Profiling farm systems according to their sustainable performance: the Irish livestock sector

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Abstract

Sustainable farming systems are those that are economically profitable, environmentally protective and socially efficient through time, therefor the importance of farm sustainable performance is highly acknowledged, and there are various methods for its measurement and assessment at different spatial levels.

The aim of this study is to profile and classify Irish livestock farms according to their performance using farm-level data on profitability, environmental efficiency and social integration derived from the Teagasc National Farm Survey. In contrast to previous research that assesses Irish farms' sustainable performance at farm level, this study is attempting to create a farm system typology based on farm performance and characteristics. Economic, social and environmental performance indicators are determined and aggregated to be used as the conceptual framework to identify and classify types of farms. A combination of multivariate analysis techniques is developed for the aggregation of indicators and for the creation of farm systems typologies. The results indicate the relation between economic, ecological and social performance of Irish farms and establish a typology of livestock farms that can prove useful for future policy design.

1. Introduction

Over eighty per cent of utilized land in Ireland is used for agricultural purposes mainly as pasture land for dairy and dry-stock production. The dairy and livestock production industries is a major contributor to the Irish economy and holds the largest share of its agricultural sector, with Ireland's meat and livestock exports accounting for one third of all food and drink exports. Given climatic conditions that are ideal for natural pasture growth, the Irish livestock sector is based on extensive, low input systems, which accordingly can be characterized a low profit (Ryan et al., 2014). Data from the Teagasc National Farm Survey (NFS) indicate that the average size of all systems (including dairy and tillage) was 47 ha with an average income of 541 Euro/ha for 2012, which remained steady for 2013. The NFS data also reveal heavy dependency on subsidies, with the Single Farm Payment covering more than half of the total farm income for all farms (57%), reaching 100% for some systems (i.e. sheep) (Hennessy et al., 2014).

According to the Food Harvest 2020 implementation report for 2014, the economic performance of Irish beef and dairy farms has been satisfactory in terms of meeting its milestones for the past few years. Despite the national and global recession, both sectors exceeded €2 billion in output in 2013, accounting for over two-thirds of the total €6.18 billion of primary output. However, the goals set by the Food Harvest 2020 strategy are to increase dairy production by 50% and beef production by 20% by 2020 to meet increased national and global demand. At the same time it is recognized that environmental sustainability is an essential requirement for 21st century food production systems.

As the demands for a more intensive production increase worldwide on the one hand, and climate change challenges dictate a reduction of pollution on the other, it is necessary for the livestock sector to meet the challenge of intensifying its production systems in a sustainable way that will help preserve the landscape and protect the environment. The sustainable performance of farms has been the focus of research attention in recent years. In broad terms sustainability is defined as a system's ability to continue into the future (Hansen and Jones, 1996). A sustainably performing farm is one that can maximize its financial outputs, meet the needs of society and contribute to environmental protection and preservation of natural resources (Dillon et al., 2009).

In their attempt to formulate policy plans to increase the sustainability of agriculture many organizations, such as the EU are concerned with measuring and evaluating farm sustainable performance. Consequently, in recent decades researchers have acknowledged the need for farm performance evaluation and various methods have been developed for its measurement, such as estimating farm

efficiency through benchmarking techniques (e.g. Derks et al., 2014; Galanopoulos et al., 2011), Life Cycle Assessment (LCA) (e.g. Dolman et al., 2014; Weiss and Leip, 2012) or Environmental Impact Assessment (e.g. Crosson et al., 2011). Also many researchers have developed multi-dimensional sets of indicators to evaluate farm performance. Indicators are synthetic variables describing complex systems and can explain various aspects of sustainability (Castoldi and Bechini, 2010). Indicators are considered a safe alternative to direct measurement of farm performance, because they explain complex systems through variables that can be derived from easily accessible datasets (Bockstaller et al., 2009, Donnelly et al., 2007).

One approach to measuring farm performance is the construction of indicator indices that can measure the overall performance of farms. In this context, sustainable performance evaluation covers, in most cases, three pillars of sustainability, as recognized in the literature: economic, social and environmental. Indicator indices have been developed by several evaluation programs across Europe and studies that use this approach provide a holistic evaluation of sustainable performance at farm level (e.g. Firbank et al., 2013; Gómez-Limón et al., 2012).

However, given the great disparities that can appear between farms it is often valuable to examine farms by classifying them into farming systems (Morgan-Davies et al., 2012).The literature suggests that each individual farm is a subsistent unit that has specific characteristics and unique structural interrelations among many components (e.g. resources, geography, and infrastructure, human, social and financial capital) (Dixon et al., 2001). Given the interdependency of all the physical, social and economic elements of each farm we can assume that a farm is a unique system and can be analysed as such. Farming systems, on the other hand, are defined by FAO as "populations of individual farms that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate" (Dixon et al., 2001). In agricultural economics, identifying farming systems is an efficient way to simplify the explanation of the diversity of farms, through artificially grouping them into types based on specific criteria, which represent the real situation but are easily interpreted by policy makers (Valbuena et al., 2008). The purpose of this study is to define and classify dairy and cattle farm systems in Ireland, using sustainability indicators derived from the NFS and designed to encompass the three pillars of sustainability, in order to assess farm performance. Farm classification with help group farms into cluster according to their performance, identifying, this way, farming systems based on sustainability criteria. This classification may prove useful for policy makers in order to meet their targets as they might address the issue at farming system level.

This paper is structured as follows: the first section outlines the background of the study and presents brief reviews of studies assessing the performance of Irish farms and of studies using multivariate analysis for farm classification according to performance of European farming systems. Also, the existing systems of farm classification are presented in this section, as is the contribution of this study to the relevant literature. The second section gives an explanation of the data and methodology used. The third section presents the results of the analysis and gives a description of the farms types identified. Finally, the last section includes a discussion of the results and some concluding remarks.

1.1   Farm performance assessment in Ireland

In Ireland, studies to evaluate sustainable farm performance at farm level using sustainability indicators have been produced by a number of researchers: Ryan et al. (2014) used a set of indicators developed from NFS data capturing the economic, environmental, social and innovation performance of farms to assess farm sustainability for all farm systems. They applied the OECD protocol for normalization and presented the results at farm level. Dairy and tillage farms were found to be the most economically and socially sustainable. The most economically sustainable farms were also the ones with better environmental performance and had the highest adoption of innovation rates.

Dillon et al. (2014) assessed the overall sustainability of Irish dairy farms only using the same indicators. Their analysis found large variation in household incomes. However, more than 70% of the farms were found to be economically viable and market orientated. High economic performance was correlated with low rates of GHG emissions and sustainable water management.

Mauchline et al. (2012) used participatory methods and multi-criteria analysis to construct an Agri-environmental Footprint Index (AFI) and measure environmental performance of livestock farms in 5 European countries including Ireland. The basic finding indicated that the mean AFI score for farms that participate in Agri-environmental schemes was higher than that for non-scheme farms in most of the areas of study. AFI was also developed by Louwagie et al. (2012) based on survey data to estimate the environmental performance of Irish livestock farms and reached similar conclusions. Foley et al. (2011) studied the effect of alternative production systems (environmental practices) on GHG emissions at farm level. They assessed environmental quality of beef production on Irish farms using NFS data by applying a bio-economic model (Grange beef Systems model) to evaluate 4 different scenarios. Bull beef systems resulted in lower GHG emissions than steer beef systems. Increasing stocking rate above a certain level results in diminishing returns from purchased inputs such as fertilizers and, consequently, increasing GHG emissions per kg beef carcass.

Previously Dillon et al. (2009) and Dillon et al. (2010) performed in depth analyses of farm performance using sustainability indicators also derived from the NFS (1996 - 2006) and developed a spatial micro-simulation model to map Irish farms accordingly. Results indicated that less than half of all Irish farms were economically viable over the 10 year period, and that subsidies play a very important role in viability. Also, only the dairying and tillage systems appear to show a significantly positive market return, which however, also proved to be associated with higher methane emissions. Dairy and tillage systems had higher rates of nitrogen use. In term of social sustainability their results indicated that overall farmers tend to become more isolated over the years and find it harder to identify successors for their farms.

Newman and Matthews (2007) measured the productivity of Irish dairy farms in the period 1984 – 2000 using multiple output distance functions. The indicators used were derived form a survey and weighted according to the NFS system. The results of the distance function were used to estimate a generalised Malmquist index of total factor productivity and its decomposition into technical change, efficiency and scale effects, given by equations for each farm in each system. There was evidence, of a slowdown in growth in the 1990s and differences were found in productivity performance. Sheep farming exhibited the most impressive performance because of an early burst in productivity growth rates.

1.2   Review of methodological application

The method used for the classification of farms into systems follows the protocol of multivariate analysis as suggested by Köbrich et al. (2003), based on performance indicators developed to describe the outcomes of farmers' economic, social and environmental management practices. The purpose of multivariate analysis is to use quantitative data to create types of farms described as variables, which are produced by the reduction of an original dataset, by organizing them into groups based on their similarities.

One strand of this kind of research focuses on the description of farms according to farming processes and farmer's characteristics and management practices (e.g. Gelasakis et al., 2012; Milán et al., 2011; Sturaro et al., 2013). A different approach is the identification of farming systems based, not only on the structural and physical farm characteristics or management practices, but also on performance indicators, in an attempt to evaluate farm's sustainability. The majority of studies in this vein focus on economic and technical performance, although some attempt to classify farm systems based on their performance in other sustainability pillars. Table 1 presents a brief summary of the relevant studies.

These studies derive the indicators from given datasets and perform the multivariate analysis using them as variables. This, however, implies that all indicators are of the same importance and influence farm performance evaluation equally. This study attempts to perform a multivariate analysis identifying farming systems based on performance indicators that have formerly been normalized and weighted according to importance (Nardo et al., 2008). Weights are assigned to indicators to reflect their significance, statistical adequacy, and importance in performance assessment and usually have an important impact on the resulting ranking. To set weights some authors use normative approaches that include participatory methods, expert opinion or survey data (e.g. Maxim, 2012; Meul et al., 2009; Paracchini et al., 2015; Ripoll-Bosch et al., 2012). Other authors use a range of statistical tools such as principal component analysis (e.g. Gomez-Limon et al., 2012), analysis of variance (e.g. Carpani et al.,

2012) multicriteria analysis (e.g. Castoldi and Bechini, 2010), regression coefficients (e.g. Reig-Martínez et al., 2011) or data envelopment analysis (DEA) (e.g. Gerdessen and Pascucci, 2013). In this study we use the Principal Component Analysis method as suggested by the OECD (Nardo et al., 2008)

1.3 Irish farming systems

The NFS groups farms into systems using the FADN framework based on the unified typology the European Union has developed for its members which is based on two criteria (EUROPEAN COMMISSION, 1985):

i) the nature of the agricultural enterprises they involve, which refers to a list of characteristics of agricultural holdings which include: land use and area (crops), livestock, main crops, farm labour force (including age, gender and relationship to the holder), economic size of the holdings, type of activity, other gainful activity on the farm, machinery and organic farming. These characteristics are defined by the EC Regulation (EEC) No1166/2008.

ii) the threshold determining the class limits. The thresholds for each type of crop are defined by the EC Regulation (EEC) No1166/2008.

Crowley et al. (2008) spatially grouped farms by electoral district to evaluate the number of farms and the average farm size and identified four farms systems in terms of land utilization and farm structure patterns: consolidation, dispersal, contraction and expansion.

Grouping of farms according to performance using indicators has been performed by Ashfield et al. (2013) who used the Grange Dairy Beef Systems mathematical model to simulate 4 different scenarios. Construction of farming systems was based on 4 sub models: farm system, animal nutrition, feed supply and financial and the scenarios simulated were based on beef and concentrate prices and grass land management. Results indicated very small net margins for beef farms regardless of their technical efficiency and indicated high dependency on beef price and concentrate prices.

In terms of methodology, multivariate analysis for the identification and classification of farming systems in Ireland has been used by O'Rourke et al. (2012) who established a farm typology of the Iveragh uplands hill sheep farming based on farming intensity, farm continuity and the extent of semi-natural vegetation present on the farms. They used Principal Component Analysis (PCA) followed by K-mean cluster analysis to group farms and a further statistical analysis to calculate the main technical and socio-economic characteristics of the emerging clusters. As a result they distinguished 4 farms groups: Environmental stewards, Support optimizers, Traditionalists and Production maximizers.

1.4 Contribution

The studies measuring farm performance in Ireland give a substantially good overview of the farming sectors and explain the strategies that could lead to improving performance as well as the constraints farmers face when trying to improve their farm sustainability. They also, however, highlight the great disparities that exist between individual farms. Researchers notice large variation between farms, not only in terms of characteristics but also in terms of performance. As mentioned earlier an approach to measuring performance that can overcome the issue of farm diversity is to use sustainability indicators as a framework to identify farming systems, which can be classified according to performance levels. However, in Ireland this approach has not been widely used. The studies identified previously that create farm typologies (ref), group farms either according to structural characteristics or based on economic outcomes, and little attention is paid to social and environmental factors.

The methodology proposed by most of the literature for the identification and classification of farming systems is multivariate analysis; a technique that has rarely been used in an Irish context for this purposes. Also, studies that use indicators to identify and classify farming systems do not take into account their relevant importance but consider them equally weighted. Furthermore, although the methodological framework has been used in the international literature, most Irish studies focus only on indicators of numeric values, as they use linear methods that cannot easily include nominal variables.

This study attempts to make a modest contribution to literature by filling both a contextual and a methodological gap. A non-linear multivariate analysis will be used to identify and classify Irish livestock farming systems using performance indicators that have been weighted according to their importance. Following the suggestions that the identification of farm types and the classification of farms according

to indicators that go beyond simple structural or economic criteria may be useful for the design of policies to provide customized support appealing to each farm type's socio-economic situation (O'Rourke et al., 2012), the typology developed in this study could assist the formation of targeted policies that focus on the relationship between production objectives and social and environmental sustainability, at farming system level.

2. Methodology

1.5 Data

To achieve the goals of this study we have used indicators that express economic, environmental and social sustainable performance of Irish dairy and livestock farms. The development of the indicators was performed by Teagasc (Dillon et al., 2014, Hennessy et al., 2013) using data from the 2012 Teagasc NFS. The Teagasc NFS is conducted annually and provides the data for the EU Farm Accountancy Data Network. It has a sample of approximately 1000 randomly selected Irish farms, which provide information on their physical, social and economic characteristics. Each farm is assigned a weighting factor so that the results of the survey are representative of the national population of farms. Farm performance indicators were derived from the data of the NFS following criteria for consistency and suitability. Table 2 presents the indicators developed, the way they were measured and the units used.

1.6 Sustainability evaluation

The conceptual framework for the evaluation of sustainable farm performance emerges for the combination of the OECD methodology for aggregation of indicators as developed by Nardo et al. (2005, 2008) and the protocol for farm classification of Kobrich et al. (2003).More specifically, the analysis in this study is guided by the following steps:

From the OECD methodology:

- Developing the theoretical framework
- Selection of indicators
- Correlation testing
- Quantification and optimal scaling
- Data normalization
- Weighting

From the Kobrich (2003) farm classification protocol

- Factor analysis
- Cluster analysis
- Link to the original dataset variables

The selected indicators were first tested for correlation though a Pearson correlation matrix. The purpose was to examine the validity of these indicators as variables to be used in the consequent multivariate analysis. As some indicators used in this analysis were qualitative they appear as nominal or binary variables that cannot effectively be used in multivariate analysis (factorial analysis). Therefore, before performing the multivariate analysis they have to be transformed into numeric variables that have a variance in the statistical sense). Optimal scaling can also be used on variables with numeric values to allow for their re-scaling. This can prove useful to address the problem emerging in multivariate analysis of variables that range within very small intervals (Gomez-Limon et al., 2012). The CATPCA package of SPSS is a tool that can perform a non-linear PCA that uses optimal scaling to transform nominal variables into numeric ones through non-linear regressions. The idea behind optimal scaling is to assign numerical values to the categorical variables, thereby allowing standard statistical processes to be applied. The optimal scale values are assigned based on an optimizing criterion that can vary according to the research needs. In this study the indicators were quantified and/or rescaled based on numeric quantification and random grouping (more information on the optimal scaling techniques can be found in

IBM SPSS Statistics 22 Documentation). The new assigned values have numeric properties that allow them to be used in multivariate analysis.

To facilitate the interpretation of results the scaled indicators were normalized on a scale from 0-1. Normalization is an essential step when using indicators measured in different units. The method used to normalize the indicators was the MIN-MAX approach as explained by Nardo et al. (2008) using the following formula:

$$I_j = \frac{x_j - \min(x_j)}{\max(x_j) - \min(x_j)}$$

Where I_j is the normalized value, x_j is the numeric value of the indicator as created by the non-linear PCA and $\min(x_j)$ and $\max(x_j)$ are, respectively, the minimum and maximum values of indicatorx_j. The categorical PCA runs similarly to the traditional PCA on the quantified variables and the decision on the number of components to be maintained follow the same rules of thumb as the linear PCA. Here, the number of components to be retained followed the Kaiser criterion; therefore components with an eigen-value > 1 were used further in the analysis. The components can be also rotated (like in traditional PCA) to reduce the number of variables highly correlated to each other. The component loadings are used to assign weights to the indicators. The weight assigned to each indicator was calculated using the following formula as suggested by Nardo et al. (2008) and developed by Gómez-Limón and Riesgo (2009):

$$w_{kj} = \frac{\left(\text{factor} - \text{loading}_{kj}\right)^2}{\text{eigen} - \text{value}_k}$$

where $\text{factor} - \text{loading}_{kj}$ is the value of the factor loading of indicator j in the Principal Component k and $\text{eigen} - \text{value}_k$ is the eigen-value of the kth Principal Component.

As mentioned, farm classification follows the protocol of Kobrich et al. (2003). In the first step of the process, farms can be grouped into types using PCA. In this study, PCA is performed on the dataset of weighted indicators. Again, the number of components to be retained follows the Kaiser Criterion (eigen-value >1) and only the component loadings with a value higher than 0.35 are accounted for in the analysis (Field, 2009). The factors retained in the PCA were subjected to a two-step cluster analysis. Hierarchical cluster analysis, (Ward's method) was used to identify the number of clusters, followed by K-mean clusters analysis to indicate the cluster centres and the number of farms in each cluster.

To evaluate the emerging clusters according to performance the average value of the indicator for each cluster is compared to an optimal indicator value as this emerges for the dataset. The level of sustainability is calculated as a percentage of the optimum performance of the entire sample. Optimal values are the values of the indicators for the best performing farms of the dataset. That is:

   a) The maximum value of all numerical economic indicators and the highest per cent for viability of investment. The percentage for these indicators is calculated by dividing the cluster average by the optimal value (for viability of investment the cluster average is compared to the optimal value, which is estimated at 100% - the farm is 100 viable).
   b) The minimum values for all environmental indicators. The percentage for these indicators is calculated by dividing the optimal value by the cluster average.
   c) The minimum percentage for household vulnerability and isolation risk (for these indicators the optimum performance is considered to be 0%) and the maximum percentage for household viability and education level. For these indicators the performance of each cluster is, therefore, evaluated by comparing the cluster average to the optimum percentage. For work-life balance the performance rate is calculated as a percentage of hours worked on farms / minimum hours worked on farm for all sample.

3. Results

The methodology was applied to the selected indicators database separately for dairy, cattle and sheep farms. The following section presents the results of the analysis for each:

1.7 Dairy farms

1.7.1 Normalization and weighting

Indicators were normalized using formula 1 to produce an intermediate dataset of indicators to be weighted using PCA.

The optimal scaling process using CATPCA produced an intermediate dataset of scaled variables that were normalized using formula 1. Using the component loading of the yielded components the weights to be assigned to each normalized indicator were calculated (formula 2). The values produced and used to weight the indicators for dairy farms are presented in Table 3. The produced weighted indicators were used in a final dataset on which principal component analysis and cluster analysis were applied to classify farms according to performance.

1.7.2 Principal Component Analysis

The PCA performed on the dataset of weighted indicators yielded 4 Principal Components with an Eigen-value > 1, explaining 67% of the original variance. The component loadings for each indicator are presented in Table 4. The first components shows a positive correlation with three economic indicators (productivity of land, profitability and market orientation) and two environmental ones (GHG emissions and N balance per ha). The second component is positively correlated to viability of investment and productivity of labour and negatively correlated to household vulnerability and fuel and electricity emissions. The third component is positively correlated with high N balance and high GHG emissions per farm. Finally the fourth component relates to high age profile, high education level and number of hours worked on farm, and is negatively correlated to isolation risk.

1.7.3 Cluster analysis

These four components were subject to hierarchical cluster analysis – using the ward method and K-mean cluster analysis, which indicated that farms can be clearly grouped into three distinct clusters. Tables 5 and 6 present the frequencies and percentages of the qualitative indicators for each cluster and descriptive statistics of the quantitative ones for each cluster.

Cluster 1: This cluster was made up by 59 farms (23% of the sample). Approximately 83% of the farms in this cluster are viable. The cluster includes farms with an average gross margin of 3436.83 €/ha, with 1547.07 €/ha of market gross margin market and with the market orientation rate of farms in this cluster being, on average, 88%. The average productivity of labour was 51886 €/labour unit. Regarding the environmental indicators, farms in this cluster has GHG emission reaching an average of 824.82 Tonnes of CO_2 equivalent per farm and 8.91 per hectare. The nitrogen balance is on average 180.88 Kg of Nitrogen surplus per hectare and 16428.68 Kgs per farm. Finally, emissions from fuel and electricity are 0.2 kg of CO_2 equivalent Kgs of output. On average 13.56% of the farm households of this cluster are identified as vulnerable and 8.47% of the farmers in the cluster live alone. The performance rate in education level is approximately 83% (farmers having higher education). All farm households in the cluster seem to be viable; meaning that in all farm households have at least one member below 45 years of age.

Cluster 2: The second cluster consists of 37 farms (14% of the sample). Fifty six per cent of the clusters are viable. The average gross output is estimated at 2796.77 € /ha, with profitability ranging between -111.85 and 2531.66 €/ha. The productivity of labour is on average 33.366.2 €/ labour unit and their market orientation rate is approximately 85%. The GHG emissions per farm and per hectare are 355.8 and 7.24 tonnes of CO_2 equivalent respectively, with 0.05 Kgs/kg output emissions coming from fuel and electricity. The Nitrogen balance is significantly lower than the previous cluster, reaching 125.69 and 5880.61 Kgs of Nitrogen surplus per hectare and per farm respectively. Fourteen per cent of the

37 households in the cluster are identified as vulnerable, with the same percentage having a high age
38 profile. Only 32.8% of the farmers in this cluster have higher education and around 27% of them are in
39 isolation risk.

40 **Cluster 3**: This cluster includes 162 dairy farms (63% of the entire dairy farm sample). The average
41 land productivity of these farms ranges from 953.29 to 5407.90 €/ha and their market gross margin is
42 between -42.97 and 3557.51 €/ha. The market orientation rate is on average 85%, similarly to cluster 2
43 and the productivity of labour reaches a mean of 37374.13 €/labour unit. The tonnes of CO_2 equivalent
44 emitted by farms in this cluster reach on average 365.87 and 7.67 per farm and per ha respectively. The
45 Nitrogen balance is 131.68 Kg per ha and 131.68 per farm and the emissions form fuel and electricity
46 are ranging from 0.02 to 0.15 kg of CO_2 Kg of output. A little over 25 % of farm households in this
47 cluster are considered vulnerable; however there are no farmers in isolation risk. The education level is
48 high with approximately 79% of farmers having higher education. Finally, almost all farms in this cluster
49 (similarly to cluster1) have viable households.

1.7.4   Evaluation of performance
51 The performance evaluation is estimated by comparing the values of the indicators for each cluster to
52 the optimal value of the indicator as derived from the dataset. The performance of farms is presented as
53 a percentage of that optimal value for each cluster and for the entire sample in Table 7.

1.7.4.1 Economic performance
55 According to the results we can say that all the farms of the sample are highly efficient in terms of
56 market orientation with the efficiency rates exceeding 80% in all three clusters and the entire sample.
57 This indicates that, regardless of other aspects of performance, Irish dairy farming can be considered
58 market oriented. This result confirms the finding of previous studies on the performance of the Irish
59 dairy sector (Ryan et al. 2014, Hennessy at al. 2013). On the other hand it is noticeable that all clusters
60 have relatively low performance in terms of productivity of labour with the efficiency percentage of the
61 best performing cluster being just above 36%, while for the other cluster it does not exceed 26%. Again,
62 previous studies have shown that labour productivity could be improved in the Irish dairy sector
63 (Newman & Matthews, 2007). Figure 1 compares the three clusters and the entire sample based on
64 their economic performance. In comparing the clusters, the first cluster appears to be the most efficient
65 regarding all economic indicators. This cluster showed the highest percentages of performance in all 5
66 economic indicators, compared to the other clusters, and, also, exceeds the estimated performance of
67 the entire sample. The farms of this cluster appear to be 53.7% efficient in terms of land productivity and
68 are 49.43% efficient in terms of profits. Their performance in productivity of labour is just above 36%.
69 Finally cluster around 88% of the farms are market oriented and their performance in terms of viability
70 reaches 83.1% of the optimal. Given these results we may draw the conclusion that cluster 1 consists of
71 more intensive farm businesses that are targeted to increased production and economic efficiency.
72 The third cluster, which represents the majority of the dairy farms in the sample, is the second rated in
73 economic performance with its efficiency percentages being lower than those of cluster 1. The exception
74 is market orientation which reaches similar levels (84.54% of the optimal). Farms in this cluster have a
75 relatively high efficiency rate in terms of viability of investment (71.6% of the optimal) similar to the rate
76 of the entire sample. Performance rates for productivity of land and for profitability are 46.62% and
77 40.41% respectively and when it comes to productivity of labour, the cluster has low efficiency levels
78 just above 26%.
79 The second cluster is the one with the lowest performance rates compared to the other two and to the
80 entire sample, except for market orientation where it stands slightly above cluster 3. Labour productivity
81 is low (23.5%) as is their performance in terms of profitability (36.1%). The productivity of land is 43.8%
82 - 10 units lower than the best performing cluster. Viability of investment also has a low rate with almost
83 half the farms appearing to be not economically viable (56.76% rate compared to optimal).

1.7.4.2 Environmental indicators
85 Examining the environmental performance, all clusters have relatively low performance rates compared
86 to the optimal values, with none of the percentages across the 5 indicators exceeding 31%, in all

87   clusters. Also, the performance rates across the clusters are widely dispersed meaning that there are
88   important disparities between clusters. Figure 2 presents the comparisons of clusters between each
89   other and to the entire sample.
90   The second cluster is the most efficient one, presenting better performance rates in all 5 indicators
91   compared to the other clusters and to the entire sample. Farms in this cluster are 30.37% efficient when
92   it comes to GHG per ha and 17.1% per farm. Their performance rates in N balance is 17% when
93   measured per ha and 14.48% when measured per farm and the in terms of emission from fuel and
94   electricity the rate is 20.8%.Second after cluster 2 in terms of environmental performance is cluster 3,
95   which as mentioned represents the majority of the sample. The performance rates of farms in cluster 3
96   regarding GHG are close to the best performing cluster, only 0.47% lower for emissions per farm and
97   1.69% for emissions per ha. The performance rates for N balance are also close to the best performing
98   cluster, with only 0.73% lower rate for N balance per ha and 0.58% for N balance per farm. Cluster 1 is
99   the least well performing cluster, with the rates in all indicators being lower than in the other clusters and
100 the entire sample and with some of the indicators presenting remarkably low performance rates. More
101 specifically, performance on GHG emissions per farm is at 7.37% of the optimal (the rate for GHG
102 emission per ha is better, increasing to 24.7%), and performance in terms of N balance per farm is only
103 up to 5.18%. N balance per ha is also low compared to the other clusters reaching a value just above
104 12%. The only aspect where performance of this cluster can compare to the others is emission from fuel
105 and electricity, where the rate, although lower is relatively high(17.92%).

1.7.4.3   Social Indicators

107 From a social point of view, results indicate that all clusters perform well when it comes to hours worked
108 on farm with performance rates ranging from 74.5% to 79.61%. Also, all clusters have high rates of
109 performance when it comes to isolation risk. There are, however, large disparities between clusters in
110 high age profile and in education level. In comparing the clusters, the most important remark is that
111 there is no identified best performing clusters on all indicators. Figure 3 presents the comparison of
112 clusters according to their social performance.
113 As seen, the performance of the first cluster is very high regarding household vulnerability and
114 education level with the performance rates being 86.44% and 83.05% respectively. This cluster also has
115 the best performing on hours worked per farm, with 79.61% performance rate. Also, the cluster is
116 completely efficient in household viability, the performance rate being 100% for this indicator. The
117 second cluster has the lowest performance rates for all social indicators with some of them being
118 significantly lower than the other clusters. More specifically, the education level rate is only 32.43%, less
119 than half of the best performing cluster. Also, the household vulnerability indicator has a percentage of
120 62.16, almost 25% lowers than cluster 1. Similarly, Isolation risk, although it shows a relatively high
121 percentage rate, it is more than 25% lower for this cluster than the best performing one (cluster 3).The
122 third cluster presents the best performance related to isolation risk, being 100% efficient. It also
123 presents relatively high percentages for the other indicators. For hours worked on farm it almost reaches
124 the performance rate of cluster 1 (78.79%) and it has high percentage of education level (79%).
125 Performance related to household vulnerability is 12.4% less compared to the best performing cluster; it
126 is however high reaching 74.1%. When it comes to high age profile, this cluster has very high levels of
127 performance with only 1.23% of farms being inefficient.

1.7.4.4   Farming systems

129 Following the comparison of clusters and the evaluation of performance of their member farms Irish
130 dairy farms can be classified according to their performance as follows

System 1:   Productive, viable, market oriented farms owned by educated farmers

System 2:   Environmentally friendly farms, with low productivity and poor demographics

System 3:   Family farms with good demographics, average productivity and average environmental
performance

1.8 Cattle farms

1.8.1 Normalization and weighting
After optimal scaling though CATPCA and normalization of the original indicators, they were weighted as described in the methodology. The CATPCA produced 4 Principal Components the loading of which were used for the weighting (Table 8). These weights were used as already explained to produce the dataset of indicators for farm classification.

1.8.2 Principal Component Analysis
The PCA on the weighted indicators produced, again 4 Principal Components (Table 9). The first component correlated with high GHG/ha, high productivity of land, high amount of N kgs/per ha and market orientation. The second described viable farms, with high productivity of labour and profitability, which are not vulnerable and have low emission from fuel and electricity. The third component was correlated to high GHG emissions and N balance per farm and with hours worked on farm. Finally, the fourth was negatively correlated to isolation risk and positively to high age profile and high education level.

1.8.3 Cluster analysis
The hierarchical cluster analysis performed on the Principal Components yielded from the PCA indicated that cattle farms can be grouped into 4 clusters, which were identified through K-mean cluster analysis. Tables 10 and 11 present the frequencies and percentages for the qualitative indicators for each cluster and descriptive statistics of the quantitative ones for each cluster

Cluster 1: The first cluster includes 69 farms representing 18.85% of the entire sample of cattle farms. 50 out of 59 farms are identified as viable. The average gross output is €1650.54. The market gross margin is €590.65 and 65% are market orientated. The hours worked on farm range from 0 to 3000. On average 24.6% of the households are considered vulnerable and 62 out of 69 farms are owned by people over 60 years old who have not identified a successor. The GHG emissions per farm and per ha are on average 403.18 and 4.53 tonnes of CO_2 equivalent respectively, while the N balance per farm ranges from 0 to 25816.89, with an average at 6280.89. Performance in terms of isolation risk is 94.20% Most of the farms in this cluster are cattle finishing farms (84.06% of farms in the cluster).

Cluster 2: cluster 2 includes 82 farms that account for 22.4% of all cattle farms out of which 29 are found to be viable (35.4%). Almost 70% of the households do not have members under 45 years old; 42% are considered vulnerable and 17% face isolation risk. Gross output/ha ranges between €579.18 and €2872.24, while gross margin form the market/ha is between €-208.74 and €1798.56. Market orientation rates reach 67.08%. GHG per farm rise up to 164.35 tonnes of CO_2 equivalent and the N balance per farm and per hectare is 58.43 and 1708.71 kgs of N respectively. On average the hours worked on farm are 1428.04. The greatest proportion of farms in this cluster is cattle finishing farms (60.98%).

Cluster 3: 95 farms are included in this cluster that is 25.96% of the entire sample. 26 of those have viable investments with their gross output/ha being on average €917.89 and the average of gross margin derived from the market being €313.03/ha. The market orientation efficiency rate is 53.93%. The productivity of labour ranges from €-1379.16 to €159448.94 and, on average, farmers in this cluster worked 2032.78 hours. 61 households are found vulnerable, 43 are in isolation risk and 28 show a high age profile. Finally, GHG emissions per farm reach 121.19 tonnes of CO_2 equivalent and the N balance per farm is 1171.34 Kgs of N. Again, the majority of farms in the cluster are finishing farms (58.95%).

Cluster 4: the last cluster includes 120 farms (32.79% of the sample). These farms make, on average, €936.17 gross output/ha, of which €276.55 derives from the market (per ha). Only 10.8% of these farms are viable and 56% is market oriented. Almost all households have a high age profile (98.3%) but isolation risk is low at 6.7%. The productivity of labour ranges from €-51391.47 to €44843.82 and the

hours worked on farm are on average 1567.74. Regarding emissions the GHG emissions per farm are 115.87 tonnes of CO_2 equivalent and the N balance is 1638.49 kg of N. This is the only cluster where more than half of the farms are cattle rearing farms (52.5%).

1.8.4 Evaluation of performance

Similarly to dairy farms, the performance of cattle farms is evaluated by comparing the values of the indicators for each cluster to the optimal value of the indicator present in the dataset. The performance of farms is presented as a percentage of that optimal value for each cluster and for the entire sample in Table 12.

1.8.4.1 Economic performance

Based on the results we notice that overall the rates of efficiency in term of economic performance are low in all clusters, not exceeding 50% in any case. The exception is for market orientation where the percentages are over 50%, but are relatively low compared to the performance rates of dairy farms discussed previously. It is worth noticing that only 19.14% of all cattle farms are market oriented although some clusters show higher percentages. Figure 4 shows the comparison of the economic performance of the four clusters and the entire sample.

In comparing the clusters it is noticeable that the first two clusters share the highest rates of economic performance. The farms of the first cluster are best performers in terms of labour productivity and viability of investment with 42.85% and 72.46% efficiency rate respectively, followed by the second cluster that has much lower percentages but still higher than cluster 3 and 4. The farms of the second cluster show best performance in terms of land productivity, profitability and market orientation (47.41%, 36.40% and 67.08% respectively) again followed by cluster 1 that has similar percentages. The poorest performing cluster is cluster 4, which as mentioned represents the highest number of farms. Particularly for market orientation and viability of investment the performance rates (8.63% and 10.83%) are remarkably low compared to the optimal value and to the best performing cluster.

1.8.4.2 Environmental performance

Again, similarly to dairy farms the environmental performance of Irish cattle farms appears to be low. The performance rate for GHG emissions does not exceed 30% for the entire sample and 40% for the best performing cluster, while for N balance is only 17.2%, for the entire sample and 33% for the best performing cluster, compared to the optimal values. The performance rates across the clusters are within smaller ranges than dairy farms. In Figure 5 the comparison of clusters and the sample is presented.

The best environmentally performing cluster is the cluster 3 with 3 out 5 indicators having the highest rates among clusters, with 39.56% performance rate in GHG emissions/ha, 33% in N balance per farm and 8.2% in N balance per ha. However, when it comes to GHG emissions/ha this cluster comes second after cluster 4.Cluster 4 (representing the highest number of farms) also scores relatively high in environmental performance with the percentages being close to the previous cluster. As mentioned it has the highest score in GHG emissions/ ha and it is second in the rest of the environmental indicators. Specifically, the rates are 34.65% for GHG emissions /farm, 21.7% for N balance per farm and 5.9% for N balance/ha.

The least well performing cluster is the first with its performance rates being significantly lower than the previously mentioned clusters. Only 10.6% of the farms are efficient in terms of GHG emissions/farm, almost 25% lower than the best performing cluster. Also, efficiency in N balance is very low, with a rate of only 1.5% when it comes to n balance/farm.

Cluster 2 lies somewhere in between, leaning more towards the low performing side, in some indicators like N balance/ha (14.2%) and GHG emissions/ha (20.89%). Regarding emissions per farm, however, the indicators have better rates closer to those of cluster 4 (20.89% for GHG emissions/farm, 5.6% for N balance per farm).

1.8.4.3 Social performance

Cattle farm have an overall low social performance the only exception to this being the isolation risk, where for the overall sample the performance rate is 81.10%. Similarly to dairy farms, there is no cluster

227 performing best on all indicators. There is large disparity between clusters when it comes to household
228 vulnerability, with a difference of almost 40% between the first and the last cluster. There is also
229 remarkable variability in terms of high age profile with the rates ranging from 1.67% to 70.53%. It is also
230 noticeable that there are great variations within clusters with some of them performing very well on one
231 indicator and being the worst performers on another. Figure 6 shows the comparison of performance of
232 clusters and the entire sample.

234 Cluster 2 includes the least vulnerable farms (75.36% performance rate) with the highest education level
235 (55.07%) and the lowest isolation risk (94.2% efficiency rate). It is also second in terms of household
236 viability with only 98.86% of its farms being efficient. It is, however, the least well performing in work life
237 balance (15.01% efficient).In terms of high age profile the best performing cluster is cluster 3 with
238 70.53% efficiency rate on that indicator. However, all other indicators have low percentages and this
239 cluster is the worst performer in household vulnerability and isolation risk. Farms in cluster 4 perform
240 well in terms of isolation risk with the percentage being very close to cluster 2 (93.33%). Also, their
241 performance in household viability is very high exceeding 98%%, meaning that the demographics of this
242 cluster is very good. Cluster 2 is the most efficient in work life balance (24.51%) followed by cluster 4
243 with 22.33%. It also performs well in isolation risk as well with a rate of 82.93% and has an average
244 performance in household vulnerability with 57.32% of efficiency rate which is close to the rate for the
245 entire sample. Finally, cluster 3 is the one with the worst demographics, with only 29.47% of households
246 being viable.

1.8.4.4 Farming systems
248 Based on the results and the cluster comparison cattle farms could be classified according to their
249 performance as follows:

System 1:   Viable, market orientated farms with off farm income and high education levels

System 2:   Productive, work efficient farms

System 3:   Vulnerable households with good environmental performance and poor demographics

System 4:   Family, non-market oriented farms with average production

4. Discussion and conclusion

251 The results of this study indicate the strengths of the dairy sector, in economic terms, compared to the
252 low economic performance rates of the cattle sector. This concurs with the Food harvest 2020 report for
253 2014 (Department of Agriculture and Food and the Marine, 2014) that recognizes that although both
254 sectors' economic performance has been satisfactory in terms of meeting its milestones for the past few
255 years (with both exceeding €2 billion in value terms in 2013 and when combined accounted for over
256 two-thirds of the total €6.18 billion value of primary output), the dairy sector is economically healthy,
257 whereas the beef sector is more vulnerable, with low farm incomes and market orientation.
258 Dairy farms are divided into three groups, the good performers, the bad performers and the ones that
259 have reasonably good performance but could be improved (this group representing the majority of dairy
260 farms). Cattle farms are divided into four groups and the distinction is not as clear as in dairy farms.
261 There are various reasons justifying this, one of the most important being that cattle farms in Ireland are
262 often mixed with other farming activities that may be increasing production costs and may have labour
263 demands that do not directly relate to cattle production activities (e.g. sheep) (National Farm Survey,
264 2013). Further investigation may reveal that the additional farming activities of each cluster to explain in
265 more detail the variability in performance.
266 Cattle farms' grouping also distinguishes good and bad economic performers (cluster 1 and 2 showing
267 better rates than cluster 3 and 4). The productivity of land is almost equally high for the two best
268 performing groups (0.5% difference). Cluster 1 includes farms that make the most out of their labour
269 management (combines productivity of labour and viability of investment) and cluster 2 farms that

270 profitable and market oriented. The sample is divided by the NFS into cattle rearing and cattle finishing
271 farms. The best performing clusters have smaller percentages of rearing farms, with the group that best
272 manages labour consisting mostly of cattle finishing farms. Again, the largest part of the sample belongs
273 to the last two groups, indicating potential for improvement in the sector.
274 It is worth pointing out that the clusters that represent the majority of farms in both sectors are classified
275 between best and worst performing clusters and do not have best performance in any of the three
276 sustainability pillars. This is an important finding indicating that there is room for improvement for the
277 majority of Irish farms. As recognized by Department of Agriculture, Food and the Marine (Food Harvest
278 Report 2020) the Irish beef and dairy sectors have not reached their full potential and can improve
279 within the next few years.
280 In terms of environmental performance there is a great range in the performance rates but, generally
281 farms are performing poorly in both sectors. The cluster comparison for dairy farms shows a clear
282 distinction between economic and environmental performers. Regarding GHG emissions, the clusters
283 with best economic performers have the lowest environmental performance rates, and *vice versa*. This
284 is an expected result if we consider that good economic performance may be due to intensity of
285 production and intensive farms tend to produce more GHG emissions, whereas low economic
286 performance may imply the presence of more extensive systems with low inputs of N and low outputs of
287 CO_2. A similar pattern is observed for cattle farms. Viable, profitable farms tend to be poor
288 environmental performers, whereas less economically efficient farms are more efficient in environmental
289 terms. Intensification is the most apparent reason for this contradiction, similarly to dairy farms. This
290 contradicts previous findings (Jane Dillon et al., 2015, Ryan et al., 2014) that found negative correlations
291 between economic performance and GHG emissions in Irish dairy farms, meaning that good economic
292 performers are also environmentally efficient. It should be taken into consideration, however, that these
293 studies use measure sustainability at farm level, and they use GHG/KG of output as an indicator,
294 making the indicator industry specific. In this study we use GHG/farm and GHG/ha, as indicators of
295 GHG performance, which reflect the overall emissions of a farm. This difference of indicator unit may
296 explain the difference in results, given that it is usual for Irish farms to be multi-enterprise, results a fact
297 that should be taken into consideration when using GHG/farm or GHG/ha as indicators.
298 Dairy farms with good economic and good social performance are in the same cluster, with best rates
299 for both sets of indicators appearing in the same cluster. There may be a causal relation in this finding
300 as it is expected that farmers with off-farm income and high education levels will be more economically
301 orientated. For cattle farm the cluster that best performs in terms of market orientation and investment
302 viability is the one with more off-farm incomes, high education levels and low isolation risk. Again, this is
303 an expected result, given previous research (Lien et al., 2010, Dolman et al., 2012, Gerdessen and
304 Pascucci, 2013, Bernués et al., 2011). It is also noticed that the clusters with the most economically
305 efficient farms (for both sectors), consist of households with good demographics
306 To conclude, clustering Irish dairy and beef farms has proved to be useful for evaluating their
307 sustainable performance and for understanding the strengths and weaknesses of the sector. We
308 highlight the conflict between economic and environmental performance, the demographic weaknesses,
309 and the fact that most Irish farms do not belong in the best performing clusters. Examining how farming
310 systems are formulated through grouping of farms based on their performance we can identify targeted
311 areas of improvement at farming systems level.
312

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462

6.Tables & Figures

463

464

465 **Table 1: Studies using multivariate analysis to classify farm systems according to their performance**

Author	Study Area	Purpose of the research	System	Indicators	Methodology
Nahed et al. (2006)	Spain	Classify farms according to their economic sustainability	Dairy goat farms	Economy	PCA, statistical analysis
Ruiz et al. (2009)	France, Italy, Spain	To describe and classify dairy goat farms based on economy, labour area and management practices	Dairy goat farms	Economy, labour, area and management practices	PCA
Martel et al. (2008)	France	Identify connections between labour productivity and pig reproduction	Pig farms	Saw productivity and fertility, work load distribution, reproduction management.	Factorial analysis
Gaspar et al. (2008)	Spain	Farm description and typology	Sheep farms	Size, intensity, labour, capital investment, stocking rates, profit.	PCA, HCA, Statistics
Aggelopoulos et al. (2009)	Greece	Develop farm typology according to performance	Pig farms	oestrus return rate, slaughtering age and saw replacement rate with structural farm characteristics	Cluster analysis
Toro-Mujica et al. (2012)	Spain	Identify types of farms in Spain, for the evaluation of their economic and technical performance	Organic dairy farms	Economy, subsidies, size, stocking rates	PCA, CA, Statistics
Martin-Collado et al. (2014)	Spain	Develop a socio-economic farm typology	Traditional cattle breeders	Age, education, cultural capital, economy, land ownership, objectives subsidies	Canonical analysis, HCA
Groot et al. (2006)	Netherlands	group farms based on the changes in Nitrogen use efficiency in a period of 6 years	Dairy farms	Structure, Nitrogen Use efficiency	Non-hierarchical cluster analysis
Michos et al. (2012)	Greece	Identify types of farms according to environmental performance	Peach orchards	Production variables, Nitrogen use	PCA, CA
Morgan-Davies et al. (2012)	Scotland	Classification of farms	Hill side sheep farming	Structural and demographic characteristics	Principal Co-ordinate analysis
Abas et al. (2013)	Greece	Evaluation of farm performance	Sheep farms	Environmental indicators	Categorical PCA, cluster analysis

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467   **Table 2: Economic, environmental and social indicators**

Indicator	Measure	Unit
Economic		
Productivity of Land	Gross Output per hectare	€/hectare
Profitability	Market based Gross Margin per hectare	€/hectare
Productivity of Labour	Income per unpaid labour unit	€/labour unit
Market Orientation	Output derived from the market	% of total output[1]
Viability of Investment	Farm is economically viable[2]	1=viable, 0= not viable
Environmental		
GHG emissions/ farm	IPCC estimate/ farm	Tonnes CO_2 equivalent/farm
GHG emissions/ ha	IPCC estimate/ ha	Tonnes CO_2 equivalent/ha
Nitrogen (N) balance/ha	Risk to water quality	Kg N surplus/hectare
Nitrogen (N) balance/farm	Risk to water quality	Kg N surplus/farm
Emissions from fuel and electricity	CO_2 equivalent/kg output	Kg CO_2 equivalent/kg output
Social		
Household Vulnerability	Farm business is not viable - no off-farm employment (Binary =1 if vulnerable)	% of total sample
Education Level	Agricultural Educational attainment (0=N, 1=Y 2= in training)	% of total sample
Household viability	Household has a member < 45 years old (Binary =1 if viable)	% of total sample
Isolation Risk	Farmer lives alone (Binary =1 if vulnerable)	% of total sample
Work Life Balance	Work load of farmer	Hours worked on farm

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[1] Total output includes subsidies

[2] An economically viable farm is one that has the capacity to remunerate family labour used on the farm at the average agricultural wage and the capacity to provide an additional 5% return on non-land assets.

Table 3: Calcualted indicators weights base on component loadings

Indicators	Weights			
	Comp1	Comp2	Comp3	Comp4
Productivity of land	0.161			
Profitability	0.114			
Productivity of labour		0.278		
Market Orientation	0.094			
Viability of investment		0.361		
GHG emissions per farm			0.453	
GHG/ha	0.172			
Emissions fuel and electr.		0.167		
N_balance (kgs Ha)	0.115			
N_balance farm			0.501	
Household vulnerability		0.356		
Education level				0.359
Household viability				0.409
Isolation risk				0.196
Work life balance				0.171

Table 4: Principal Component loadings resulting from PCA for dairy farms

Indicator	Comp 1	Comp 2	Comp 3	Comp 4
GHG/ha	.931			
Productivity of land	.902			
N_balance (kgs Ha)	.762			
Profitability	.760			
Market Orientation	.688			
Viability of investment		.909		
Household vulnerability		-.902		
Productivity of labour		.799		
Emissions fuel and electr.		-.619		
N_balance farm			.880	
GHG emissions per farm			.837	
Household viability				.696
Education level				.654
Isolation risk				-.484
Work life balance				.452

Table 5: Descriptive statistics of qualitative indicators for the clusters of dairy farms and representation of farms per cluster

Indicator	All sample		Cluster1		Cluster2		Cluster3	
	N	%	N	%	N	%	N	%
Viability of investment	186	72.1	49	83.1	21	56.8	116	71.6
Household vulnerability	64	24.8	8	13.6	14	37.8	42	25.9
Education level	189	73.3	49	83.1	12	32.4	128	79.0
Household viability	233	90.3	59	100.0	14	37.8	160	98.8
Isolation risk	15	5.8	5	8.47	10	27.0	0	0
Total	**258**	**100**	**59**	**23**	**37**	**14**	**162**	**63**

474   **Table 6: Descriptive statistics for the quantitative indicators for the three dairy farm clusters and for the entire dairy farm sample**

Indicator	All sample			Cluster1			Cluster2			Cluster3		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Productivity of land	953.29	6403.72	3061.65	1738.56	6403.72	3436.83	1218.07	5501.49	2796.77	953.29	5407.90	2985.51
Profitability	-111.85	3557.51	1440.57	561.70	3269.76	1547.07	-111.85	2531.66	1284.39	-42.97	3557.51	1437.45
Productivity of labour	-67038.93	141725.42	40118.11	-67038.93	140645.59	51886.68	-6007.98	100692.59	33366.20	-10043.41	141725.42	37374.13
Market Orientation	.09	.96	.85	.77	.96	.88	.70	.96	.85	.09	.94	.85
GHG emissions/farm	60.77	1680.73	469.38	402.86	1680.73	824.82	69.60	854.77	355.80	60.77	691.27	365.87
GHG/ha	2.20	14.39	7.89	5.00	14.39	8.91	2.24	13.55	7.24	2.20	13.62	7.67
Emissions/fuel-elect.	.01	.15	.05	.02	.12	.05	.01	.13	.05	.02	.15	.05
N balance (kgs Ha)	0	478.21	142.07	78.77	478.21	180.88	.00	308.98	125.69	.00	293.75	131.68
N balance farm	0	30226.10	8445.99	7189.34	30226.10	16428.68	.00	16076.94	5880.61	.00	13272.56	6124.63
Work life balance	0	3700.00	2461.54	1040.00	3600.00	2599.66	300.00	3000.00	2079.27	.00	3700.00	2498.55

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Table 7: Perfromance rates (%) through comparison of cluster mean with the optimal indicator values (dairy farms)

Indicator	Optimal value	All clusters	Cluster1	Cluster2	Cluster3
		Efficiency %	Efficiency %	Efficiency %	Efficiency %
Productivity of land	6403.72(100%)	47.87%	53.67%	43.67%	46.62%
Profitability	3557.51(100%)	40.55%	43.49%	36.10%	40.41%
Productivity of labour	141725.42(100%)	28.32%	36.61%	23.54%	26.37%
Market Orientation	0.96(100%)	85.38%	88.09%	84.65%	84.54%
Viability of investment	1.00(100%)	71.98%	83.05%	56.76%	71.60%
GHG /farm	60.77(100%)	12.93%	7.37%	17.08%	16.61%
GHG/ha	2.20(100%)	27.85%	24.70%	30.37%	28.68%
Emissions –fuel/electr	0.00(100%)	18.75%	17.92%	20.80%	18.68%
N_balance (kgs Ha)	21.95(100%)	15.14%	12.14%	16.99%	16.26%
N_balance/ farm	851.38(100%)	10.07%	5.18%	14.48%	13.90%
Household vulnerability	0.00(100%)	75.10%	86.44%	62.16%	74.07%
Education level	1.00(100%)	73.26%	83.05%	32.43%	79.01%
Household viability	1.00(100%)	90.27%	100.00%	37.84%	98.77%
Isolation risk	0.00(100%)	94.16%	91.53%	72.97%	100.00%
Work life balance	530.00(100%)	78.46%	79.61%	74.51%	78.79%

478 **Table 8: Principal Component loadings resulting from PCA for cattle farms**

Indicator	Weights			
	Comp1	Comp2	Comp3	Comp4
Productivity of land	.132			
Profitability		.153		
Productivity of labour		.362		
Market Orientation	.102			
Viability of investment		.367		
GHG emissions per farm			.317	
GHG/ha	.176			
Emissions from fuel and electricity		.110		
N_balance (kgs Ha)	.108			
N_balance farm			.297	
Household vulnerability		.217		
Education level				.164
Household viability				.436
Isolation risk				.190
Work life balance			.417	

479 **Table 9: Principal Component loadings resulting from PCA for cattle farms**

Indicator	Comp1	Comp2	Comp3	Comp4
GHG/ha	.908			
Productivity of land	.786	.		
N_balance (kgs Ha)	.713			
Market Orientation	.685			
Viability of investment		.885		
Productivity of labour		.882		
Household vulnerability		-.677		-.
Profitability	.	.579		
Emissions from fuel and electricity		-.488		.
Hours worked on farm			.786	
GHG emissions per farm	.	.	.689	
N_balance farm	.		.669	
Household viability				.763
Isolation risk				-.511
Education level				.464

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482 **Table 10: Descriptive statistics of qualitative indicators for the four clusters of cattle farms and representation of farms per cluster**

		Indicators					Type of farm		
		Viability of investment	Household vulnerability	Education level	Household viability	Isolation risk	Rearing	Finishing	Total no farms
All sample	N	118	163	148	265	69	145	221	**366**
	%	32.2	44.5	40.4	72.4	18.9	39.62	60.38	**100**
Cluster1	N	50	17	42	62	4	11	58	**69**
	%	72.5	24.6	61.9	89.9	5.8	15.94	84.06	**18.85**
Cluster2	N	29	35	27	57	14	32	50	**82**
	%	35.4	42.7	33.9	69.5	17.1	39.02	60.98	**22.40**
Cluster3	N	26	61	21	28	43	39	56	**95**
	%	27.4	64.2	22.2	29.5	45.3	41.05	58.95	**25.96**
Cluster4	N	13	50	58	118	8	63	57	**120**
	%	10.8	41.7	48.3	98.3	6.7	52.50	47.50	**32.79**

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484 **Table 11: Descriptive statistics of qualitative indicators for the four clusters of cattle farms and for the entire cattle farm sample**

|	All sample			Cluster1			Cluster2			Cluster3			Cluster4		
Indicator	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Maxi**	**Mean**	**Min**	**Max**	**Mean**
Productivity of land	300.35	3520.94	1230.35	800.20	3520.94	1650.54	579.18	2872.24	1669.30	300.35	2336.64	917.89	333.94	2354.05	936.17
Profitability	-459.18	1798.56	429.95	187.61	1291.36	590.65	-208.74	1798.56	654.67	-191.24	801.97	313.03	-459.18	998.01	276.55
Productivity of labour	-51391.47	164108.18	19351.50	4092.89	126039.92	39838.38	-16538.50	164108.18	21459.22	-13779.16	159448.94	16964.51	-51391.47	44843.82	8020.98
Market Orientation	.20	1.00	.60	.38	.81	.65	.43	1.00	.67	.25	.92	.54	.20	.84	.56
GHG emissions/farm	42.73	1270.74	178.24	166.76	1270.74	403.18	50.94	368.35	146.35	42.73	349.64	121.19	48.03	403.28	115.87
GHG/ha	1.02	8.89	3.59	2.44	8.35	4.53	2.42	8.89	4.90	1.02	4.80	2.59	1.09	6.91	2.95
Emission-fuel /elect.	.00	.41	.08	.01	.18	.07	.01	.31	.06	.00	.17	.06	.02	.41	.11
N_balance (kgs Ha)	.00	211.97	47.08	.00	177.88	74.47	.00	211.97	58.43	.00	69.35	25.02	.00	133.60	41.03
N_balance farm	.00	25816.67	2408.18	.00	25816.67	6280.89	.00	5340.72	1708.71	.00	5011.60	1171.34	.00	10294.16	1638.49
Work life balance	.00	3300.00	1802.99	.00	3000.00	2332.45	150.00	3000.00	1428.04	100.00	3300.00	2032.78	50.00	3000.00	1567.74

Table 12: Perfromance rates (%) of cattle farm clusters compared to the optimal indicator values

	Optimal value	All clusters %Efficiency	Cluster1 %Efficiency	Cluster2 %Efficiency	Cluster3 %Efficiency	Cluster4 %Efficiency
Productivity of land	3520.94 (100%)	35.00%	46.88%	**47.41%**	26.07%	26.59%
Profitability	1798.56(100%)	23.94%	32.84%	**36.40%**	17.40%	15.38%
Productivity of labour	92975.39(100%)	19.14%	**42.85%**	23.08%	18.25%	8.63%
Market Orientation	1.00(100%)	59.74%	65.39%	**67.08%**	53.93%	56.14%
Viability of investment	1.00(100%)	32.33%	**72.46%**	35.37%	27.37%	10.83%
GHG / farm	42.73(100%)	23.93%	10.60%	29.20%	35.26%	**36.88%**
GHG/ha	1.02(100%)	28.49%	22.61%	20.89%	**39.56%**	34.65%
Emissions- fuel/electr.	0.00(100%)	5.3%	5.7%	**7.2%**	6.9%	3.7%
N_balance / Ha	9.45(100%)	17.2%	12.0%	14.2%	**33.0%**	21.7%
N_balance/farm	96.30(100%)	4.0%	1.5%	5.6%	8.2%	5.9%
Household vulnerability	0.00(100%)	55.34%	**75.36%**	57.32%	35.79%	58.33%
Education level	1.00(100%)	37.70%	**55.07%**	29.27%	21.05%	46.67%
Household viability	1.00(100%)	72.33%	89.86%	69.51%	29.47%	**98.33%**
Isolation risk	0.00(100%)	81.10%	**94.20%**	82.93%	54.74%	93.33%
Hours worked on farm	350.00(100%)	18.89%	15.01%	**24.51%**	17.22%	22.33%

487 **Figure 1: Graphic representation of the economic perfromance of the dairy farm clusters**
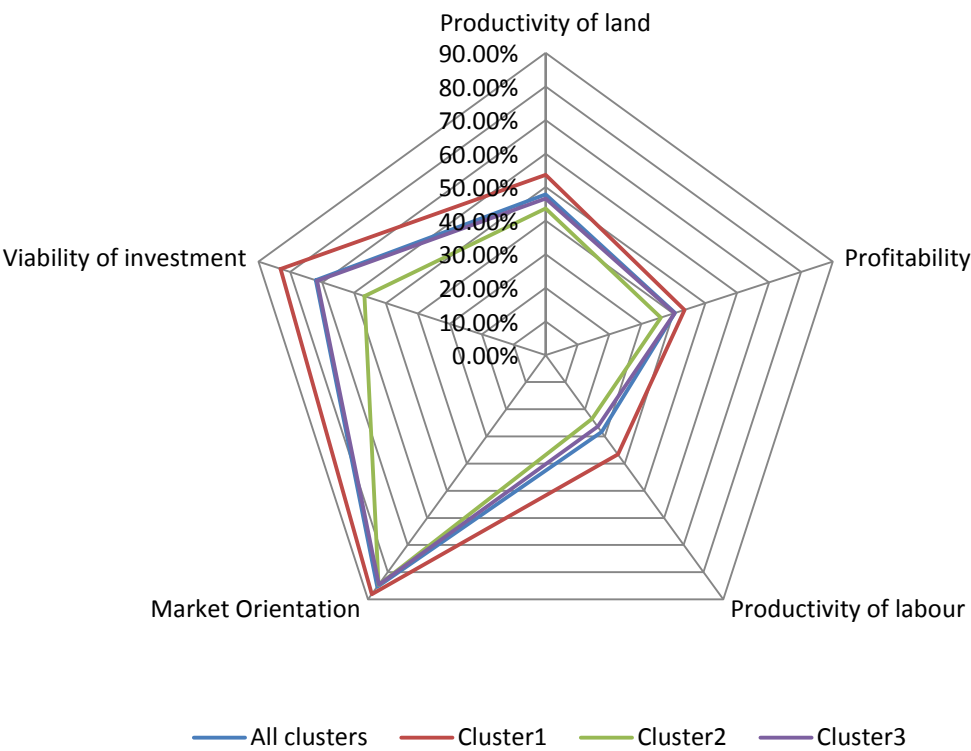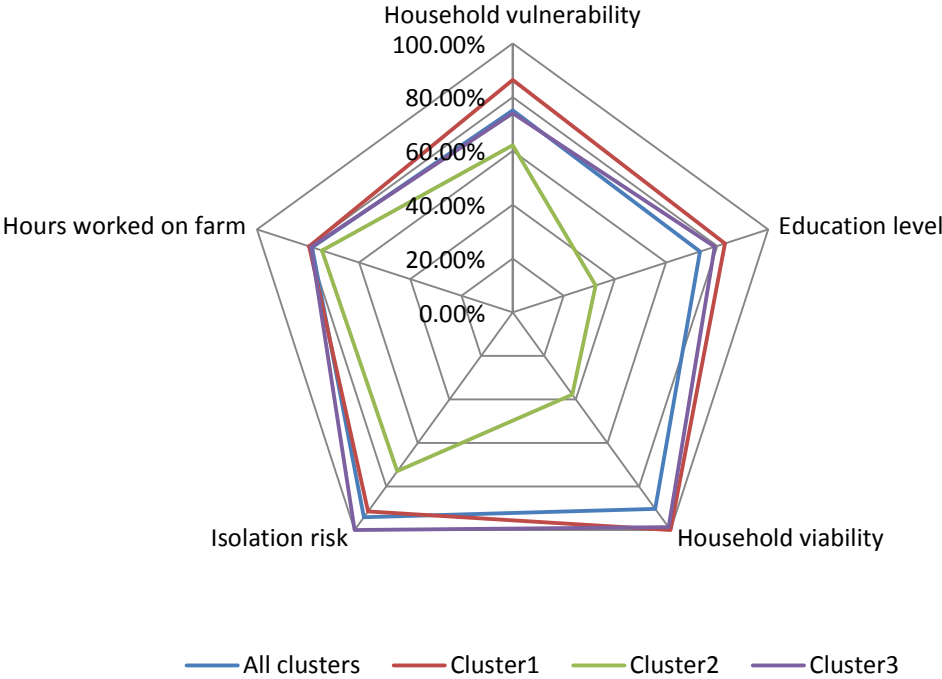

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489 **Figure 2: Graphic representation of the environmental perfromance of the dairy farm clusters**
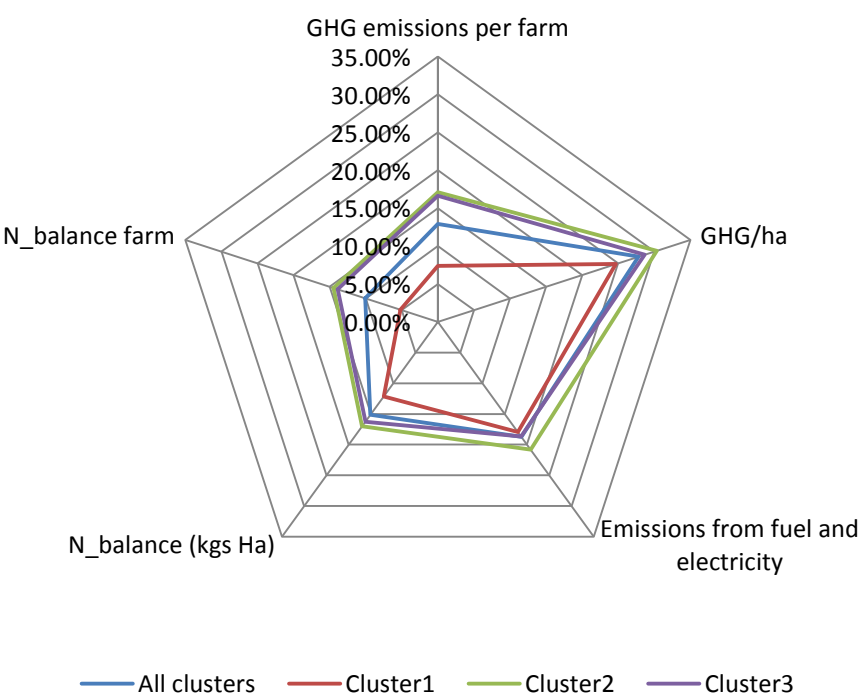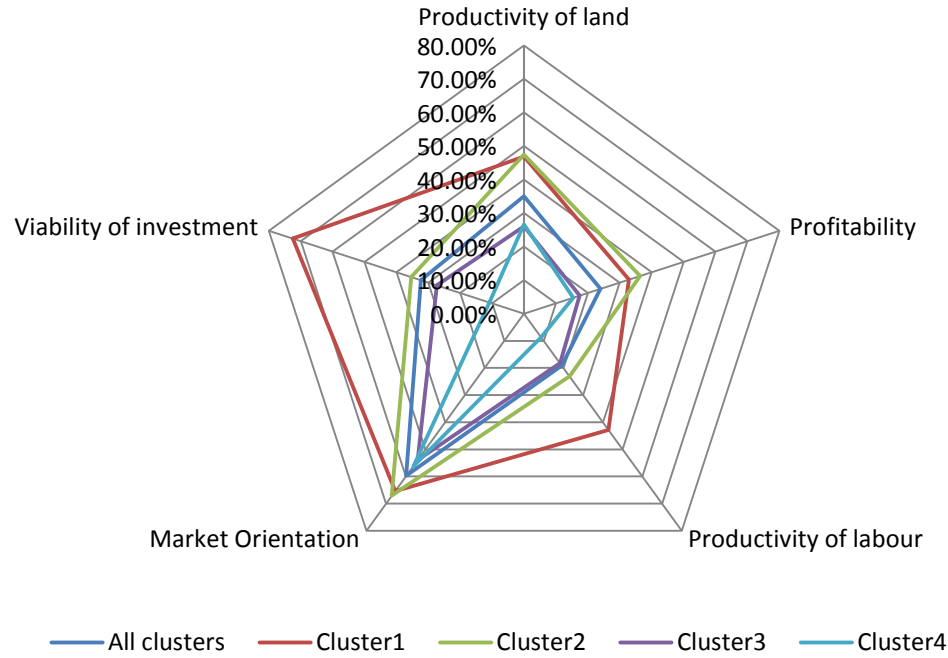

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492   **Figure 3: Graphic representation of the social perfromance of the dairy farm clusters**
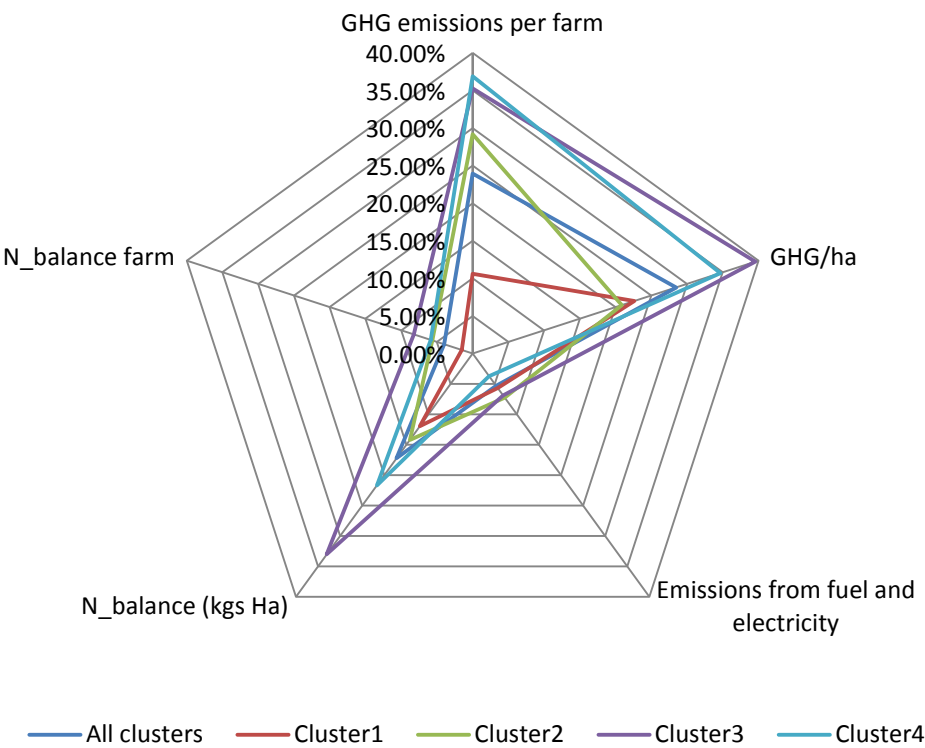

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494   **Figure 4: Graphic representation of the economic perfromance of the cattle farm clusters**
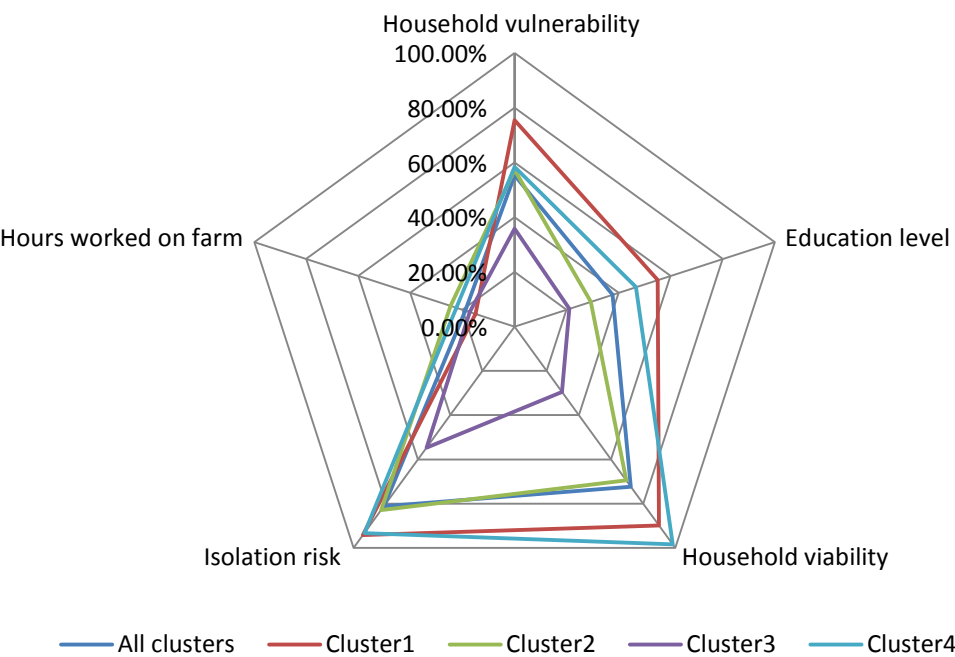

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497 **Figure 5: Graphic representation of the environmental perfromance of the cattle farm clusters**

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499 **Figure 6: Graphic representation of the social perfromance of the cattle farm clusters**

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