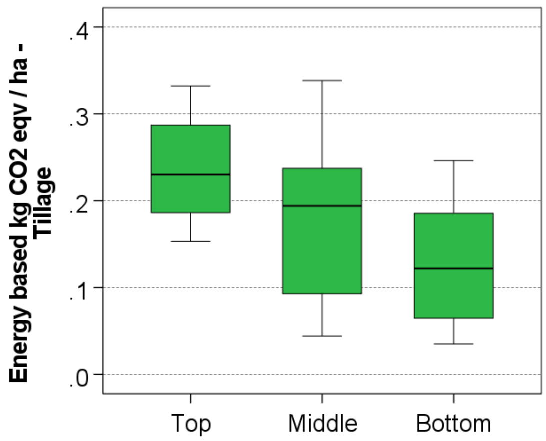
The average specialist tillage farm produced 2.5 tonnes of agricultural based CO_2 equivalent per hectare in 2021. Higher emissions per hectare was very variable across all the 3 cohorts as illustrated by Figure 8-7.

Figure 8-7: Agricultural GHG Emissions per hectare: Tillage Farms



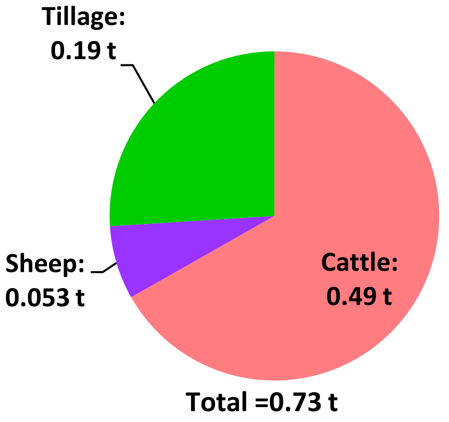
Specialist tillage farms on average produced 0.22 tonnes of energy based GHG emissions per hectare in 2021. Higher emissions per hectare were associated with higher economic performance as illustrated in Figure 8-8.

Figure 8-8: Energy GHG Emissions per hectare: Tillage Farms



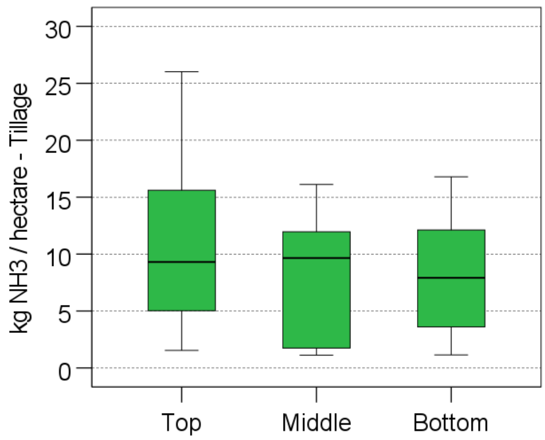
Tillage farms on average emitted 0.73 tonnes of NH_3 in 2021. Again, even though the main farm output on such farms is crop related, the bulk of NH_3 emissions are associated with cattle rearing, at 67%. Of the remaining emissions, 26% were associated with tillage production and 7.2% with a sheep enterprise.

Figure 8-9: Total Ammonia Emissions for the average Tillage Farm



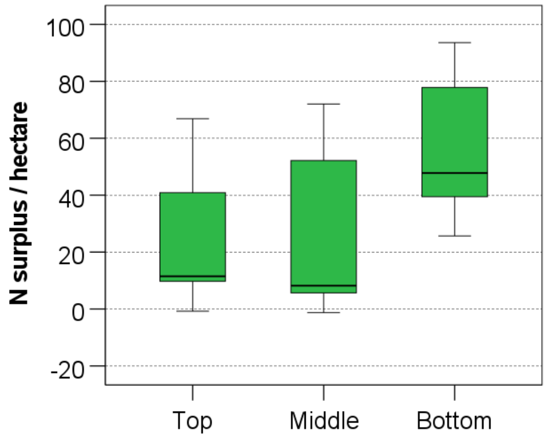
The average specialist tillage farm emitted 9.8 kg of NH_3 per hectare in 2021. Again, higher emissions per hectare were associated with higher economic performance. Economic performance tends to be positively associated with the level of farm production intensity.

Figure 8-10: Total Ammonia Emissions per hectare: Tillage Farms



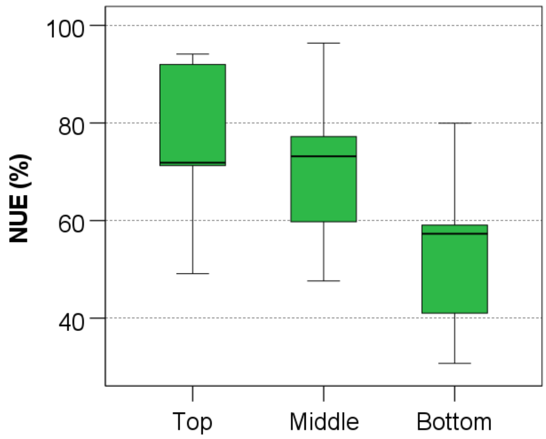
The average N surplus was 39.4 kg per hectare, but there was a large range in the farm results. Figure 8-11 shows higher N surpluses were aligned with higher economic performance.

Figure 8-11: N Balance per hectare: Tillage Farms



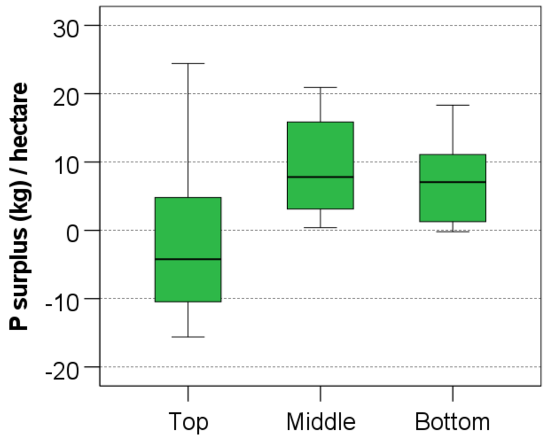
Across all tillage farms, the average NUE was 65.9%. There was a large distribution in NUE across the three groups as illustrated in Figure 8-12.

Figure 8-12: N Use Efficiency: Tillage Farms



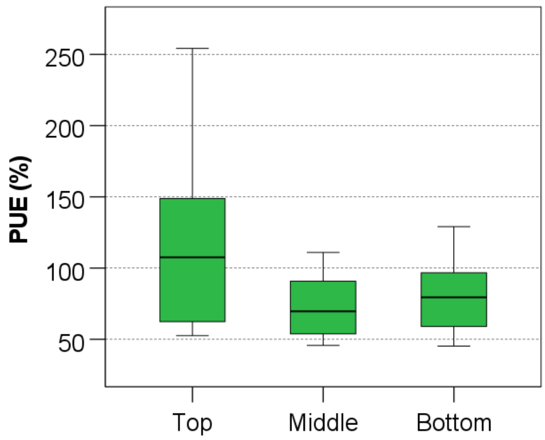
The average P balance across all tillage farms was 6.5 kg per hectare. However, as illustrated in Figure 8-13, there was again a large range of results around these group averages. Better farms, in economic terms, tended to have slightly lower P balances.

Figure 8-13: P Balance per hectare: Tillage Farms



PUE averaged 84.8% across all tillage farms. PUE tended to be higher across the top performing group, compared to the middle and bottom cohorts, as illustrated by Figure 8-14.

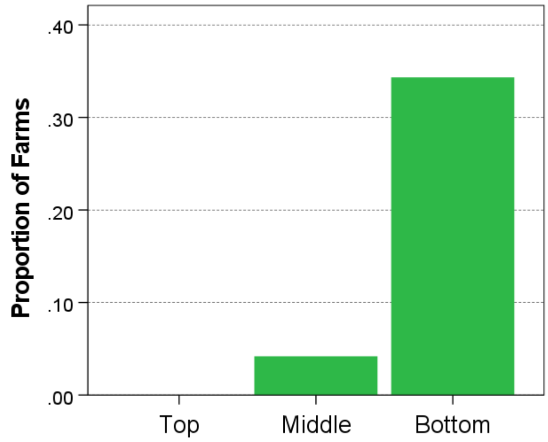
Figure 8-14: P Use Efficiency: Tillage Farms



Social Sustainability Indicators

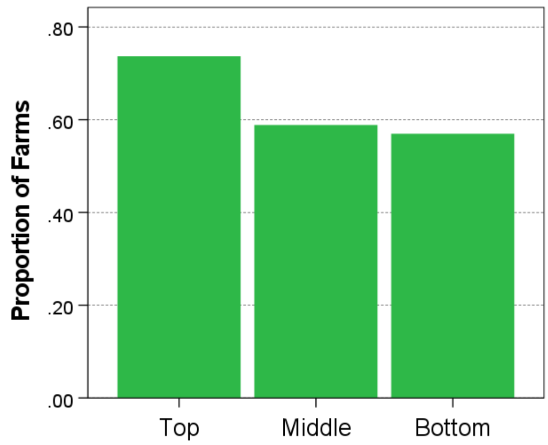
On average, 13% of tillage farm households are considered economically vulnerable. Figure 8-15 indicates that household vulnerability was highest across the bottom cohort, at 34%.

Figure 8-15: Household Vulnerability: Tillage



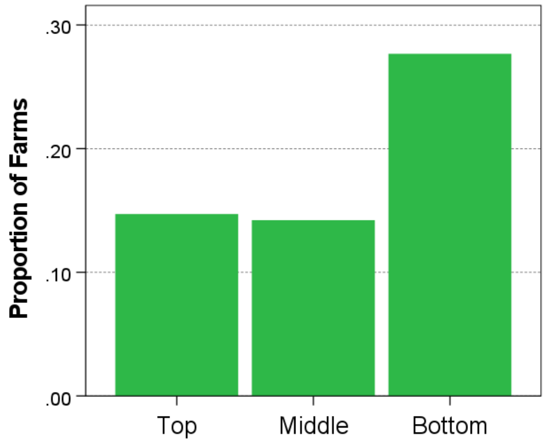
A total of 63% of tillage farmers had received some level of agricultural education or training. Figure 8-16 shows that this rate was higher for the better performing tillage farms economically.

Figure 8-16: Agricultural Education: Tillage Farms



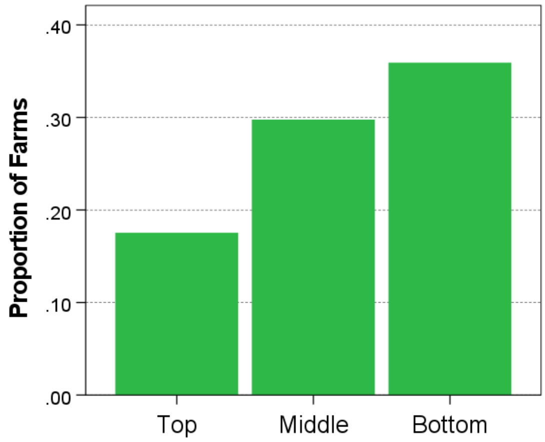
Overall, 19% of tillage farms were identified as being at risk of isolation (i.e. where the farm operator lived alone). At 28%, this rate was highest for the bottom performing cohort, as illustrated by Figure 8-17.

Figure 8-17: Isolation Risk: Tillage Farms



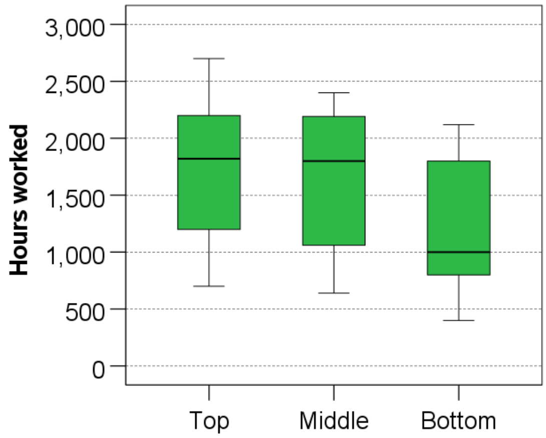
An average of 28% of tillage farms were identified as having a high age profile. Figure 8-18 shows that over 35% of farm households in the bottom group had a high age profile.

Figure 8-18: High Age Profile: Tillage Farms



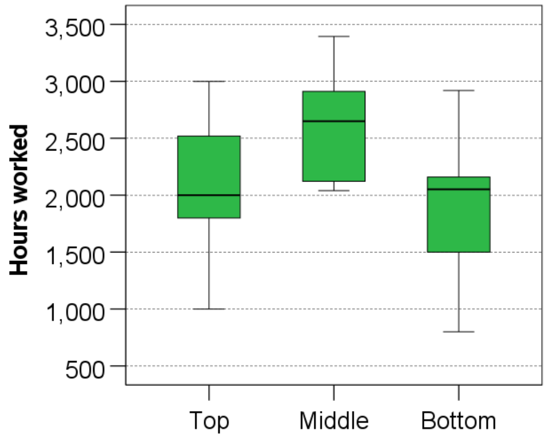
The average tillage farmer worked 1,519 hours on farm in 2021 (29.2 hours per week). However, Figure 8-19 shows that the average was lower for the bottom third of farms, ranked by gross margin per hectare. Teagasc NFS data show that the bottom cohort tend to hire more contractors to do field work, hence reducing the farm operator's own time contribution.

Figure 8-19: Hours Worked on Farm: Tillage Farms



On average, tillage farmers worked 2,215 hours per year between on and off-farm work in 2021 (approximately 42.6 hours per week). Figure 8-20 shows that total hours worked tended to be higher across the middle cohort by economic performance.

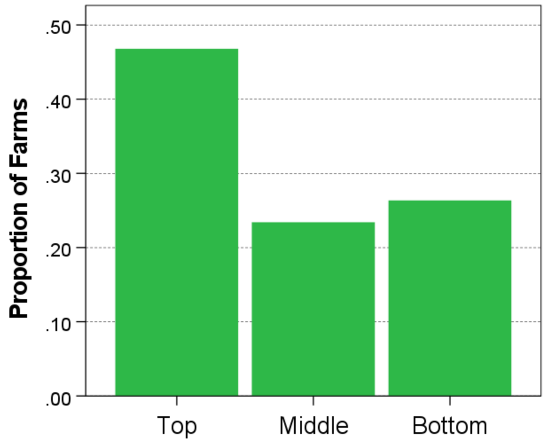
Figure 8-20: Total Hours Worked: Tillage Farm Operator



Tillage Innovation Indicators

The innovation indicators examined for tillage farms were: liming rates, membership of a discussion group and growing of a break crop. Figure 8-21 shows that liming rates were higher for the top performing cohorts (46%) compared to the middle (23%) and bottom (26%) performing cohort.

Figure 8-21: Liming: Tillage Farms



On average between 27% of tillage farms were in discussion groups. This ranged from 15% for the middle group to 45% for top performing cohort. However, this includes all types of discussion groups (e.g. beef and sheep).

Figure 8-22: Discussion Group: Tillage Farms

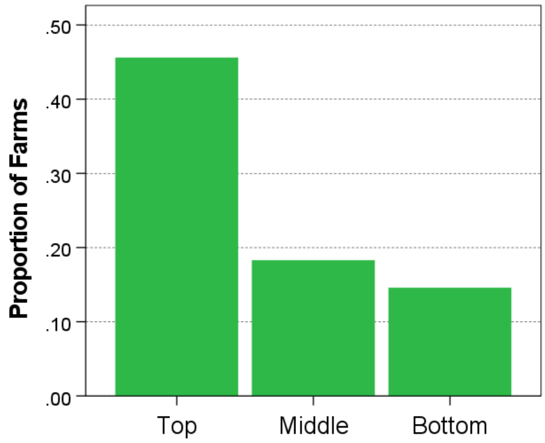
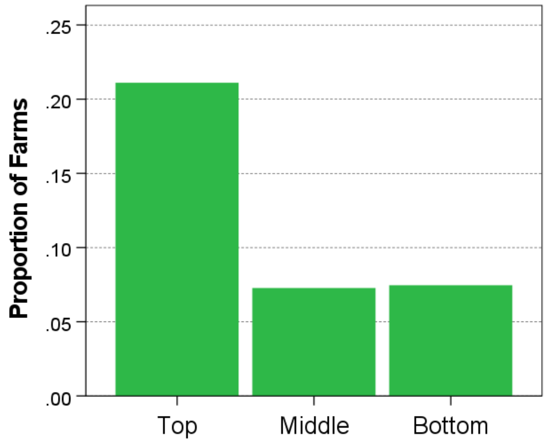


Figure 8-23 shows that 21% of the top performing cohorts grew a break crop compared to 7-8% for the middle and bottom groups.

Figure 8-23: Break Crops: Tillage



9 Farm System Comparisons 2021

Economic Indicators

A comparison of economic sustainability indicators across different farm types is shown in Figure 9-1. 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.

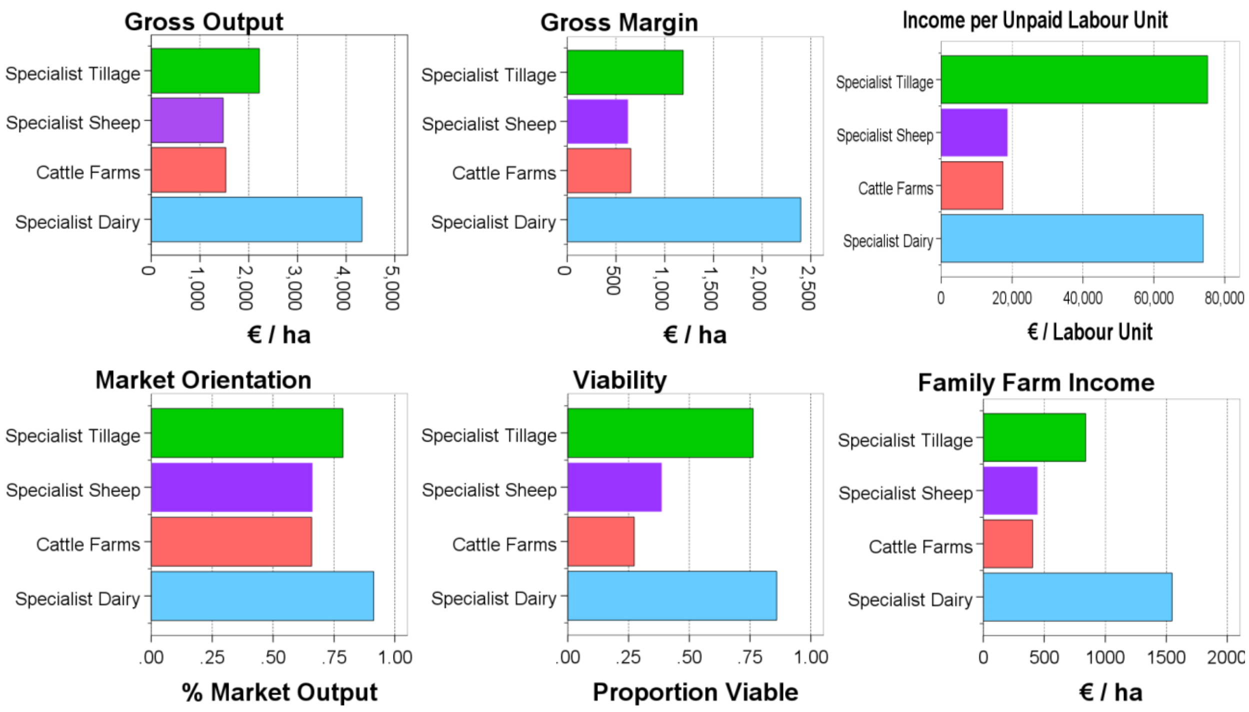
Output, Margins and Income: Tillage farms were ahead of both cattle and sheep farms (whose performance were relatively similar) in terms of gross output, gross margin and family farm income per hectare, but tillage farms were similar to dairy farms in terms of income per labour unit. Sheep and cattle farms, returned significantly lower income per labour unit in comparison to dairy farms and tillage farms in 2021.

Market Orientation: 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.

Viability: Cattle and sheep farms are most at risk financially, with 39% of sheep farms and 27% of cattle farms classed as economically viable. Dairy farms were the most economically viable (86%), followed by tillage systems (76%).

Caveat: It is important to note that these are average values for each farm type and that earlier analysis in this report 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 9-1: Economic Sustainability: Farm System Comparison 2021 (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 obtained by comparing within farm type variations (see previous section), but some shared environmental indicators across different farm types are presented in Figure 9-2.

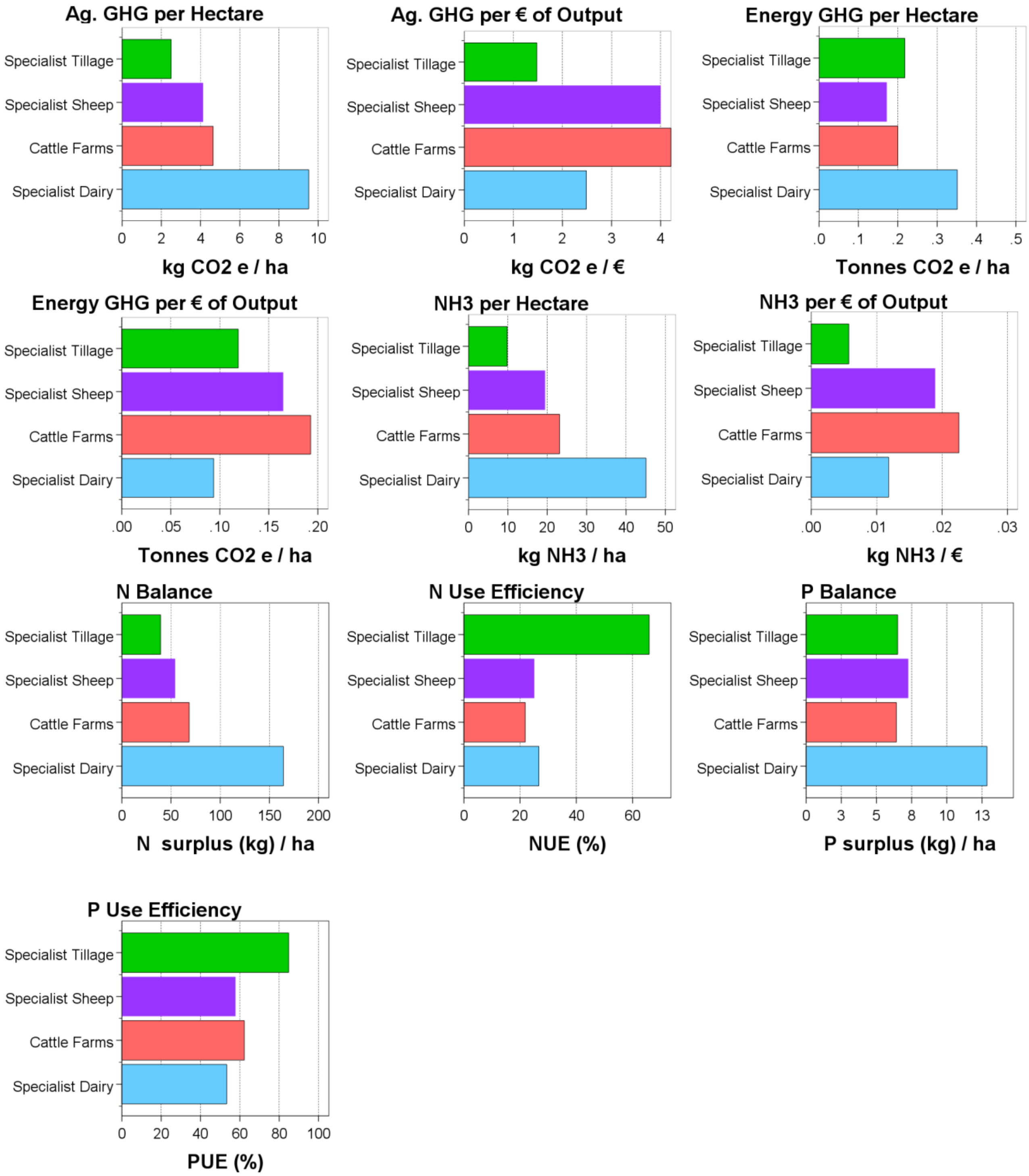
Greenhouse Gas Emissions: Animal based farming systems typically have higher greenhouse gas emissions per hectare than tillage systems, but this is to be expected due to the greater emissions associated with animal production as opposed to crops, especially in ruminant systems. Dairy farms show the highest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

Ammonia Emissions: 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) emissions per euro of market output generated, cattle farms exhibited the highest ammonia emissions intensity (due to the generally lower levels of output) followed by sheep farms. Tillage farms have the lowest level of ammonia emission per euro of output generated due to the low number of livestock on these farms on average.

N Surplus: Dairy farms have the largest N surplus per hectare due to the higher 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 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).

P Surplus: 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. PUE was highest on tillage farms, which was higher than that observed across all of the livestock systems.

Figure 9-2: Environmental Sustainability: Farm System Comparison 2021 (average per system)



Social Indicators

Comparison of the social sustainability indicators of different farm types (in Figure 9-3) shows a similar overall trend to the economic performance indicators shown in Figure 9-1, with dairy and tillage farms being distinct from cattle and sheep systems, with respect to their social sustainability performance, but with some notable exceptions.

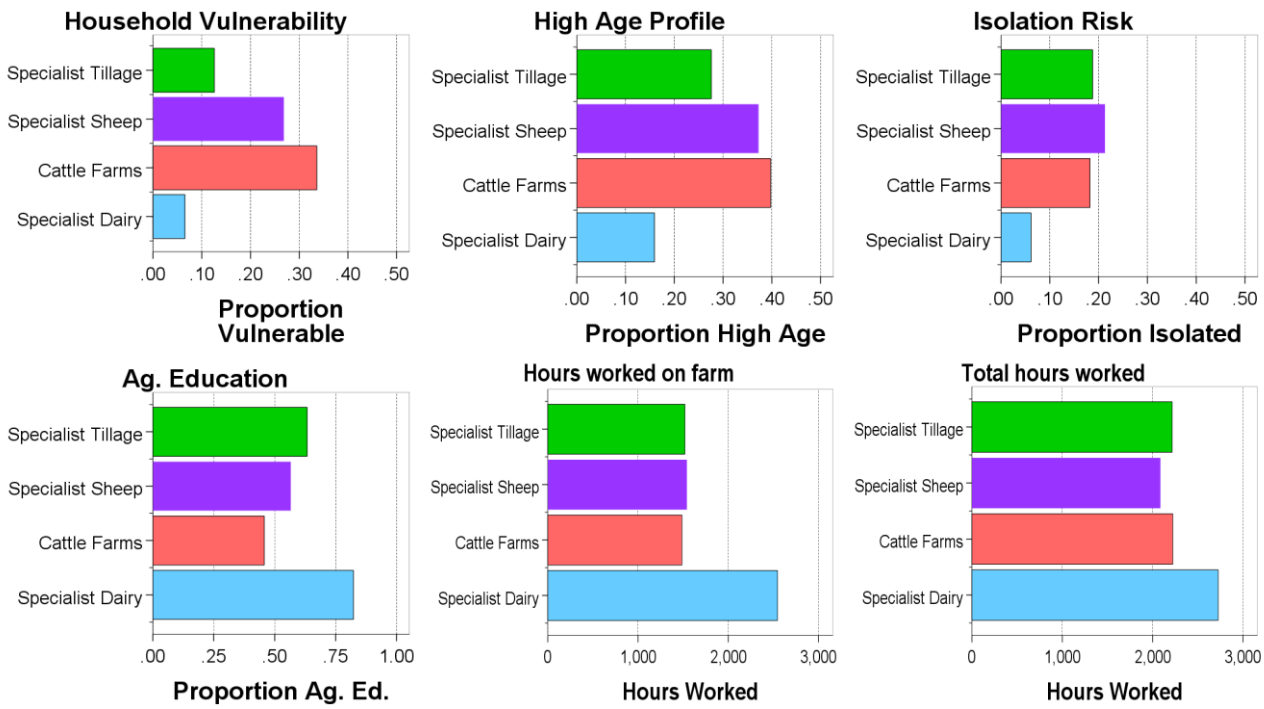
Hours Worked: The greater labour intensity of dairying is illustrated by the longer hours worked on farm. When accounting for total hours worked (on and off-farm employment), dairy farmers still have the highest number of hours worked on average, but the gap between dairy farms and other farm systems is reduced.

Household Vulnerability: Given that there were lower levels of economic viability across cattle and sheep farms (see Figure 9-1) these systems were also more likely to have a more vulnerable household structure (non-viable with no off-farm employment within the household).

High Age Profile: Cattle, sheep and then tillage 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 within these measures than for other social sustainability indicators.

Agricultural Education: On average, dairy farmers were more likely to have received agricultural education or training compared to other farm systems.

Figure 9-3: Social Sustainability: Farm System Comparison 2021 (average per system)



10 Time Series Comparisons with a three year rolling average: 2016-2021

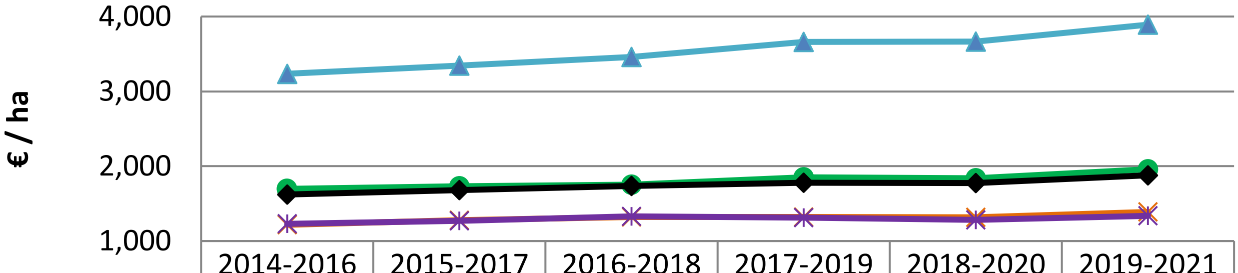
Building on research presented in previously published Teagasc Sustainability reports (Hennessy et al., 2013; Lynch et al., 2016, Buckley et al., 2019, Buckley & Donnellan, 2020a, Buckley & Donnellan, 2020b, Buckley & Donnellan, 2021), we can track the evolution of farm-level sustainability indicators 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 2016 is based on the average of the years 2014 to 2016 inclusive and is labelled as such). For reference, the **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 the control of an individual farmer** (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 data contain 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.

10.1 Economic sustainability indicators

Figure 10-1 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. Additionally over the period studied the rate of growth in output value per hectare on dairy farms was considerably higher than on all other farm types.

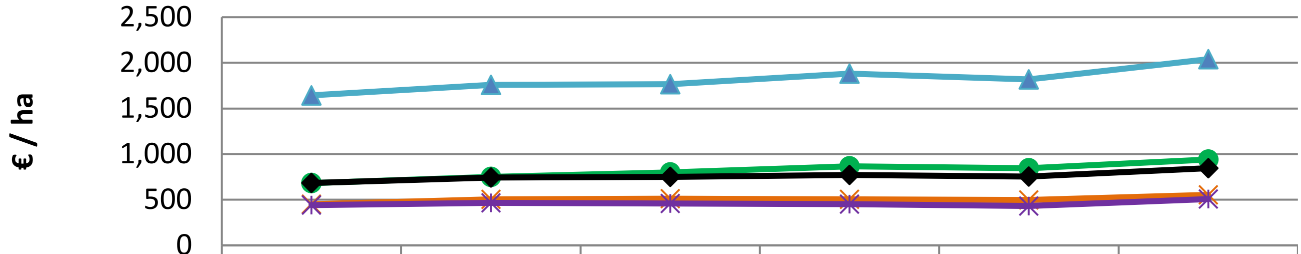
Figure 10-1: Economic Returns to Land: 3 year rolling average 2016-2021



	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021
Dairy	3,235	3,343	3,462	3,661	3,664	3,891
Cattle	1,217	1,280	1,322	1,321	1,316	1,389
Sheep	1,230	1,269	1,329	1,312	1,283	1,337
Tillage	1,698	1,731	1,754	1,852	1,838	1,959
All Farms	1,622	1,681	1,737	1,780	1,776	1,879

The profitability of land (gross margin per hectare) in dairying is again significantly higher than for all other systems and tends to increase over the years, significantly so at the end of the study period. Tillage farms again have the second highest gross margin per hectare. The lowest gross margins per hectare are on cattle and sheep farms, as illustrated in Figure 10-2.

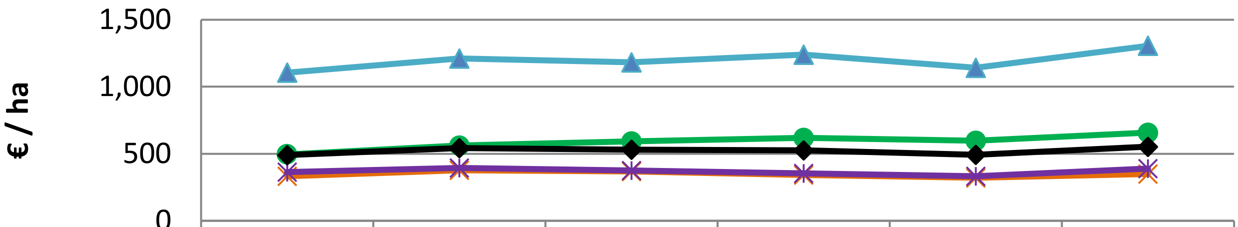
Figure 10-2: Profitability of Land: 3 year rolling average 2016-2021



	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021
Dairy	1,644	1,760	1,767	1,882	1,817	2,039
Cattle	451	504	512	506	497	553
Sheep	442	467	460	451	431	507
Tillage	682	749	797	867	845	940
All Farms	683	741	749	771	752	845

The ranking of systems based on Family Farm Income per hectare mirrors the ranking for profitability of land, with dairy incomes significantly higher than for all other systems. Similarly, Tillage farms are ranked second. The lowest family farm income per hectare are on by cattle and sheep farms, as illustrated by Figure 10-3.

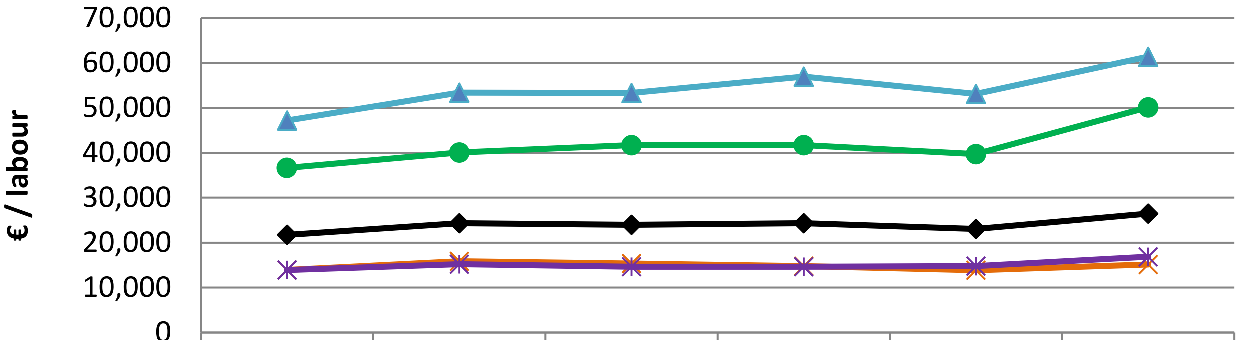
Figure 10-3: Family Farm income: 3 year rolling average 2016-2021



	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021
Dairy	1,105	1,212	1,182	1,239	1,143	1,306
Cattle	333	377	369	341	321	349
Sheep	363	394	375	354	332	389
Tillage	495	561	593	619	597	658
All Farms	490	543	532	525	493	553

Figure 10-4 illustrates farm income per unpaid labour unit broadly follow similar trends to the gross output, gross margin and family farm income per hectare indicators. However, the differences between farm types when income per labour unit is considered are not as pronounced as in the case of gross output, gross margin and family farm income. This is due to the adjustment made to reflect different labour intensities of each production system. Returns to labour are significantly higher on dairy and tillage farms, compared to cattle and sheep systems.

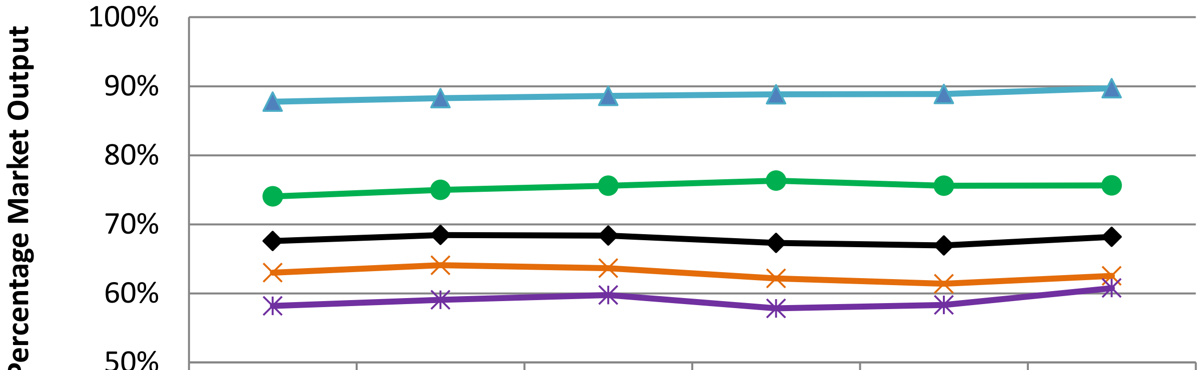
Figure 10-4: Productivity of Labour: 3 year rolling average 2016-2021



	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021
Dairy	47,189	53,426	53,300	56,961	53,082	61,401
Cattle	13,940	15,869	15,363	14,792	13,866	15,177
Sheep	13,917	15,228	14,642	14,614	14,757	16,878
Tillage	36,644	40,084	41,734	41,734	39,716	50,135
All Farms	21,734	24,331	23,992	24,330	23,024	26,468

Figure 10-5 illustrates that dairying is the most market orientated of all the systems (88 to 90%) followed by tillage systems (74 to 76%). The market orientation of cattle and sheep systems was the lowest at between 58% and 64%.

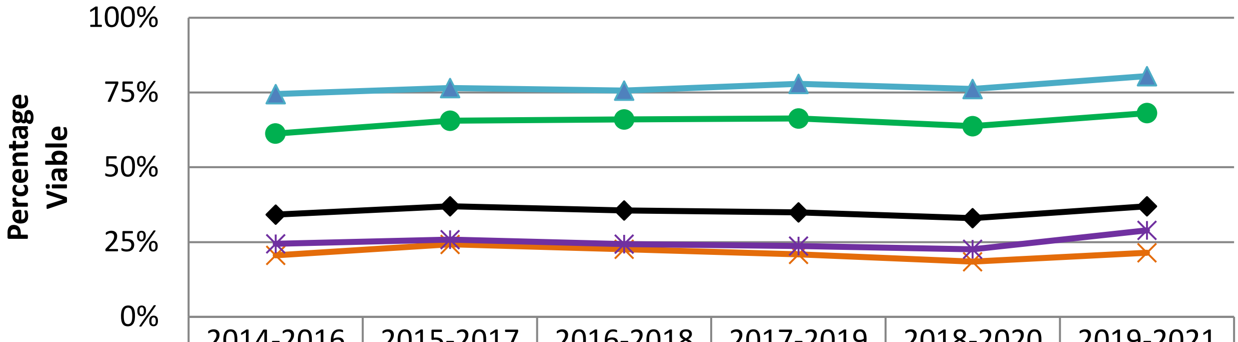
Figure 10-5: Percentage of Output Derived from Market: 3 year rolling average 2016-2021



	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021
Dairy	88%	88%	89%	89%	89%	90%
Cattle	63%	64%	64%	62%	61%	63%
Sheep	58%	59%	60%	58%	58%	61%
Tillage	74%	75%	76%	76%	76%	76%
All Farm	68%	68%	68%	67%	67%	68%

The same trends over time are also observed in terms of farm economic viability. Dairy and tillage systems have significantly higher levels of viability compared to cattle or sheep farms over the period examined. Viability, as with the other economic indicators, is effected by variations in sectoral output prices over the period examined.

Figure 10-6: Economic Viability: 3 year rolling average 2016-2021

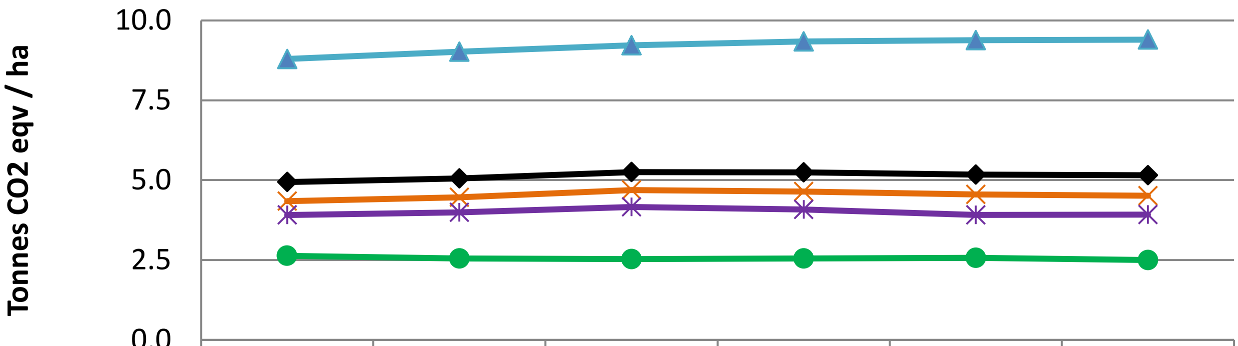


	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021
Dairy	74%	76%	76%	78%	76%	81%
Cattle	21%	24%	23%	21%	18%	21%
Sheep	24%	26%	24%	24%	23%	29%
Tillage	61%	66%	66%	66%	64%	68%
All Farm	34%	37%	36%	35%	33%	37%

10.2 Environmental sustainability indicators

Figure 10-7 shows that the overall farm average agricultural GHG emissions per hectare have been increasing over the study period (4.9 to 5.2 tonnes CO_2 equivalent per hectare). Due to the more intensive nature of production in dairy systems compared to all other grassland systems, agricultural GHG emissions per hectare on dairy farms are 2-4 times higher compared to other farm systems. The main trends observed are an increase in dairy emissions per hectare and the relative stability in emission intensity per hectare across the other systems. The increase in dairy GHG emissions is the driver for the increase in the overall average GHG emissions per hectare.

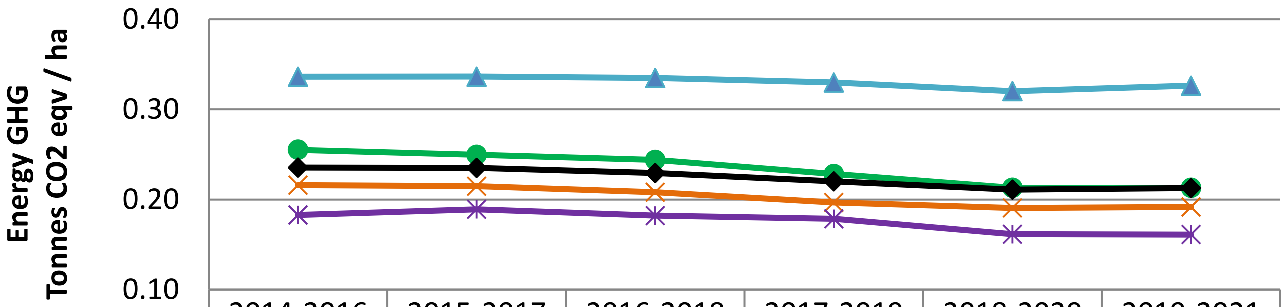
Figure 10-7: Ag. Greenhouse Gas Emissions per hectare: 3 year rolling average 2016-2021



	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021
Dairy	8.8	9.0	9.2	9.3	9.4	9.4
Cattle	4.3	4.5	4.7	4.6	4.6	4.5
Sheep	3.9	4.0	4.2	4.1	3.9	3.9
Tillage	2.6	2.5	2.5	2.6	2.6	2.5
All Farms	4.9	5.1	5.3	5.2	5.2	5.2

Figure 10-8 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.

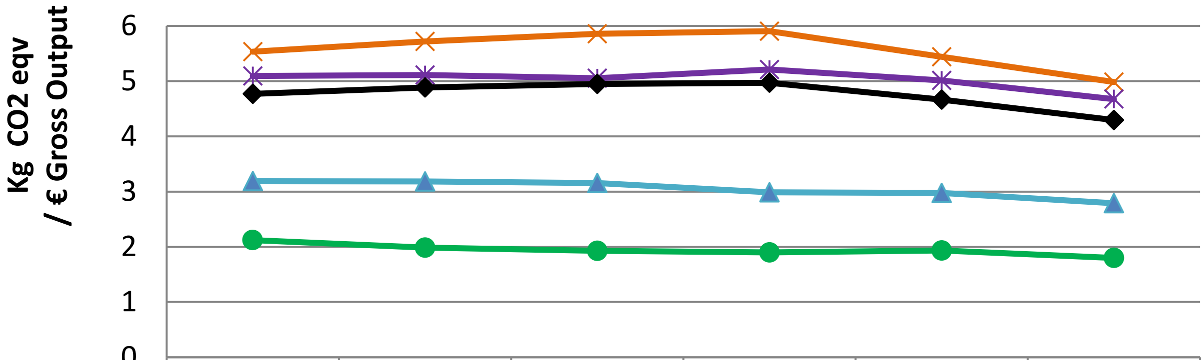
Figure 10-8: Energy Greenhouse Gas Emissions per hectare: 3 year rolling average 2016-2021



	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021
Dairy	0.34	0.34	0.33	0.33	0.32	0.33
Cattle	0.22	0.21	0.21	0.20	0.19	0.19
Sheep	0.18	0.19	0.18	0.18	0.16	0.16
Tillage	0.26	0.25	0.24	0.23	0.21	0.21
All Farms	0.24	0.24	0.23	0.22	0.21	0.21

Figure 10-9 illustrates that, over the study period, 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 value of output produced in dairying and the lower emissions associated with the limited presence of livestock in the tillage system. The increase in dairy emissions per hectare, shown in Figure 10-7, is not reflected in a similar evolution in the emissions per euro output indicator which has tended to fall, as illustrated in Figure 10-9.

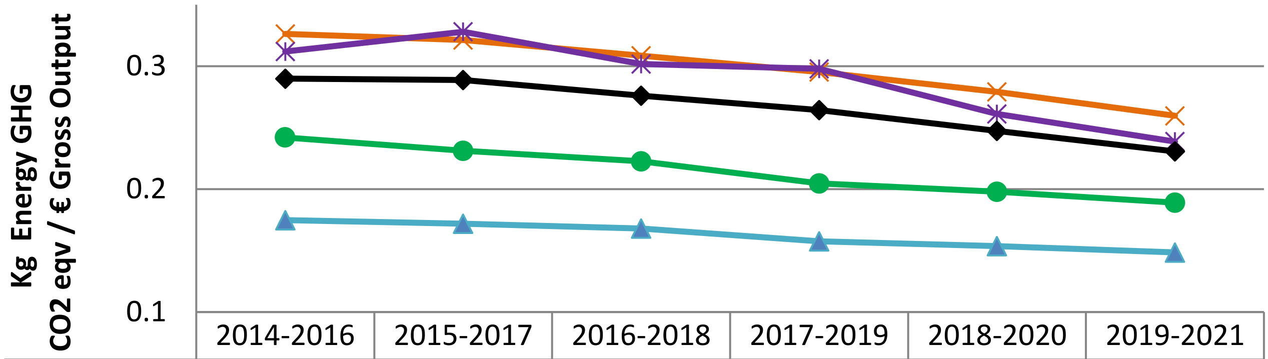
Figure 10-9: Ag. GHG Emissions per Euro output: 3 year rolling average 2016-2021



	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021
Dairy	3.2	3.2	3.2	3.0	3.0	2.8
Cattle	5.5	5.7	5.9	5.9	5.4	5.0
Sheep	5.1	5.1	5.1	5.2	5.0	4.7
Tillage	2.1	2.0	1.9	1.9	1.9	1.8
All Farms	4.8	4.9	5.0	5.0	4.7	4.3

Figure 10-10 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.

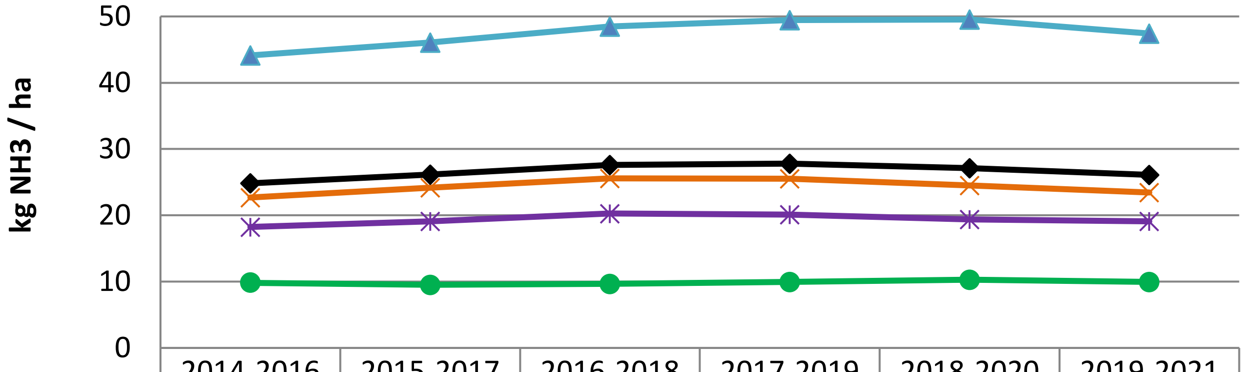
Figure 10-10: Energy related GHG Emissions per Euro output: 3 year rolling average 2016-2021



	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021
Dairy	0.12	0.12	0.12	0.11	0.10	0.10
Cattle	0.28	0.27	0.26	0.25	0.23	0.21
Sheep	0.26	0.28	0.25	0.25	0.21	0.19
Tillage	0.19	0.18	0.17	0.15	0.15	0.14
All Farms	0.24	0.24	0.23	0.21	0.20	0.18

Figure 10-11 illustrates that on a three year rolling average basis across all farms, ammonia (NH_3) emissions per hectare increased over the early part of the study period before levelling off and then decreased towards the end. 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.

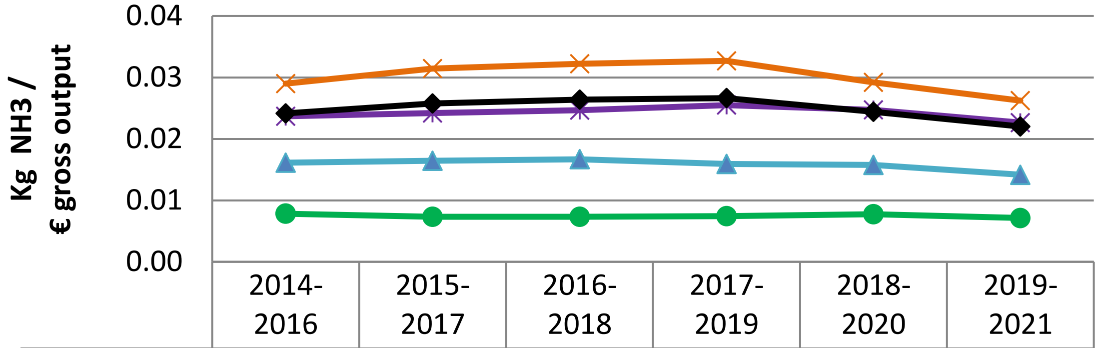
Figure 10-11: Kg of Ammonia Emissions per hectare: 3 year rolling average 2016-2021



	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021
Dairy	44.1	46.1	48.5	49.5	49.5	47.4
Cattle	22.7	24.2	25.6	25.5	24.5	23.5
Sheep	18.2	19.1	20.3	20.1	19.4	19.1
Tillage	9.8	9.5	9.7	9.9	10.3	10.0
All Farms	24.8	26.1	27.6	27.8	27.1	26.1

Figure 10-12 illustrates NH_3 emissions per euro of market based gross output. Results indicate that emissions per euro of output are higher on cattle and sheep farms compared to all other systems over the study period. This is a function of the low levels of output on these farms. Dairy had the second lower levels of NH_3 emissions per euro of output generated (due to high output value). Tillage farms had the lowest emissions per euro of market based output.

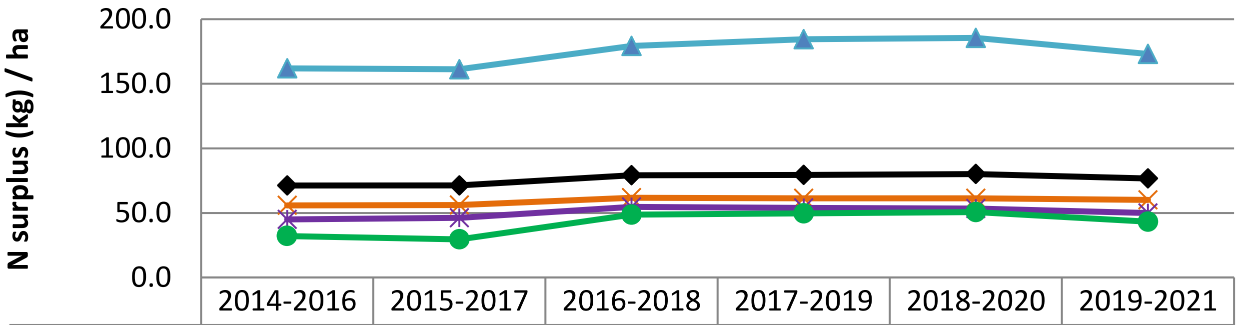
Figure 10-12: Ammonia (NH_3) Emissions per Euro Output: 3 year rolling average 2016-2021



	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021
Dairy	0.02	0.02	0.02	0.02	0.02	0.01
Cattle	0.03	0.03	0.03	0.03	0.03	0.03
Sheep	0.02	0.02	0.02	0.03	0.02	0.02
Tillage	0.01	0.01	0.01	0.01	0.01	0.01
All Farms	0.02	0.03	0.03	0.03	0.02	0.02

Across all farm systems, the N balance per hectare was higher at the end versus the start of the period examined. Again, due to the more intensive nature of production, N surpluses are significantly higher for dairy farms compared to all other systems. Due to the non-livestock orientated nature of production on tillage farms, N surpluses are, on average, lowest across these farms over the period examined. 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 10-13: Nitrogen Balance per ha: 3 year rolling average 2016-2021

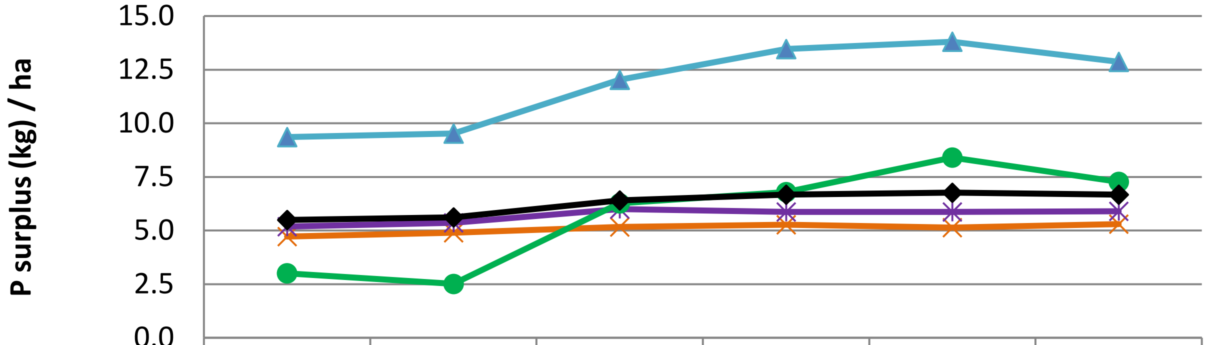


	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021
Dairy	161.8	161.2	179.4	184.4	185.5	173.1
Cattle	55.8	56.1	61.7	61.3	61.3	60.0
Sheep	44.9	46.2	54.6	53.9	53.4	49.8
Tillage	32.1	29.5	48.5	49.7	50.6	43.1
All Farms	71.3	71.3	79.0	79.5	80.1	76.5

Figure 10-14 illustrates that P balances have tended to increase over the study period. P surpluses are significantly higher on dairy farms compared to all other systems. It should also be noted that farm gate P balances must be interpreted with care, since establishing the optimal balance requires a soil test.

Farmers are allowed to run significant farm gate surpluses, if soil P status is sub optimal (deficient). In 2021, Teagasc analysed a total 33,876 soil samples comprising of dairy, drystock and tillage farm enterprises (Teagasc, 2022). Results indicate that 54% of samples taken are P deficient (at either index 1 or 2 for phosphorus).

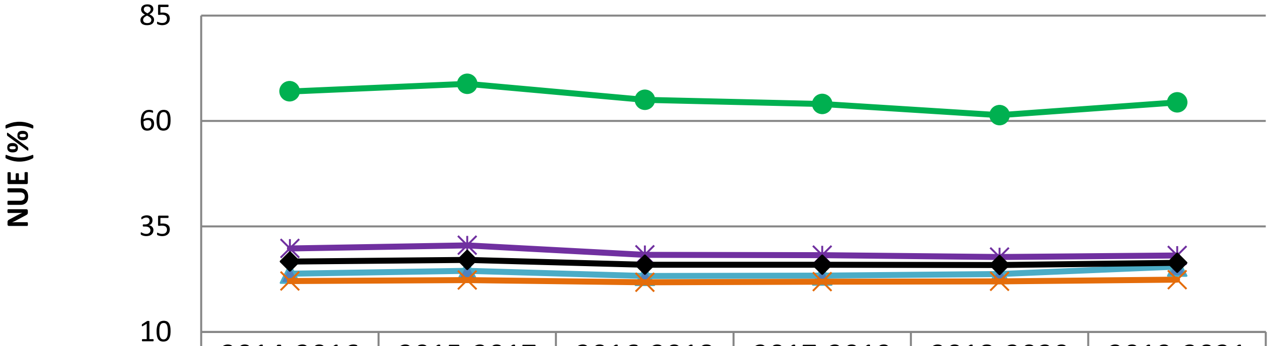
Figure 10-14: Phosphorus (P) Balance per ha: 3 year rolling average 2016-2021



	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021
Dairy	9.4	9.5	12.0	13.5	13.8	12.9
Cattle	4.7	4.9	5.2	5.3	5.1	5.3
Sheep	5.2	5.4	6.0	5.9	5.9	5.9
Tillage	3.0	2.5	6.3	6.8	8.4	7.3
All Farms	5.5	5.6	6.4	6.7	6.8	6.7

Figure 10-15 illustrates that dairy and cattle farms tended to have the lowest NUE over the study period. Tillage system NUE was generally significantly higher than all other systems due to the mainly non-livestock nature of this system.

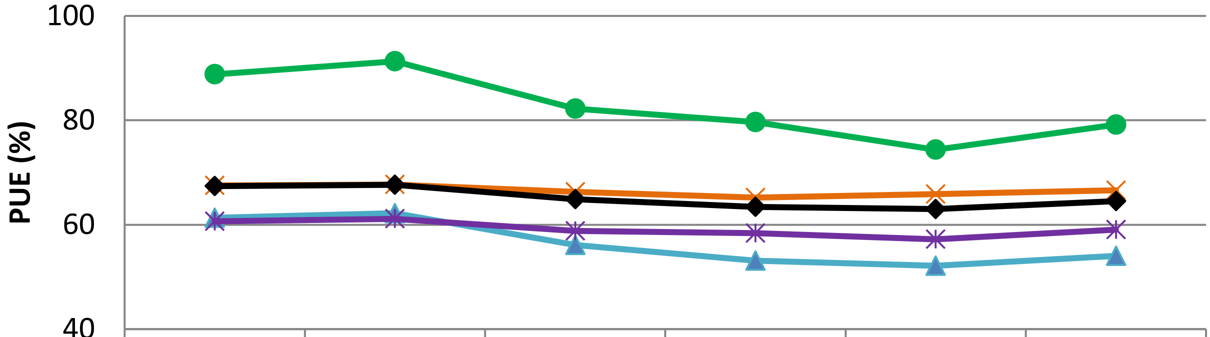
Figure 10-15: Nitrogen Use Efficiency: 3 year rolling average 2016-2021



	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021
Dairy	23.8	24.5	23.3	23.3	23.7	25.5
Cattle	22.1	22.3	21.8	21.9	22.0	22.4
Sheep	29.8	30.5	28.3	28.2	27.8	28.1
Tillage	67.0	68.8	65.0	64.0	61.4	64.4
All Farms	26.7	27.1	26.0	25.9	25.9	26.4

Figure 10-16 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 analysed, for dairy and tillage, while it has increased for cattle systems. 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 PUE measures must be interpreted with care, since establishing true PUE requires a soil test.

Figure 10-16: Phosphorus Use Efficiency: 3 year rolling average 2016-2021

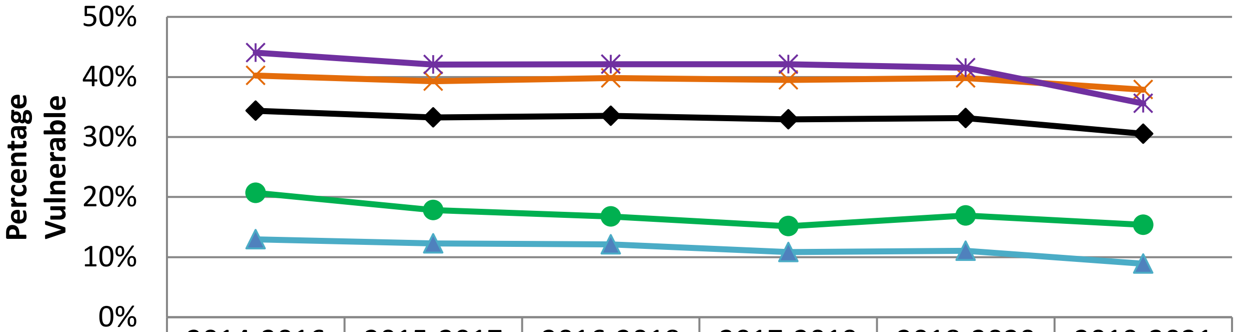


	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021
Dairy	61.3	62.2	56.1	53.1	52.1	54.0
Cattle	67.5	67.7	66.3	65.2	65.9	66.6
Sheep	60.7	61.1	58.8	58.4	57.2	59.1
Tillage	88.8	91.3	82.2	79.7	74.4	79.2
All Farms	67.4	67.7	64.9	63.4	63.0	64.5

10.3 Social Sustainability Indicators

Figure 10-17 shows that on a three-year rolling average basis the rate of vulnerability (non-viable farm business and no off-farm employment) of all farming households has remained stable over the 2016-2021 period across all systems at between 31% and 34%. Dairying and tillage systems tend to have significantly lower levels of household vulnerability than cattle and sheep systems.

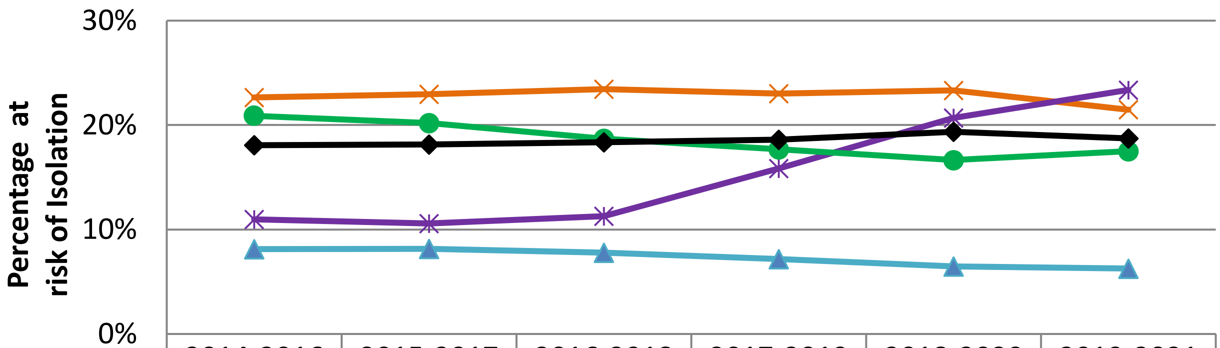
Figure 10-17: Farm Household Vulnerability: 3 year rolling average 2016-2021



	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021
Dairy	13%	12%	12%	11%	11%	9%
Cattle	40%	39%	40%	40%	40%	38%
Sheep	44%	42%	42%	42%	42%	36%
Tillage	21%	18%	17%	15%	17%	15%
All Farms	34%	33%	34%	33%	33%	31%

Figure 10-18 shows that on a three-year rolling average basis the percentage of farmers at risk of isolation was relatively static from the start to the end of the study period across all systems (except for sheep). However, overall isolation risk tends to be higher on non-dairy farms.

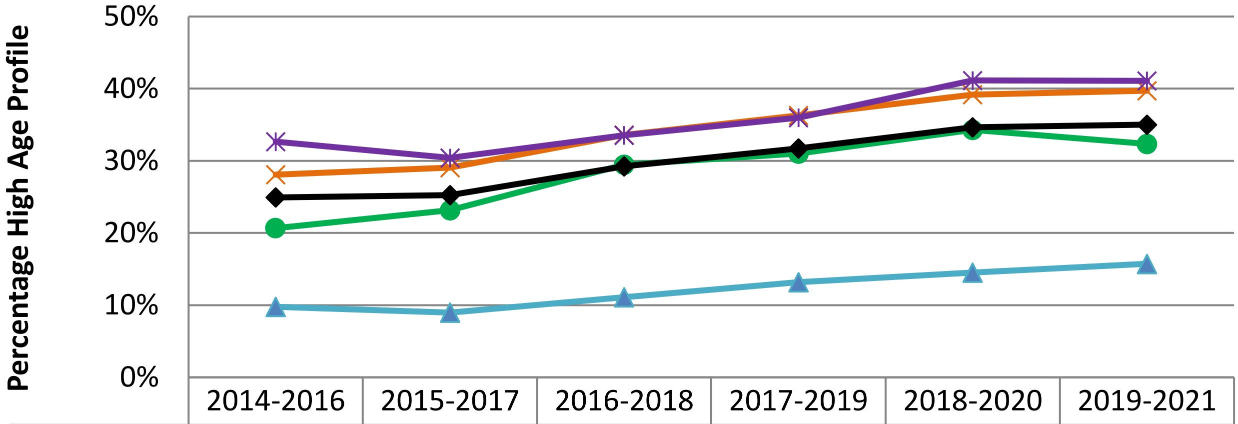
Figure 10-18: Isolation Risk: 3 year rolling average 2016-2021 (average per system)



	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021
Dairy	8%	8%	8%	7%	6%	6%
Cattle	23%	23%	23%	23%	23%	21%
Sheep	11%	11%	11%	16%	21%	23%
Tillage	21%	20%	19%	18%	17%	17%
All Farms	18%	18%	18%	19%	19%	19%

Figure 10-19 shows that on a three year rolling average basis the percentage of all farms with a high age profile has increased between the start and end of the study period (25% to 35%). Dairy farms tend to have the lowest age profile across all the farm systems compared to other systems (15-16% towards the end of the study period) which tend to be double or treble this rate.

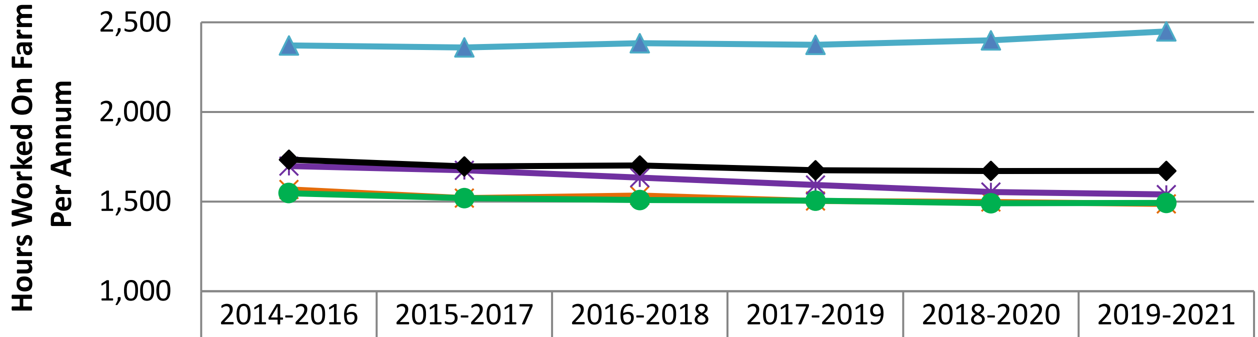
Figure 10-19: High Age Profile: 3 year rolling average 2016-2021 (average per system)



	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021
Dairy	10%	9%	11%	13%	15%	16%
Cattle	28%	29%	34%	36%	39%	40%
Sheep	33%	30%	34%	36%	41%	41%
Tillage	21%	23%	29%	31%	34%	32%
All Farm	25%	25%	29%	32%	35%	35%

Figure 10-20 shows that the hours worked on-farm per annum has declined slightly across all farms systems except dairying between 2016 and 2021. Hours worked on farm per annum is significantly higher on dairy farms, compared to all other farm systems.

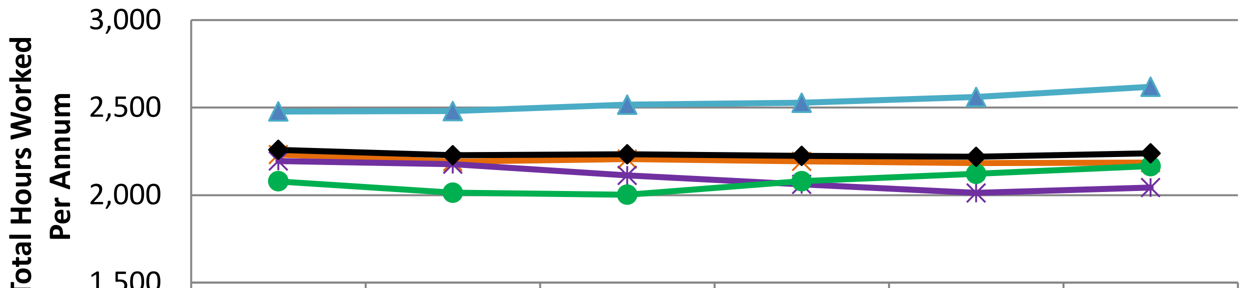
Figure 10-20: Hours Worked On Farm Per Annum: 3 year rolling average 2016-2021 (average per system)



	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021
Dairy	2,371	2,360	2,383	2,374	2,400	2,449
Cattle	1,568	1,519	1,534	1,503	1,498	1,487
Sheep	1,698	1,674	1,634	1,593	1,553	1,540
Tillage	1,546	1,519	1,509	1,505	1,491	1,493
All Farms	1,734	1,696	1,702	1,675	1,671	1,672

Figure 10-21 illustrates the total hours worked by the farm operator (including on and off farm employment) by farm systems. Results indicate that longer overall hours are worked by dairy farmers and that the number of hours worked has increased over time. The opposite trend is observed for livestock farmers (fewer hours worked over time) with the number of hours worked by farmers on tillage farms increased slightly over the study period.

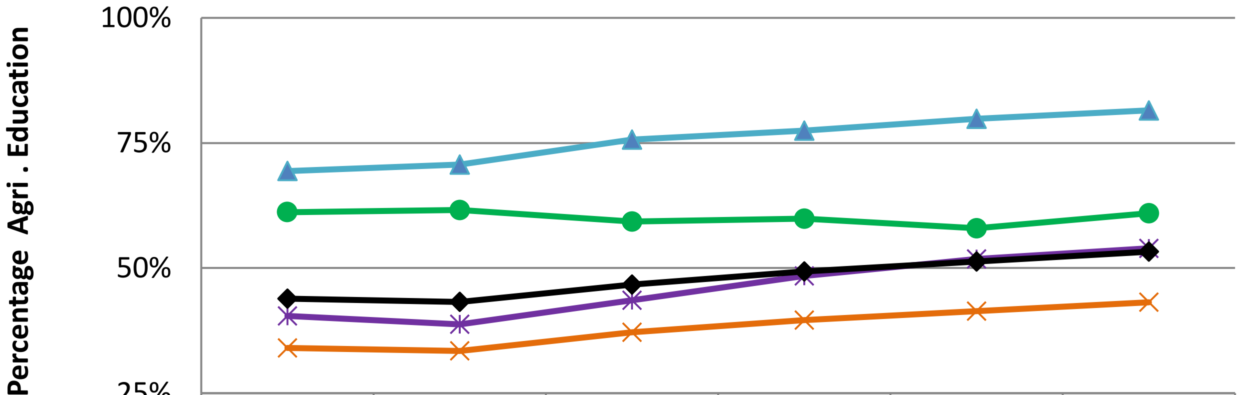
Figure 10-21: Total Hours Worked Per Annum: 3 year rolling average 2016-2021 (average per system)



	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021
Dairy	2,477	2,481	2,517	2,528	2,561	2,619
Cattle	2,232	2,192	2,207	2,193	2,183	2,185
Sheep	2,194	2,177	2,113	2,061	2,013	2,043
Tillage	2,078	2,013	2,002	2,079	2,121	2,166
All Farms	2,258	2,228	2,232	2,223	2,219	2,239

Figure 10-22 indicates that the percentage of all famers who have received some form of agricultural education has increased over the period 2016-2021 from 44% to 53%. Significantly, higher levels of formal agricultural education are observed for dairy farmers.

Figure 10-22: Formal Agricultural Education: 3 year rolling average 2016-2021 (average per system)



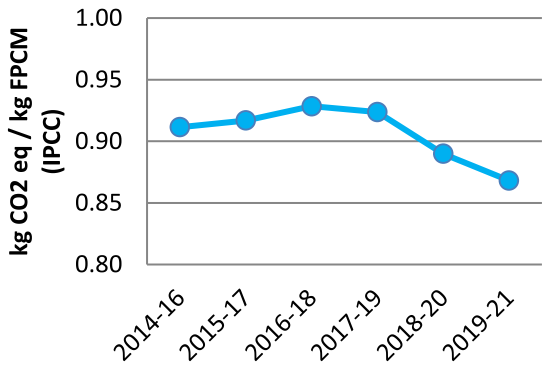
	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021
Dairy	69%	71%	76%	77%	80%	82%
Cattle	34%	33%	37%	40%	41%	43%
Sheep	40%	39%	44%	48%	52%	54%
Tillage	61%	62%	59%	60%	58%	61%
All Farms	44%	43%	47%	49%	51%	53%

10.4 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 2014-2014 results are the average of 2014, 2015 and 2016 results). Results for individual years are reported in the appendices for each farm system.

Results presented in Figure 10-23 show that, the kg of CO_2 equivalent per kg of FPCM (IPCC based) has generally followed a declining trend since the middle of the period analysed.

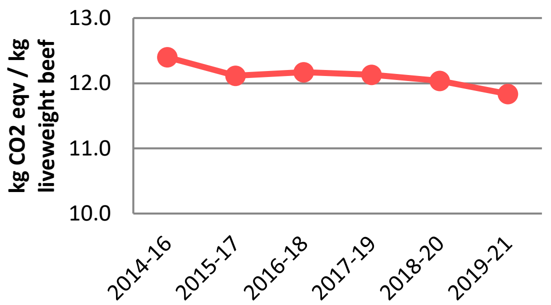
Figure 10-23: Ag. GHG Emissions per kg FPCM: 2016-2021 Dairy Farms



Note: (IPCC approach) 3 year rolling average

Figure 10-24 indicates that kg of CO_2 equivalent per kg of live-weight beef produced on cattle farms also tended to follow a declining trend towards the end of the period analysed.

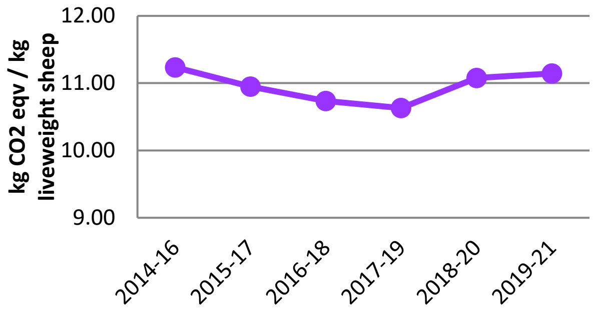
Figure 10-24: Ag. GHG Emissions per kg live-weight beef produced: 2016-2021 (Cattle Farms)



Note: (IPCC approach) 3 year rolling average

Figure 10-25 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, with an increase thereafter towards the level of earlier years.

Figure 10-25: Ag. GHG Emissions per kg live-weight sheep produced: 2016-2021 Sheep Farms

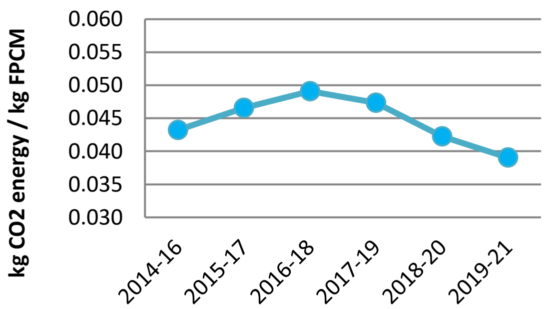


Note: (IPCC approach) 3 year rolling average

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 10-26 indicate a gradual decline in energy based GHG emissions associated with milk production towards the end of the study period, following a spike in the middle of the study period.

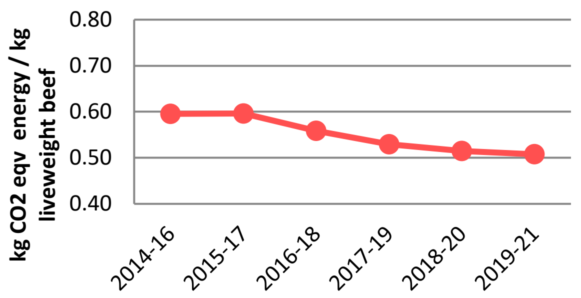
Figure 10-26: Energy use related GHG emissions per kg FPCM: 2016-2021 Dairy Farms



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 10-27.

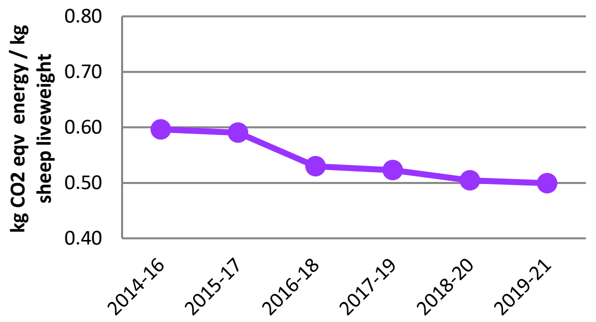
Figure 10-27: Energy use related GHG emissions per kg live-weight beef produced: 2016-2021 Cattle Farms



Note: (IPCC approach) 3 year rolling average

Energy related GHG emissions from the production of live-weight sheep tended to follow a declining trends over the course of the study period as illustrated in Figure 10-28.

Figure 10-28: Energy use related GHG emissions per kg live-weight sheep produced: 2016-2021 Sheep Farms

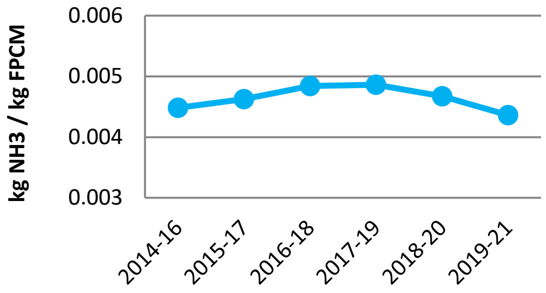


Note: (IPCC approach) 3 year rolling average

On a three year rolling average basis, the NH_3 emissions intensity of milk production tended to be relatively stable over the study period, outlined in .

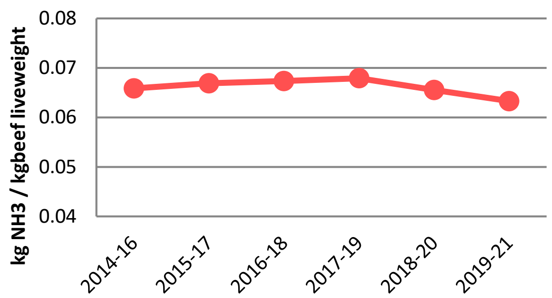
Figure 10-29.

Figure 10-29: Ammonia emissions per kg FPCM: 2016-2021 3 year rolling average Dairy Farms



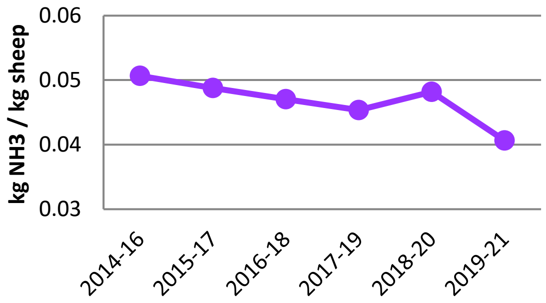
On a three year rolling average basis, NH_3 emissions per kg of live-weight beef produced on cattle farms were relatively stable over the period presented, as shown in Figure 10-30.

Figure 10-30: Ammonia emissions per kg live-weight beef produced: 2016-2021 Cattle Farms



The NH_3 emissions per kg of live-weight sheep meat produced on sheep farms was seen to decline towards the end of the study period, as illustrated in Figure 10-31.

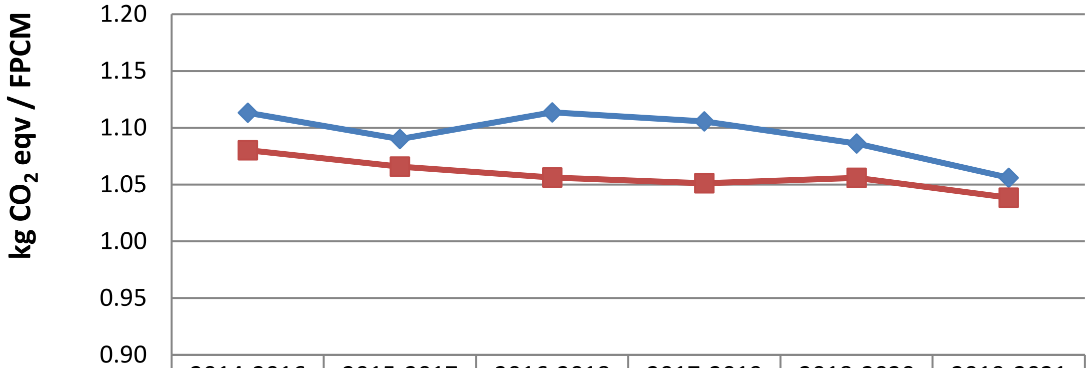
Figure 10-31: Ammonia emissions per kg live-weight sheep produced: 2016-2021 Sheep Farms



11 National Cross Validation of Carbon Footprint of Milk Production

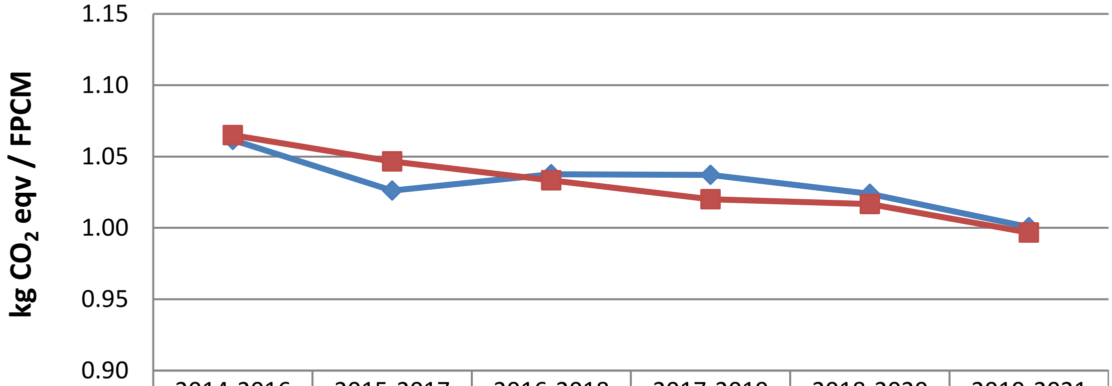
Using the broader LCA approach (including agricultural and energy based emissions) the Teagasc NFS data have been used in conjunction with the Teagasc LCA model (O'Brien et al., 2014; Herron et al., 2021) to produce an LCA based carbon footprint of milk indicator. Results from this LCA approach indicate that, except for a spike mid study period, the carbon footprint of Irish milk production (CO_2 equivalent per kg of FPCM produced) declined between 2016 and 2021 on a rolling three year average basis, both on a weighted farm and national aggregate basis (results weighted by milk supply). This mid-study period spike can be largely attributed to adverse weather experienced in 2018. 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, 2022) as outlined below.

Figure 11-1: GHG per kg FPCM (LCA Approach) – 3 year rolling nationally weighted farm average



	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021
Teagasc NFS	1.11	1.09	1.11	1.11	1.09	1.06
Bord Bia SDAS	1.08	1.07	1.06	1.05	1.06	1.04

Figure 11-2: GHG per kg FPCM (LCA Approach) – 3 year rolling average weighted by milk supply.



	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020	2019-2021
Teagasc NFS	1.06	1.03	1.04	1.04	1.02	1.00
Bord Bia SDAS	1.07	1.05	1.03	1.02	1.02	1.00

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Appendix 1 – Individual year results by farm system 2016-2021

Table A 1: Sustainability Indicator results for Dairying Farms 2016-2021

Indicator	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
Economic Sustainability Metrics			€			
Economic return per hectare (gross output)	3,021	3,722	3,641	3,620	3,730	4,324
Profitability per hectare (gross margin)	1,457	2,113	1,730	1,802	1,920	2,396
Family farm income per hectare	948	1,537	1,059	1,122	1,246	1,548
Productivity of labour	41,466	69,449	48,986	52,449	57,813	73,941
Market orientation	87%	90%	89%	88%	90%	91%
Viability	69%	85%	73%	75%	80%	86%
Social Sustainability Metrics						
Household vulnerable	16%	8%	13%	12%	8%	7%
Isolation	8%	8%	7%	7%	6%	6%
High age profile	9%	12%	12%	15%	16%	16%
Hours worked on farm	2,405	2,345	2,398	2,380	2,422	2,545
Total hours worked	2,513	2,487	2,552	2,545	2,586	2,725
Agricultural education	74%	76%	77%	79%	83%	82%
Environmental Sustainability Metrics						
		tonnes CO_2 eqv per farm				
Total farm average Ag. GHG emissions	518.8	545.0	572.5	576.5	598.1	614.1
of which dairy	359.0	381.4	400.5	416.5	436.5	454.3
cattle	157.8	161.8	171.0	158.8	160.8	158.2
sheep	1.5	1.5	1.6	1.4	1.2	1.2
other	0.5	0.3	0.0	0.0	0.0	0.4
energy use	17.7	17.9	18.3	18.4	17.8	20.5
		tonnes CO_2 eqv per ha				
Ag GHG Emissions	9.0	9.2	9.5	9.3	9.3	9.5
Energy GHG Emissions	0.34	0.33	0.33	0.32	0.30	0.35
		kg CO_2 eqv				
Ag. GHG Emissions per kg milk	0.91	0.91	0.92	0.90	0.88	0.88
Ag. GHG Emissions per kg FPCM	0.90	0.91	0.92	0.89	0.86	0.85
Ag. GHG Emissions per € output	3.5	2.9	3.0	2.8	2.9	2.5
Energy GHG Emissions per kg milk	0.049	0.053	0.046	0.044	0.038	0.037
Energy GHG Emissions per kg FPCM	0.036	0.037	0.037	0.034	0.032	0.036
Energy GHG Emissions per € output	0.137	0.107	0.109	0.098	0.095	0.094
GHG Emissions per kg FPCM (LCA)	1.08	1.11	1.14	1.07	1.06	1.05
		tonnes NH_3 per farm				
Total farm average NH3 emissions	2.68	2.82	3.09	3.03	3.07	2.89
of which dairy	1.82	1.94	2.15	2.18	2.23	2.13
cattle	0.86	0.87	0.93	0.85	0.83	0.76
sheep	0.01	0.01	0.01	0.01	0.01	0.00
tillage	0.00	0.00	0.00	0.00	0.00	0.00

Indicator	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
		Kg NH_3				
NH3 emissions per hectare	46.1	48.0	51.4	49.1	48.2	45.1
NH3 emissions per Euro output	0.018	0.015	0.017	0.014	0.015	0.012
NH3 emissions per kg milk	0.005	0.005	0.005	0.005	0.004	0.004
NH3 emissions per kg FPCM	0.005	0.005	0.005	0.005	0.004	0.004
N Balance per hectare	164.8	172.3	201.0	179.9	175.6	163.7
P Balance per hectare	9.0	11.4	15.7	13.3	12.4	12.9
		percentage				
N use efficiency	24.0	24.3	21.5	24.2	25.5	26.8
P use efficiency	62.4	58.3	47.7	53.3	55.4	53.3
Innovation Metrics						
Discussion Group Membership	43%	43%	42%	44%	44%	45%
Milk Recording	42%	41%	38%	46%	43%	48%
% of slurry spread using LESS	4%	5%	5%	32%	52%	67%
% of slurry applied during spring	54%	56%	51%	54%	53%	51%
% chemical N applied as Protected Urea	0%	0%	0%	3%	5%	7%
% of farms reseeding	19%	28%	26%	25%	32%	31%
% of farms liming	37%	33%	30%	36%	38%	44%

Table A 2: Sustainability Indicator results for Cattle Farms 2016-2021

Indicator	***2016***	***2017***	***2018***	***2019***	***2020***	***2021***
Economic Sustainability Metrics						
Economic return per hectare (gross output)	1,312	1,338	1,316	1,309	1,324	1,532
Profitability per hectare (gross margin)	514	536	486	495	511	653
Family Farm Income per hectare	392	393	321	310	333	404
Productivity of labour	15,544	17,035	13,510	13,831	14,255	17,445
Market orientation	64%	64%	62%	60%	62%	66%
Viability	24%	25%	18%	19%	18%	27%
Social Sustainability Metrics						
Household vulnerable	42%	39%	39%	41%	39%	34%
Isolation	24%	22%	24%	23%	23%	18%
High age profile	31%	32%	38%	39%	40%	40%
Hours worked	1,573	1,510	1,521	1,480	1,494	1,486
Total Hours Worked	2,202	2,203	2,215	2,161	2,173	2,221
Agricultural education	33%	38%	40%	40%	43%	46%
Environmental Sustainability Metrics						
	tonnes CO_2 eqv per farm					
Total farm average Ag. GHG emissions	147.0	152.3	161.1	150.0	147.4	156.6
of which dairy	0.0	0.0	0.0	0.0	0.1	0.1
cattle	142.1	147.5	156.1	145.2	142.3	151.4
sheep	4.6	4.2	4.6	4.4	4.7	4.4
other	0.3	0.5	0.4	0.4	0.4	0.6
energy use	6.6	6.2	6.1	5.9	5.6	6.1
	tonnes CO_2 eqv per ha					
Ag GHG Emissions	4.6	4.7	4.8	4.5	4.4	4.7
Energy GHG Emissions	0.2	0.2	0.2	0.2	0.2	0.2
	kg CO_2 eqv					
Ag. GHG Emissions per kg live-weight beef	11.9	12.0	12.6	11.7	11.7	12.0
Ag. GHG Emissions per € output	5.2	6.5	5.8	5.4	5.1	4.5
Energy GHG Emissions per kg live-weight beef	0.59	0.53	0.52	0.49	0.48	0.51
Energy GHG Emissions per € output	0.26	0.26	0.25	0.22	0.21	0.19
	tonnes NH_3 per farm					
Total farm average NH3 emissions	0.78	0.84	0.89	0.82	0.76	0.79
of which dairy	0.00	0.00	0.00	0.00	0.00	0.00
cattle	0.76	0.82	0.87	0.80	0.74	0.77
sheep	0.02	0.02	0.02	0.02	0.02	0.02
tillage	0.00	0.00	0.00	0.00	0.00	0.00
	Kg NH_3					
NH_3 emissions per hectare	24.4	26.1	26.2	24.3	22.9	23.1
NH_3 emissions per Euro output	0.03	0.04	0.03	0.03	0.03	0.02
NH_3 emissions per kg live-weight beef	0.06	0.07	0.07	0.07	0.06	0.07
	kg per ha					
N Balance per hectare	59.0	58.9	67.2	57.7	58.9	63.3
P Balance per hectare	4.6	5.2	5.7	4.9	4.8	6.2

Indicator	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
			percentage			
N use efficiency	21.9	22.8	20.6	22.3	23.0	21.9
P use efficiency	70.8	66.9	61.1	67.6	68.9	63.3
			Per kg of N Surplus			
Innovation Metrics						
Discussion Group Membership	16%	17%	21%	19%	11%	16%
% of slurry spread using LESS	1%	2%	3%	12%	18%	25%
% of slurry applied during spring	44%	48%	43%	41%	44%	49%
% chemical N applied as Protected Urea	0%	0%	0%	1%	2%	2%
% of farms reseeding	10%	6%	9%	8%	9%	14%
% of farms liming	15%	15%	14%	11%	11%	21%

Table A 3: Sustainability Indicator results for Sheep Farms 2016-2021

Indicator	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
Economic Sustainability Metrics						
Economic return per hectare (gross output)	1,291	1,382	1,314	1,241	1,293	1,476
Profitability per hectare (gross margin)	435	549	396	409	489	623
Family Farm Income per hectare	385	466	275	321	401	445
Productivity of labour	14,339	17,224	12,363	14,256	17,652	18,725
Market orientation	61%	60%	59%	55%	61%	66%
Viability	25%	28%	20%	23%	25%	39%
Social Sustainability Metrics						
Household vulnerable	41%	41%	45%	41%	39%	27%
Isolation	9%	12%	13%	23%	26%	21%
High age profile	33%	30%	38%	40%	46%	37%
Hours worked on farm	1,679	1,644	1,579	1,555	1,524	1,541
Total hours worked	2,212	2,132	1,996	2,055	1,988	2,085
Agricultural education	39%	42%	50%	53%	52%	57%
Environmental Sustainability Metrics						
	tonnes CO_2 eqv per farm					
Total farm average Ag. GHG emissions	154.6	161.5	158.6	153.0	153.4	166.0
of which dairy	0.0	1.9	0.0	0.0	0.0	0.0
cattle	76.9	77.3	76.6	72.6	72.2	75.4
sheep	77.3	81.8	81.5	80.1	80.5	89.8
other	0.4	0.5	0.6	0.4	0.7	0.8
energy use	6.2	6.5	6.2	6.1	5.3	6.0
	tonnes CO_2 eqv per ha					
Ag GHG Emissions	4.1	4.3	4.1	3.9	3.8	4.1
Energy GHG Emissions	0.18	0.20	0.17	0.17	0.14	0.17
	kg CO_2 eqv					
Ag. GHG Emissions per kg live-weight sheep produced	10.5	10.5	11.3	10.2	11.8	11.4
Ag. GHG Emissions per € output	5.1	5.1	5.0	5.6	4.5	4.0
Energy Emissions per kg live-weight sheep produced	0.52	0.55	0.52	0.5	0.49	0.51
Energy GHG Emissions per € output	0.24	0.28	0.23	0.23	0.17	0.16
	tonnes NH_3 per farm					
Total farm average NH3 emissions	0.74	0.79	0.79	0.77	0.74	0.78
of which dairy	0.00	0.01	0.00	0.00	0.00	0.00
cattle	0.42	0.45	0.45	0.43	0.41	0.42
sheep	0.32	0.34	0.34	0.34	0.33	0.36
tillage	0.00	0.00	0.00	0.00	0.00	0.00
	kg NH_3					
NH_3 emissions per hectare	19.7	20.7	20.4	19.2	18.6	19.4
NH_3 emissions per Euro output	0.02	0.02	0.03	0.03	0.02	0.02
NH_3 emissions per kg live-weight sheep	0.05	0.04	0.05	0.04	0.05	0.04
	kg per ha					
N Balance per hectare	49.1	50.7	64.1	47.0	49.0	53.4
P Balance per hectare	5.2	5.8	7.0	4.8	5.8	7.1

Indicator	***2016***	***2017***	***2018***	***2019***	***2020***	***2021***
			percentage			
N use efficiency	29.7	30.6	24.6	29.4	29.3	25.7
P use efficiency	62.2	62.1	52.2	60.8	58.6	57.8
Innovation Metrics						
Discussion Group Membership	17%	28%	26%	25%	16%	19%
% of slurry applied during spring (where slurry is generated)	27%	26%	22%	28%	31%	33%
% chemical N applied as Protected Urea	0%	0%	0%	0%	2%	2%
% of farms reseeding	8%	3%	16%	7%	8%	13%
% of farms liming	19%	22%	17%	12%	16%	28%

Table A 4: Sustainability Indicator results for Tillage Farms 2016-2021

Indicator	***2016***	***2017***	***2018***	***2019***	***2020***	***2021***
Economic Sustainability Metrics						
Economic return per hectare (gross output)	1,671	1,737	1,855	1,966	1,693	2,218
Profitability per hectare (gross margin)	671	819	902	878	753	1,189
Family farm income per hectare	506	618	656	584	550	839
Productivity of labour	36,682	44,591	43,928	36,684	38,537	75,185
Market orientation	73%	76%	79%	75%	73%	79%
Viability	61%	74%	63%	62%	66%	76%
Social Sustainability Metrics						
Household vulnerable	22%	11%	17%	17%	17%	13%
Isolation	21%	19%	16%	17%	16%	19%
High age profile	28%	27%	33%	32%	37%	28%
Hours worked on farm	1,550	1,466	1,510	1,539	1,422	1,519
Total hours worked	1,988	1,937	2,081	2,220	2,062	2,215
Agricultural education	62%	61%	54%	64%	56%	63%
Environmental Sustainability Metrics						
	tonnes CO_2 eqv per farm					
Total farm average Ag. GHG emissions	160.2	152.4	169.1	162.0	166.7	176.9
of which dairy	0.1	0.0	0.0	0.0	0.0	0.0
cattle	96.9	98.3	112.4	102.6	110.7	104.5
sheep	9.6	9.3	10.1	12.6	14.9	15.0
other	53.5	44.8	46.6	46.8	41.1	57.4
energy use	16.7	13.6	14.4	14.2	13.0	16.5
	tonnes CO_2 eqv per ha					
Ag GHG Emissions	2.41	2.47	2.72	2.47	2.53	2.50
Energy GHG Emissions	0.28	0.23	0.22	0.23	0.19	0.22
	kg CO_2 eqv					
Ag. GHG Emissions per € output	1.98	1.91	1.89	1.90	2.02	1.48
Energy GHG Emissions per € output	0.21	0.16	0.15	0.16	0.14	0.12
	tonnes NH_3 per farm					
Total farm average NH3 emissions	0.62	0.60	0.74	0.74	0.68	0.73
of which dairy	0.00	0.00	0.00	0.00	0.00	0.00
cattle	0.50	0.51	0.57	0.51	0.54	0.49
sheep	0.03	0.04	0.04	0.05	0.06	0.05
tillage	0.09	0.05	0.13	0.16	0.08	0.19
	kg NH_3					
NH_3 emissions per hectare	9.2	9.0	10.8	10.0	10.1	9.8
NH_3 emissions per Euro output	0.01	0.01	0.01	0.01	0.01	0.01
	kg per ha					
N Balance per hectare	42.3	41.4	61.9	45.8	44.2	39.4
P Balance per hectare	4.5	4.4	9.9	6.1	9.2	6.5
	percentage					
N use efficiency	68.5	69.7	56.8	65.6	61.8	65.9
P use efficiency	89.9	86.4	70.4	82.2	70.5	84.8

Indicator	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
Innovation Metrics						
Discussion Group Membership	24%	24%	21%	29%	21%	26%
Break Crop	11%	9%	19%	19%	15%	12%
% of farms liming	27%	32%	27%	28%	20%	32%

Table A 5: Sustainability Indicator results for All Farms 2016-2021

Indicator	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
Economic Sustainability Metrics						
Economic return per hectare (gross output)	1,638	1,800	1,774	1,766	1,787	2,085
Profitability per hectare (gross margin)	680	840	727	746	783	1,006
Family Farm income per hectare	498	626	471	479	528	652
Productivity of labour	21,530	28,506	21,941	22,544	24,588	32,271
Market orientation	68%	69%	68%	65%	68%	72%
Viability	35%	40%	32%	33%	34%	44%
Social Sustainability Metrics						
Household vulnerable	35%	31%	34%	34%	32%	26%
Isolation	19%	18%	18%	19%	20%	17%
High age profile	27%	28%	33%	35%	36%	34%
Hours worked on farm	1,741	1,678	1,688	1,660	1,663	1,691
Total hours worked	2,244	2,222	2,230	2,218	2,209	2,291
Agricultural education	43%	47%	50%	51%	53%	56%
Environmental Sustainability Metrics						
	tonnes CO_2 eqv per farm					
Total farm average Ag. GHG emissions	214.9	223.7	235.3	228.8	232.3	243.4
energy use	9.3	8.9	8.9	8.8	8.4	9.5
	tonnes CO_2 eqv					
Ag GHG Emissions per hectare	5.1	5.3	5.4	5.1	5.1	5.3
Ag GHG Emissions per Euro output	0.24	0.23	0.22	0.21	0.20	0.22
Energy GHG Emissions per hectare	4.7	5.3	4.9	4.7	4.4	3.8
Energy Emissions per Euro output	0.2	0.23	0.21	0.20	0.18	0.16
	tonnes NH_3 per farm					
Total farm average NH3 emissions	1.10	1.17	1.26	1.21	1.17	1.17
	kg NH_3					
NH_3 emissions per hectare	26.4	27.8	28.6	26.9	25.9	25.5
NH_3 emissions per Euro output	0.02	0.03	0.03	0.02	0.02	0.02
	kg per ha					
N Balance per hectare	73.9	74.4	88.8	75.3	76.1	78.2
P Balance per hectare	5.4	6.1	7.7	6.2	6.4	7.4
	percentage					
N use efficiency	26.7	27.2	24.0	26.6	27.0	25.5
P use efficiency	69.7	66.5	58.4	65.4	65.2	62.9