Paper Title	Nitrogen use efficiency of milk production – A comparative study of the Republic of Ireland and the Netherlands

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Abstract	***200 words max***
Policymakers are increasingly interested in the sustainability of milk production due to the intensive nature of the production system and the associated risk to the environment. This study uses national extensions of the EU Farm Accountancy Data Network to derive nationally representative farm gate level nitrogen use efficiency indicators for specialist dairy farms in the Republic of Ireland and the Netherlands between 2006 and 2014. The Republic of Ireland and the Netherlands are of particular interest as dairy production is an important sector in both countries and milk production has grown in these two Member States following the removal of the EU milk quota regime in 2015. Results indicate relatively similar N balances per hectare across both countries with the Netherlands returning significantly higher N use efficiency and lower N surplus per kg of milk solids produced. Results generally show improvements in nutrient use over the study period across both countries, due to efficiency gains, but highlight differences between a grazed grass system and a more concentrate feed high input orientated system and illustrate the need for the development of a life-cycle analysis approach to fully capture the full scale environmental efficiency of differing systems of milk production.	

Keywords	Nitrogen balance, Nitrogen use efficiency indicators, EU FADN
JEL Code	Environmental Economics: Pollution Control Adoption and Costs Q520

Nitrogen use efficiency of milk production – A comparative study of the Republic of Ireland and the Netherlands

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INTRODCUTION

Feeding a growing global population while concurrently complying with environmental legislation is one of the great challenges facing modern society. The dairy sector, in particular, is coming under increasing pressure to improve environmental performance due to the resource intensive nature of production systems. This is especially true in the European Union where, since the removal of the milk quota system in 2015, production is no longer constrained yet member states are bound by environmental legislation such as the Water Framework Directive (WFD) which sets deadlines for EU waters to achieve good status (European Parliament and Council, 2000).

Now under the umbrella of the WFD, the EU Nitrates Directive (ND) (OJEC, 1991) was one of the first pieces of water quality legislation introduced into the EU statute books in 1991. The ND aims to optimise nutrient use on agricultural land and to avoid incidental losses to water bodies (Jordan et al., 2012). Although initial implementation of the ND was slow, it has been ratified into national legislation across member states. The directive sets limits on the magnitude, timing and placement of inorganic fertiliser and organic manures. In EU member states that have adopted a whole country approach, the regulations represent the most complete set of measures to manage diffuse transfers of nutrients from agricultural land (Surridge and Harris, 2007; Jordan et al., 2012). The Republic of Ireland first implemented the EU Nitrates Directive in 2005-06 on a whole country basis. In the Republic of Ireland the Good Agricultural Practice (GAP) regulations put this into effect since 2006, these regulations constrain the use of N on farms to agronomic optima and ensure that infrastructure and nutrient management practices are in place to minimise losses to the aquatic environment. These regulations include closed periods for the application of slurry (liquid manure) from mid October to mid to mid/late January and setting a stocking rate limit of 170 kg organic N ha^{-1} as standard[1]. Grassland farmers in the Republic of Ireland can however apply for a derogation or exemption from this limit to allow stocking rates at levels up to 250 kg organic N ha^{-1}. This necessitates them to meet more stringent recording and reporting requirements and has principally been availed off by dairy farmers. The Netherlands started implementation of the ND in 1994 but regulations became more restrictive from 2006 onwards. The national manure laws defines application standards (limits) for the use of minerals from fertilizers and organic manure. These standards are soil and crop dependent. Regulations also prescribe that the spreading of liquid manure is restricted to the period of the 1st of September until mid of February. Like in Ireland dairy farmers can apply for derogation to allow for application up to 250 kg organic N ha^{-1}. The main conditions are a minimum of 80% of grass land, the need for a manure application plan and periodic soil sampling. In practise, the large majority of dairy farmers have applied for derogation.

[1] In the Republic of Ireland one dairy cow is equivalent to 85 kg organic N yr^{-1}. In the Netherlands this value depends on milk production and urea content of the milk. At a milk production of 8,000 kg cow^{-1} yr^{-1} and a urea content of 23 mg kg^{-1} (values close to Dutch averages) this value is 118 kg organic N yr^{-1}

Inefficient use of nutrients in agricultural production has significant implications for the aquatic environment as well as economic consequences for farmers (Oenema and Pietrzak 2002; Buckley and Carney 2013). The European Environment Agency (2012) notes that despite progress, diffuse pollution from agricultural production is still significant in over 30-40% of Europe's rivers, coastal waters, lakes and transitional waters. Jordan et al. (2012) note that as a package of measures to mitigate eutrophication impacts in water bodies, the ND has twin objectives of increasing the efficiency of nutrient use and decreasing loss from land to water. Hence, policymakers are increasingly interested in the environmental efficiency and performance of different farming systems, especially dairying, and seek reliable indicators of improvements in sustainability (Brouwer 1998; Halberg et al. 2005). This is particularly relevant in a post milk quota environment where milk production across Europe is growing and especially at a rapid pace in some Member States with favorable conditions for milk production.

Gerber et al. (2014) notes that several frameworks have been developed for the assessment of nutrient use in livestock based systems. These can be broadly classified into four categories: nutrient balance, nutrient use efficiency, material flow analysis and life cycle assessment. Material flow analysis and life cycle assessment provide much more information on environmental pressure and impacts but they have a major drawback in being data intensive. Nutrient balance and nutrient use efficiency indicators are less data intensive and have been widely used as a means of assessing farm level nutrient management efficiency while also providing an indicator of environmental pressure for water quality. Nutrient balance and use efficiency indicators rely on the same data to measure nutrient inputs onto a farm, mainly through imported feeds and fertilizers, and subtract quantities exported from the farm through outputs such as milk, meat, crops and organic manures (Ondersteijn et al. 2003; Nevens et al. 2006; Bassanino et al. 2007; Treacy et al. 2008; Buckley et al., 2015; 2016a,b).

The objective of this study is to use nationally representative farm-level data from Ireland and the Netherlands to derive and compare farm gate level nutrient use efficiency indicators for nitrogen across specialist dairy farms over a 9 year study period. This is the first time that a standardized approach and harmonized dataset has been used to develop indicators across 2 countries in the scope of the EU FADN. The Republic of Ireland and the Netherlands are selected as two Member States that were expected to expand milk production following the removal of the milk quota policy and hence the sustainability of this expansion is of particular interest. The Irish government has set the ambitious target to increase national milk production by 50 percent in the first five years following milk quota removal (DAFM 2010). Predictions for milk expansion in the Netherlands vary from less than 10% (Jongeneel et al, 2013) to more than 20% (Jongeneel and Van Berkum, 2015) compared to the national milk quota of 2014. Because of the introduction of phosphate rights in 2017-2018 in the Netherlands, it is expected that the growth in milk production will be reduced. It should be noted that the current Dutch milk production is more than twice the Irish production: so, expressed in billions kg of milk, the growth could be quite comparable.

METHODOLOGY

Data

The EU FADN data are used for this analysis. FADN, a European system of harmonized farm level data collection, is conducted annually to collect structural and accountancy data on farms across the EU in order to monitor the income and business activities of agricultural holdings and to evaluate the impacts of the Common Agricultural Policy (CAP). Holdings are selected to take part in the survey on the basis of sampling plans established at the level of each region in the Union. The methodology aims to provide representative data along three dimensions: region, economic size and type of farming. FADN does not cover small or semi-subsistence farms but focuses on commercial farms which produce for the market. For 2013, the sample consisted of approximately 83,000 holdings in the EU-27, which represents nearly 5.0 million farms (40%) out of a total of 12.2 million farms. This is approximately 90% of the total utilized agricultural area (UAA) and about 90% of the total agricultural production. The FADN is the only harmonized source of micro-economic data on farming in Europe. In this study we use the national extensions of FADN which also cover the environmental performance of farms. This analysis was conducted through the EU-FP7 Flint project, which aims to extend the traditional FADN dataset to include more environmental and social indicators.

The scope of the FADN survey covers only farms whose size exceeds a minimum threshold so as to represent the largest possible proportion of agricultural output, agricultural area and farm labor, of holdings run with a market orientation. It is important to note that the minimum threshold for the sample varies by country to reflect the structure of farming in each Member State. In Ireland the minimum threshold for participation in FADN is €8,000 of standard output, or approximately 6 dairy cows, the threshold for the Netherlands is €25,000 of standard output (8 to 9 dairy cows).

Table 1 presents summary statistics for the samples used in this analysis. In both cases a balanced panel of dairy farms was generated consisting of 104 farms for Ireland and 122 for the Netherlands. The Irish sample can be aggregated to represent 6,767 farms nationally or approximately one-third of the total dairy farming population. While the Dutch sample represents 9,107 farms or just over 50% of the Dutch dairy farming population. A balanced panel approach was used across each country to track year on year changes across a consistent cohort of farmers devoid of sampling frame issues.

Sample Profile

Farm size, in terms of land area, is similar in Ireland and the Netherlands with more of the land area devoted to grassland in the Republic of Ireland. On average 96 per cent of farm area was devoted to grassland in the Republic of Ireland compared to 83 per cent in the Netherlands. Ireland has a climate that is well suited to grass growth between April and October (Hennessy and Roosen, 2003) and one of its major competitive advantages is the potential to produce between 12 and 16 tons of grass dry matter per hectare over a long growing season (O'Donovan et al., 2010; Laepple et al. 2012). Hence cows in Ireland tend to be mostly fed off grass with a relatively low use of concentrate feeds but also resulting in relatively lower output per cow. Natural conditions for forage production (grass and maize) on own farmland are also good in the Netherlands (Reijs et al., 2013). Dutch dairy farmers apply more manure and fertilizer and face lower prices per kg of concentrates than in other countries, due to lower transportation costs of overseas ingredients that arrive at the port of

Rotterdam. Prices of purchased roughage tend to follow the prices of concentrates which eases the purchase of roughage in the Netherlands. These factors explain the higher stocking rates and higher milk production per cow in the Netherlands. Average dairy herd size is about one-third larger in the Netherlands and stocking rates are also circa 10 per cent higher than in the Republic of Ireland. It has been argued that the relatively restrictive rules governing the transfer of quota from exiting to expanding farmers in Ireland in the 1990s and 2000s hampered structural change and resulted in relatively smaller herd sizes in Ireland than in the Netherlands or Denmark where quota trade was not as restricted (Donnellan et al 2009). Milk solids produced per cow and per hectare in the Netherlands are almost double those achieved in Ireland, but in both countries output per cow and per hectare has been following an upward trajectory over the study period as outlined in Table 1.

<Table 1>

Indicators derivation

Farm level indicators are generally derived either at the farm gate level or on a whole farm basis. The farm gate approach limits the analysis to nutrient imports and exports over which the farmer has direct control (passes through the farm gate). This eliminates the need to account for elements outside the control of the farmer such as biological fixation, atmospheric deposition and mineralization of nutrients in soils and losses to air and water. Farm gate level indicators are acknowledged as useful in assessing nutrient use and environmental pressure (Schroder et al., 2004).

Three indicators were derived at the farm gate level for each farm in both countries for each year in the study period. The first was an N balance, this is an indicator of pressure on environmental quality all other things being equal, and is derived by subtracting the total quantities of N exported from the total quantities imported on a per hectare basis. Nitrogen use efficiency (NUE) was the second indicator derived. This is a measure of agronomic efficiency and based on the proportion of N retained within the production system and is derived by dividing total quantities (kg) of N exported by total quantities imported, expressed as a percentage. The final indicator derived was N surplus per kilogram of milk solids produced. This is estimated from surplus of N (imports – exports on a kg basis) generated by dairy[2] enterprise per kilogram of milk solids (protein and butterfat) produced. This is analogous to emissions per unit of production.

The three indicators require a full audit of N imports and exports passing through the farm gate. The main N imports through the farm gate in this study were those

[2] Where other livestock or crop enterprises exist, allocation of surplus is based on livestock unit equivalents and area dedicated to enterprise.

contained in chemical fertilizers, concentrate feeds, forage feeds, livestock purchases and organic manures in the case of the Netherlands. Exports of N primarily included milk, livestock, cereal / forage crops and organic manures in the case of the Netherlands. Transport of manures in the Netherlands are closely monitored and sampled because of national manure laws. Table 2 provides an overview of the standardized approach used for both countries in converting imports and exports to kg of N ha^{-1}. The coefficients for milk and animals have been derived from the Netherlands Enterprise Agency (2015).

<Table 2>

RESULTS

Results in Table 3 confirm that the Netherlands is a higher N inputs and output based system. Total N inputs for the Republic of Ireland ranged from circa 191 to 222 kg N ha^{-1} over the period compared to 253 to 273 kg N ha^{-1} in the Netherlands. However, it is notable that in the Netherlands, N imports through fertilizers and concentrates are similar in magnitude with each component responsible for 44% of total N imports on average. This was in contrast to Republic of Ireland based dairy systems where fertilizers accounted for 80 per cent of total N imports with concentrates on average responsible for a further 16 per cent. Typically N imports in the Republic of Ireland were circa 77 per cent of total imports in the Netherlands.

Total N exports for the Republic of Ireland dairy farms in the sample ranged from circa 40 to 45 kg N ha^{-1} over the period compared to 100 to 130 kg N ha^{-1} in the Netherlands. Results indicate that on average 80% of exports in Republic of Ireland related to milk off-takes compared to 66% for the Netherlands. Livestock based N exports accounted on average for 19% of total off-takes in the Republic of Ireland compared to 11% in the Netherlands. Notably, 20% of total exports of N in the Netherlands[3] are accounted for by organic manure moved off farm, this is not a typical practice in the Republic of Ireland[4] and in fact no farm in the Irish sample exported organic manure. Typically total N exports in the Republic of Ireland were 40% of that in the Netherlands.

[3] This is highly regulated and there are significant economic costs and incentives associated with import/export and application of this manure.

[4] As reported by Hennessy et al., (2011) a total of 6% of dairy farms imported or exported organic manures. No data was available on the volumes imported or exported, hence this cohort were excluded from the analysis.

Farm gate N balances were broadly similar across both countries ranging from 148–178 kg N ha^{-1} for the Republic of Ireland compared to 143–160 kg N ha^{-1} for the Netherlands. As shown by Table 3, N balances in the Republic of Ireland tended to be more temporally volatile, this is associated with weather volatility (rainfall), which tends to significantly influence balance and use efficiencies in grazing orientated systems (Buckley et al., 2016a,b). Due to the nature of the dairy systems in the Netherlands (higher levels of imported feeds, export of organic manure, animal genetics) N use efficiencies were significantly higher on average (80 per cent higher on average). This was also reflected in farm gate level N surpluses per kilogram of milk solids.

Table 3 indicates that although temporally volatile (especially in the case of the Republic of Ireland) results show a general trend of declining N balances and increasing N use efficiency over the study period across both countries. This is particularly reflected in the N surplus per kg of milk solids (which is analogous to emissions per unit of product) which decreased by circa 11% for the Republic of Ireland and 22% for the Netherlands between the start (2006) and end of the study period (2014).

DISCUSSION

The national FADN systems have been used previously to evaluate the environmental performance of farms for instance nutrient use efficiency on Irish farms (Buckley and Carney, 2013; Buckley et al., 2015, 2016a,b) and on Dutch farms (Daatselaar et al., 2015) as well the carbon efficiency of milk production in Ireland (O Brien et al 2015) and the Netherlands (Dolman et al., 2014). However to date this data has not been used to generate international comparisons of environmental performance of milk production using harmonized methods and datasets. The EU-FP7 FLINT project has contributed to the development of the EU FADN and has resulted in data to a level where a standardized approach to generate farm gate balances and N use efficiency indicators is possible. This required additional data to be collected across both countries and is different to other studies in this area which have used the EU FADN to-date which tended to rely on some modeling or imputing elements of the inputs or outputs (Dalgaard et al. 2006; Nevens et al. 2006). FLINT aims to broaden the EU FADN system to cover more environmental and other sustainability issues. Such a broadening is required to be able to also monitor and evaluate the broader set of objectives of the CAP. The FLINT project has evaluated the possibilities to extend the data collection in each of the 9 partner countries. On a pilot of 1000 farms, farm level data has been collected to calculate environmental, social and economic indicators. This study could not have been conducted without such additional data collection. In the EU FADN system no information is available on quantities on important flows such as fertilizers and concentrate feed, inferring these from the financial values would lead to much less reliable figures.

Results generally show improvements in overall nutrient use efficiency over the study period across both countries. Results indicate that the Netherlands has similar N balances to Ireland, but significantly higher N use efficiencies and lower N Surplus per kg milk solids. While the Netherlands is well-known for its' efficiency of production system (OECD, 2015; Barnes and Revoredo Giha, 2011) some of the disparity in environmental performance reported here requires further elaboration and context. While farm gate balances and nutrient use efficiencies are well established for over 2 decades (Aarts et al., 1992), there are several limitations associated with these metrics as highlighted by Godinot et al., (2014). These limitations are particularly relevant in this comparative study when comparing two distinct production systems, namely the Irish grazing orientated system to the higher feed importing and organic manures export system in the Netherlands. Firstly, as highlighted earlier, farm-gate level indicators do not consider all N inputs into the farm system such as symbiotic N fixation, atmospheric N deposition or changes in soil organic matter stocks. Secondly, these indicators exclude losses associated with the production of inputs that occur outside the farm gate e.g. purchased feed crops produced elsewhere. This is a significant difference between the comparative countries here as the Netherlands is purchasing much higher levels of concentrates and forage crops compared to the Republic of Ireland, three times the quantity on average.

Thirdly, in mathematical terms NUE increases when the same value is added to both the numerator and denominator. This therefore leads to potential ‘‘purchase resale’’ bias where NUE is higher for systems relying on external inputs compared to systems that are more self-sufficient. This is relevant in a comparison between the Republic of

Ireland and the Netherlands, where farms in the Republic of Ireland are using mainly chemical fertilizer to pre-dominantly grow their own feed. Fourthly, these indicators do not distinguish among outputs valuing 1 kg of N output as manure is equivalent to 1 kg of animal/crop based output. By considering that all N outputs have the same value; NUE for example expresses the efficiency of minimizing N losses and not of producing agricultural products. Indeed, some have argued for excluding manure output from the N efficiency calculation, as it is not an end product for human consumption (Simon et al., 2000). Others have argued that when manure output exceeds manure input it should be represented as a negative net input instead of a positive net output as organic manure exports are considered to offset inorganic fertilizer inputs (Godinot, 2014).

While the EU FADN data collection schedule has been widened across the countries in this comparative study to enable farm gate level indicators to be developed, future work should focus on how to develop the indicator to a stage where a life cycle assessment based (LCA) indicator could be calculated. This could potentially address the issues identified in this paper, in terms of arriving at a more holistic comparison of milk production systems across comparator countries. As outlined by Gerber et al. (2014), LCA takes a unit of product as a reference and examines all upstream and downstream activities and related environmental impacts. It is a holistic accounting system that captures environmental pressure related to the production, usage and disposal of a product. LCA is interestingly being applied to agricultural commodities and is growingly accepted as a valuable environmental management tool for decision-makers. LCA is however a data intensive approach, which can represent a considerable constraint to its development. Future work could also benefit from the integrated data collection on economic and environmental issues in the FADN system by analysing the variation in economic and environmental performance among farms (Dolman et al, 2012) and analyzing the trade-off and jointness of these measures.

The relationship between N balance and loss to the aquatic environment and atmosphere are very complex and are highly dependent on local influences such as soils, hydrology, weather, farm structures and management practices (Jordan et al. 2012). Results here indicate a general declining trend (all be it with some temporal volatility) in N balances across specialist dairy systems in both countries over the 2006-2014 period. This coincides with the decline observed in nitrate concentrations in rivers across the Republic of Ireland and the Netherlands over the period. In the case of the Republic of Ireland the number of sites[5] monitored by the Irish Environmental Protection Agency with average concentrations of less than 10 mg l^{-1} NO_3 (2.3 mg l^{-1} NO_3-N) increased from 55 per cent in 2007 to 71.5 per cent in 2012. This decline is accredited to a number of influences including several related to agriculture including reduced chemical fertilizer applications; improved manure storage facilitates; and spreading practices associated with the implementation of the EU Nitrates Directive based Good Agricultural Practice regulations (Environmental Protection Agency, 2013). In the Netherlands about 75% of the dairy farms had average concentrations of less than 50 mg l^{-1} NO_3 (The EU-threshold) in the period 2012-2015 (Fraters et al, 2016), about 10% more than in the period 2004-2011. The decline in the Netherlands can be accredited to more stringent manure legislation with tighter rules on the application of manure and the way farmers respond to this legislation. Dairy farmers are allowed to use lower nitrogen and phosphate excretion

[5] The number of operational and surveillance river monitoring stations for which data was available in 2012 was 1521 covering 682 rivers.

values for their cattle if they can prove these lower values with adequate registration and calculation (Netherlands Enterprise Agency, 2015). Both the tighter standards and the possibility to work with lower excretion values have stimulated a more efficient use of nutrients, which reduces the surpluses of nitrogen and phosphate.

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Table 1 Production profile of sample

	Production Profile - Republic of Ireland									Production Profile - Netherlands								
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Farm size (ha)	41.2	41.9	42.4	43.0	44.1	44.7	44.8	45.1	46.6	44.1	44.6	45.4	46.2	46.0	46.9	47.7	48.6	47.3
Grassland (ha)	40.1	41.1	41.3	42.0	43.1	43.7	43.8	44.2	45.7	36.6	36.6	37.0	38.0	38.2	39.2	40.0	40.9	40.6
Arable (ha)	1.1	0.8	1.1	1.1	1.1	1.0	1.0	0.9	0.9	7.4	8.0	8.4	8.2	7.7	7.7	7.7	7.7	6.7
Total livestock units	79.5	79.4	80.1	82.4	82.0	82.6	83.6	85.2	89.5	88.7	90.5	93.6	94.7	96.8	98.0	99.2	103.4	103.0
Dairy cow livestock units	49.9	51.9	53.5	55.0	54.4	56.5	57.4	58.4	61.1	68.5	70.6	74.2	74.9	75.9	77.3	78.8	82.5	82.0
Other livestock units	29.6	27.5	26.5	27.4	27.5	26.1	26.2	26.8	28.4	20.2	19.9	19.4	19.8	20.8	20.8	20.4	20.9	21.0
Stocking rate (lu ha^{-1})	1.93	1.90	1.89	1.92	1.86	1.85	1.87	1.89	1.92	2.01	2.03	2.06	2.05	2.11	2.09	2.08	2.13	2.18
Milk solids kg ha^{-1}	695	675	659	622	694	699	686	709	741	960	1003	1029	1026	1061	1052	1028	1061	1093
Milk solids kg cow	343	345	336	316	359	365	351	361	370	618	633	629	633	642	639	622	625	630
No of sample dairy farms	104	104	104	104	104	104	104	104	104	122	122	122	122	122	122	122	122	122
Population weighted*	6767	6767	6767	6767	6767	6767	6767	6767	6767	9107	9107	9107	9107	9107	9107	9107	9107	9107

*** Based on average weight of the selected farms during reference period (2006-2014)**

Table 2: Standardized co-efficient used to generate indicators

Main Import	**Co-efficient applied**
Chemical Fertilizer	Kilograms * N per cent in fertilizer
Concentrates and forage crops	Kilograms *dry matter% * (crude protein % / 6.25)
Animals	Kilograms of live weight purchases * 0.0294 (0-1 years) Kilograms of live weight purchases * 0.0241 (1-2 years) Kilograms of live weight purchases * 0.0225 (> 2 years)
Organic Manure	Kilograms * N per cent in manure (per manure category)
Main Export	**Co-efficient applied**
Milk	Kilograms of milk protein solids exported / 6.38 (Ref)
Animals	Kilograms of live weight sales/deaths * 0.0294 (0-1 years) Kilograms of live weight sales/deaths * 0.0241 (1-2 years) Kilograms of live weight sales/deaths * 0.0225 (> 2 years)
Crops	Kilograms of crops sold * dry matter%* (crude protein % / 6.25)
Organic manures	Kilograms * N per cent in manure (per manure category)

Table 3: Nutrient use efficiency indicator results

	Republic of Ireland									Netherlands								
Imports	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
N Fertilizer kg ha^{-1}	181.1	164.3	149.1	157.3	161.0	155.5	155.5	172.9	169.3	119.6	123.7	114.3	117.6	112.3	109.0	111.5	111.7	124.4
N Concentrates kg ha^{-1}	33.6	29.4	39.5	30.0	33.1	28.9	33.9	40.3	32.0	113.3	111.2	114.7	108.2	113.9	117.8	120.0	125.5	123.9
N Forage Feeds kg ha^{-1}	4.8	5.2	4.2	5.1	5.1	5.9	6.5	7.8	7.8	15.5	21.5	18.9	15.9	31.3	17.5	18.6	17.9	15.7
N Livestock Imports kg ha^{-1}	1.0	1.2	0.9	1.0	0.6	0.9	0.9	0.7	0.6	2.0	2.3	1.4	0.9	1.1	1.0	0.7	0.9	0.6
N Organic manures kg ha-1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.4	7.5	11.4	10.2	9.4	12.3	11.0	8.8	8.8
Total N Imports kg ha^{-1*}	220.5	200.0	193.7	193.4	199.9	191.2	196.8	221.7	209.7	259.9	266.3	260.7	252.8	268.0	257.5	261.9	264.8	273.4
Exports																		
N Milk Exports kg ha^{-1}	32.6	33.5	32.7	31.1	34.3	35.3	34.7	35.5	36.8	65.8	69.1	71.1	70.8	73.3	72.6	71.3	73.7	75.9
N Livestock Exports kg ha^{-1}	9.4	9.0	8.1	7.9	8.1	7.6	7.7	7.0	7.5	12.8	12.4	12.5	11.6	11.0	11.0	10.4	10.7	10.9
N Crops Exports kg ha^{-1}	0.7	0.7	0.8	0.5	0.7	0.7	0.6	1.0	0.6	3.2	6.2	5.2	4.4	3.9	3.3	3.8	3.5	5.1
N Organic manures kg ha^{-1}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.	17.7	21.3	18.9	15.0	21.3	19.7	22.2	22.2	38.7
Total N Exports kg ha^{-1*}	42.8	43.1	41.6	39.5	43.1	43.6	43.0	43.5	44.9	99.5	109.0	107.7	101.8	109.5	106.5	107.8	110.1	130.5
Balance and indicators																		
N Balance kg ha^{-1}	177.8	156.9	152.1	153.9	156.8	147.6	153.8	178.2	164.7	160.4	157.2	153.0	151.0	158.5	151.0	154.1	154.7	142.8
Nitrogen use efficiency %	20.9	23.1	23.0	21.6	22.4	28.1	22.6	23.4	22.0	38.3	40.9	41.3	40.3	40.8	41.3	41.1	41.6	47.8
N Surplus per kg milk solids	0.27	0.23	0.25	0.26	0.24	0.22	0.23	0.26	0.24	0.17	0.16	0.15	0.15	0.15	0.14	0.15	0.15	0.13
No of dairy farms	104	104	104	104	104	104	104	104	104	122	122	122	122	122	122	122	122	122
Population weighted*	6767	6767	6767	6767	6767	6767	6767	6767	6767	9107	9107	9107	9107	9107	9107	9107	9107	9107

***Based on average weight of the selected farms during reference period (2006-2014)**